Increasingly national and international education officials, accreditors, and faculty leaders associate “quality” education with student learning outcomes and continuous quality improvement processes. Academic leaders and accrediting bodies discourage viewing education as a simple act of passing a static body of knowledge from faculty to students. Instead, they value education practiced as a commitment to a set of collectively-practiced, ongoing activities: making institutional choices about the most important goals for student learning and defining the learning in terms of desired outcomes; developing a shared faculty commitment to actions such as high impact, active learning strategies and faculty development designed to increase student achievement; making informed judgments about student achievement; and ensuring continuous improvements in the educational program. Despite the commitment of academic leaders and accreditors to these processes, too few institutions have succeeded in applying systematic improvement processes to the general education program. As a result, higher education accountability and improvement discussions assume higher education can benefit from models of innovative and effective general education program assessment.

The Association for General and Liberal Studies is the national organization whose mission is singularly committed to quality general education programs and their central role in the liberal education of students. The organization invites institutions to apply for the 2012 AGLS Award for Improving General Education: Exemplary Program Processes. The Award promotes institutional commitment to continuous quality improvement processes, recognizes faculty and institutions that practice these quality behaviors, and provides much needed examples of effective improvement processes. The 2012 Award will recognize institutions committed to systematic improvements driven by learning assessment. The Award will recognize institutions using assessment to reconsider learning goals, develop a shared commit to improved learning strategies, and check to determine the success of these efforts. AGLS will recognize as many as three institutions employing effective and innovative assessment processes. Application narratives should limit their focus to assessment of just one area of learning.

Judges will identify the best improvement model for each of three different learning domains. The Awards presentation will be made during the 2012 Annual AGLS Conference, September 20-22, in Portland, OR. Representatives from recognized institutions will be asked to present their assessment processes in identified special sessions and, if possible, provide a poster presentation for display throughout the conference. Recipients will receive the following: a plaque recognizing their successes; recognition on the AGLS website, listserv, and other publications; half-priced registration for the up-coming conference; and a year’s membership in AGLS.

Applications will be reviewed by an Awards Committee comprised of AGLS Executive Council members, members of accrediting associations, and recognized leaders in general education. The application narrative questions are based on the Systems Analysis questions found in the AGLS publication, Improving Learning in General Education: An AGLS Guide to Assessment and Program Review. Information about assessment and other essential general education program processes can be found in the publication (see below). Awards judging will focus on how well the institution’s program improvement efforts are systematic and can serve as a practical model for other institutions, and it will consider how innovatively and effectively an institution has assessed one general education area of learning. Special consideration will be given to applications describing learning areas or methods not previously recognized by the Award. Previous winning applications can be found on the AGLS website: www.agls.org. The application must describe the full “loop” of assessment processes: defining learning, checking student success, analyzing data, implementing needed improvements, and ideally, completing follow-up assessment to identify the impact of the improvement efforts.
ASSOCIATION FOR GENERAL AND LIBERAL STUDIES
2012 AGLS Awards for Improving General Education:
Exemplary Program Processes

Application Format

To be considered for the award, an applicant on behalf of an institution should complete:
• Section #1: Contact information for individual submitting the application
• Section #2: Institutional endorsement by either the chief executive or academic officer
• Section #3: Application summary (150 words or less)
• Section #4: Responses to four award criteria, limited to two pages per criterion

Examples of Evidence for Award Criteria

Evidence of merit requires answering the questions under each of the criterion listed in the application below. Evidence should focus on specific activities and processes that employ the continuous quality improvement principles discussed in the AGLS publication Improving Learning in General Education: An AGLS Guide to Assessment and Program Review and found in the supporting reference materials listed in the Guide. The application should clearly present the creative solutions and leadership methods used to address the issues, concerns, and goals relevant to assessment and improvement processes. Supporting material can be summarized as part of the application and narrative, but limit your explanations to two pages per criterion. Please limit the use of web addresses and links to data summaries that readers might use to better understand your data or processes; narrative summary of your key results and processes, within the application, is preferable.

Award Timeline

March—Application materials available on AGLS website
June 15th—Materials must be received by AGLS
June 20th—Materials distributed to review panel
August 1st—Recipients notified
October—Recipients’ presentations and awards during 2012 AGLS Annual Conference in Portland, OR

Suggested Reference Material

Improving Learning in General Education: An AGLS Guide to Assessment and Learning can be found at: www.agls.org. Supporting literature (from regional and specialized accreditors and from AAC&U) is listed in the Guide.

Application Submission

Applications and supporting materials may be submitted as e-mail attachments in Microsoft Word or Adobe Acrobat format, sent to Paul Ranieri at pranieri@bsu.edu. Applications can also be mailed to:

Paul Ranieri
AGLS Executive Director
Department of English
Ball State University
RB 2109
Muncie, IN 47306
ASSOCIATION FOR GENERAL AND LIBERAL STUDIES
2012 AGLS Awards for Improving General Education:
Exemplary Program Processes

Section #1: Contact Information of Person Submitting Application

<table>
<thead>
<tr>
<th>Name</th>
<th>Ellen S. Goldey</th>
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<tbody>
<tr>
<td>Title</td>
<td>William R. Kenan Jr. Professor and Department Chair</td>
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<tr>
<td>Institution</td>
<td>Wofford College</td>
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<tr>
<td>Department/Program</td>
<td>Biology</td>
</tr>
<tr>
<td>Street Address</td>
<td>429 N. Church St.</td>
</tr>
<tr>
<td>City, State, Zip</td>
<td>Spartanburg, SC</td>
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<td>Phone</td>
<td>864-597-4622</td>
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<tr>
<td>Email</td>
<td><a href="mailto:goldeves@wofford.edu">goldeves@wofford.edu</a></td>
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Section #2: Institutional Endorsement

Chief Executive Officer or Chief Academic Officer

<table>
<thead>
<tr>
<th>Name</th>
<th>Dr. Benjamin B. Dunlap</th>
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<tr>
<td>Title</td>
<td>President of the College</td>
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<td>Institution</td>
<td>Wofford College</td>
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<td>864-597-4020</td>
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Section #3: Application Summary

Include a summary of the award application. Please begin the narrative with a brief description of your institution and the time frame for the process. Briefly explain your process and why you think it equates with quality. The summary should not exceed 150 words. The text box may be increased in size as necessary.

Motivated by the national call for transformation of STEM education, evidence from internal assessment, and the need to align introductory science courses with the College’s General Education objectives, we transformed our first year curriculum in biology with a new first-semester course, Biological Inquiry, in which >50% of first year students enroll. The course replaced a traditional, content-driven course that relied on outdated approaches to teaching and learning. The project reflects
the input of numerous constituencies and close collaboration among a team of professors and students. Targeted learning outcomes fall into three categories: knowledge, skills, and affect. To accomplish these outcomes we diversified pedagogical practices, developed open-ended experiments, and created assignments that use higher order cognitive domains. Complementary evidence from direct and indirect assessment methods reveals that compared to the course it replaced, Biological Inquiry leads to significant gains in targeted areas, and the project has had broad impact across the College.

Section #4: Award Criteria

Criterion 1: Supporting and Defining Learning
Provide a description of how your institution supports and operationally defines learning for one goal or area of learning. What are your learning outcomes for this goal and what is the evidence your institution collects to show that graduates have acquired the general education knowledge, skills, or values expressed by this outcome? Address the following issues:

- How the goal of this learning area aligns with your mission
- What process your institution used to define, in operational terms, this goal’s learning outcome(s)
- Who helped your institution develop this definition and what level of support exists for the goal and outcomes
- How you communicate this definition to faculty, students, and other interested parties
- What collaborative efforts members of your institution are making to achieve these learning outcome(s), including efforts to ensure alignment among multiple faculty, across multiple programs, courses, or sections.

Please limit your response to two pages. The following text box may be increased in size as necessary.

The sciences represent an important learning area within the General Education (GE) requirements at Wofford College, a private liberal arts college in South Carolina with approximately 1600 full-time, conventional age students. Due to Wofford’s strong tradition of preparing students for healthcare professions (e.g., thirteen percent of all Wofford graduates went on to medical or dental school in 2010), biology is the largest and most eminent department at the College. Over half of all incoming students (232 of 446 in Fall 2011) enroll in Biology in their first semester and our majors represent nearly 25% of all graduates.

The College catalogue states: “Wofford’s [GE] program seeks to develop skills in reading, written and oral communication, use of technology, critical thinking, creative expression, numerical reasoning, problem solving, and collaborative and independent learning. The college identifies these competencies as vital to intellectual and personal growth. While these competencies are developed in all courses in the curriculum, they are the explicit focus of general education courses.” However, prior to implementing our new biology course, few (if any) of these competencies were targeted learning outcomes of the introductory biology courses, whether for majors or non-majors (see Attachment A for more background on the old curriculum).

This application details how we transformed our introductory biology curriculum to embrace the institutional goal of developing science competencies (which we refer to, collectively, as science literacy) by incorporating the pedagogical practices suggested by numerous scientific foundations and agencies (e.g., from NSF, HHMI, NRC, and AAAS) in their efforts to reform undergraduate STEM education. We describe herein the development, implementation, and ongoing assessment and revision of a new course, Biological Inquiry (Bio 150), which has now been taught for three years. Our work has
had broad and positive impact across the College.

The goals of Biological Inquiry are to build strong foundational content knowledge while placing new emphasis on developing students’ competencies, including reading the primary literature, writing in a disciplinary style, presenting ideas orally, developing and testing hypotheses, analyzing data with statistical methods, graphing and interpreting results from open-ended (non-cookbook) experiments, solving problems, thinking creatively and critically, and working effectively in teams – in short, to engage in practicing all of the skills used by scholars of the field while also aligning course goals with those of our GE program. It was our overarching goal that students be inspired to imagine themselves in the role of scientist and/or to better appreciate the efficacy, as well as identify the limits, of scientific inquiry and its role in our democracy.

Each aspect of our multifaceted approach is informed by our participation in the national dialogue on reform of STEM teaching and learning as well as the movement for reform of assessment practices in higher education. Although Dr. Ellen Goldey¹ has spearheaded the reform effort, the work itself has been remarkably collaborative across multiple constituencies, including members of the faculty from across the College, external consultants, students, top administrators, and the National Science Foundation (which funded the work and added external validation, which quieted skeptics). Our approach included:

- Gathering multiple types of direct and indirect assessment evidence, putting it into interpretable formats, and using it to develop action plans (see Criteria 2 and 3)
- A series of departmental retreats and regular meetings to develop course goals and objectives and to review assessment evidence (before and after Bio 150 implementation)
- Team attendance at the SENCER Summer Institute (which fostered significant buy-in for the project from top administrators because the current Dean attended two Institutes as a team member) and attendance at other conferences (e.g., AAC&U and SACS)
- An intensive eight weeks of full-time collaborative course planning and practice of proposed course ideas among seven faculty members partnering with four students in the summer of 2009. These four students then served as preceptors in the first semester the course was taught, and championed the new course as no faculty member could. They were strong role models for the students in the course (most just one year younger than themselves), and they were invaluable young colleagues that we turned to in moments of panic when our best-laid plans went awry.
- Careful consideration (as a team) about which areas of biology content to include and how to structure it to complement the work in lab and vice versa.
- Development and/or adoption of a set open-ended research experiments to which we could add novel questions each year.
- Faculty development workshops on active learning pedagogies (many led by faculty members from other departments, including Psychology, Religion, Philosophy, and Chemistry), unfamiliar

¹ Dr. Goldey is a SENCER Leadership Fellow (a national program funded by NSF, see http://www.sencer.net/About/sencerideals.cfm), a Teagle Assessment Scholar (see http://www.liberalarts.wabash.edu/assessment-scholars/), and PI on two NSF grants and two inter-institutional grants from the Teagle Foundation for projects on value-added assessment.
and emerging content areas (led by biologists), and technical skills (led by IT professionals).

- Significant doses of morale support for the teaching team, especially in the first year when the risk of failure seemed all-too-real and anxiety levels were high.

The transformation hasn’t been easy, but it has been worth it. Each member of the teaching team has benefited from our newly collaborative approach to teaching, thus emphasizing in our own work the teamwork we seek to instill in our students. We are also better teachers as we have all diversified our pedagogical practices and created assignments, open-ended experiments, and test materials that require students (and us) to use higher order cognitive skills. We have had to hone our understanding of content areas with which we were rusty or hadn’t even been discovered when we were earning our degrees, and we are reading with our students a diversity of primary literature that has re-invigorated our own passion for biology. Most importantly, complementary evidence from direct and indirect assessment methods (detailed in Criterion 2 and 3) reveals that our students in Bio 150 are showing significant gains in all targeted areas (knowledge, skills, and attitudes, see Attachment B) compared to the course it replaced, and has had unexpectedly broad impact across campus (see Criterion 4).

**Award Criteria**

**Criterion 2: Completing the Assessment Process**
Describe how your institution assessed the learning identified in Criterion 1 above. Address the following issues:

- What assessment methods and tools your institution developed and used (What are the measures of learning, taken at what levels of student learning, reflected in what type of assignments/activities, and assessed as activities in what program[s]?)
- Who participated in the development and use of the assessment tools
- What institutional support existed for the development of the assessment tools
- How the assessments were completed and who participated (present a brief description of the process)

*Please limit your response to two pages.* The following text box may be increased in size as necessary.

We have used both direct and indirect methods to assess the student learning outcomes in three categories: acquisition of content knowledge, development of skills, and maturation of attitudes (e.g., toward science and in personal responsibility for self and others). Our direct assessment methods were designed by the course instructors and include using guided inquiry assignments (see [http://pogil.org/about](http://pogil.org/about)) used in class and lab, weekly quizzes, grading rubrics for assignments (e.g., oral presentations, and research posters), and exams with questions developed to assess higher order thinking skills (skills which students practice during class, lab, and homework activities). Our indirect assessment techniques include a customized Student Assessment of Learning Gains (SALG) survey (see [www.salgsite.org](http://www.salgsite.org)) that we designed, reflective essays, and focus groups and interviews conducted by an internal and an external evaluator. Several of our methods are further described below.

In addition, we are interested in longer-term assessment of student outcomes, and Dr. Goldey has worked as a member of our College assessment committee (which includes the Dean of the College,
David Wood, and Raymond Ruff, Director of Institutional Research, among others) to mine existing stores of assessment data, especially our many years of data from the National Survey of Student Engagement (NSSE), for example breaking down the results on the senior NSSE by individual question and declared major, and sharing these results with faculty in numerous settings, including formal presentations to the full faculty, informal meetings with department chairs, and departmental half- or full-day retreats, funded by a grant from the Teagle Foundation. This work with the NSSE data has motivated the entire faculty to engage in discussions about their majors’ perceptions and the question-level analysis allows the faculty to consider possible actions to improve scores in specific areas. The biology department’s scores on certain NSSE questions helped motivate the curriculum reform described in this application (a sample graph and its explanation is provided in Attachment C). Further extending the reach of this work, Dr. Goldey has also presented our multifaceted approach to assessment at SACS and AAC&U conferences, together with the more specific results from the assessments of Biological Inquiry. It is very clear to us that no one assessment tool gives adequate information to guide reform, and that best practices in assessment require weaving multiple types of evidence together to identify areas to target for improving student learning.

Other longer-term assessments include senior exit interviews and surveys, which also motivated this curriculum reform effort. In addition, last year we implemented two new graduation requirements for the major, which are separate comprehensive exams, one taken at the end of a student’s junior year and the other at the end of the senior year. For juniors the exam consists of 200 questions, which we extracted from out-of-cycle copies of the GRE, MCAT, and DCAT, along with some questions of our own. The junior exam gives us insight into students’ abilities, allows us to advise them in final course selections if they are weak in particular areas of content or skills, and gives them practice in standardized testing. As seniors, they then must take the second exam, the Major Field Test (from ETS), in the Spring. Our most recent graduates, who took the old course (Animal Diversity, Bio 111), were the first to take the MFT this year, whereas our rising seniors were the first to participate in the new curriculum. Therefore, we are looking forward next summer to comparing outcomes. We recognize that it will be challenging to make direct links to the impact of the new freshman year curriculum, but the information from these assessments will inform changes to more than just our first year programs. For brevity, none of our longer-term evidence is described in this application.

**Exams Designed to Foster Higher-Order Thinking**

For direct, classroom-level assessment we worked to develop exams that pushed students beyond memorization to higher cognitive domains (Bloom, 1956; Anderson and Krathwohl, 2001). To build our capacity for this work, we invited Dr. Marc Chun (see [http://www.claintheclassroom.org/academy](http://www.claintheclassroom.org/academy)) to conduct an on-campus “CLA in the Classroom” workshop, in which all biologists (and 30 faculty members from other departments in the College) practiced developing performance tasks to assess our students’ critical thinking and writing skills. This workshop helped our faculty consider ways to adapt these approaches to their own exams and assignments.

Each Bio 150 instructor develops his/her own exams, but we share exam questions with each other – especially those questions that required students to apply their knowledge to a novel situation, judge the value of information, and synthesize diverse types of information. For example, students might be given...
an abstract from a research article that they had never read before and asked to indentify the dependent and independent variables, interpret the p-value, develop a graph of the results described in the text, and/or propose a follow-up experiment to address questions that emerge from the study. Sample exam questions are not included in this application, but are readily available upon request. We also included more traditional questions (multiple choice questions and essay responses to prompts) to assess basic understanding of course content, as we believe a blend of styles is appropriate.

**Team-developed Research Posters**

Our most innovative direct assessment of student learning is the two research posters in which student teams must report on the multi-week experiments they perform in the laboratory. This work introduces students to an important form of scientific communication and engages them in reading and applying the primary literature to their own work. One poster is due at midterm and the other at the end of the semester, and students are given the opportunity to revise their first drafts after feedback from other teams, their lab assistant, and their professor (each team is strongly encouraged to meet with their professor prior to final poster submission, which we have learned leads to a much better poster, better teamwork, and builds student rapport with the professor).

We developed a poster template and grading rubric for the research posters (Attachments D & E), which we share with students during a lab session devoted to a poster-writing workshop. Qualitative feedback, discussed in Criterion 3, indicates that although the research poster assignments present unique challenges for professors (increased mentoring time with each student team) and students, they are likely the most transformative tool for attaining student learning objectives (Attachment B).

**Student Assessment of Learning Gains (SALG) Survey**

One of our indirect assessment methods is a customized Student Assessment of Learning Gains (SALG), a customizable and free survey supported with NSF funding, which students complete online during the last week of class, and for which they earn two points of extra credit toward their final exam grade (a miniscule fraction of their grade that has yielded 80 - 90% compliance, and thus a robust sample). The SALG has proven to be a very helpful tool in assessing students’ perceptions of learning outcomes from Bio 150, especially because we developed and used our SALG in advance of implementing our new course, so we are able to compare student responses about the old course (Bio 111) with responses from Bio 150 students.

We developed our SALG questions to address students’ perceptions of their gains in the targeted learning outcomes described in Table 1, and students respond to some questions by selecting a score on a Likert scale (e.g., 1 = no gains to 5 = strong gains) and to other questions by providing open-ended responses. To maintain the confidentiality of results among the seven instructors, Dr. Goldey assumed the responsibility of data analysis and reporting SALG results. Data were exported into Microsoft Excel, downloaded into JMP™ (a SAS product) for statistical analysis, and graphically displayed using Delta Graph. These graphs were shared and discussed with the all members of the department once per year at a departmental meeting, with the seven members of the teaching team at more regular intervals (especially in our planning meetings in the summers), and tenure-track assistant professors met individually with Dr. Goldey (in her role as Department Chair) to celebrate successes and consider
strategies to improve weaker outcomes. In year two, the Dean asked that Dr. Goldey give a presentation/mini-workshop to the full faculty on the progress of the departments’ first-year curriculum reform and the utility of the SALG as an assessment tool, so the work has had wide campus publicity and support.

INTERVIEWS, FOCUS GROUPS, AND OTHER QUALITATIVE ASSESSMENTS

Internal Evaluator’s Assessment
Our internal evaluator, Dr. Dennis Wiseman (Professor of Foreign Languages and Director of Institutional Assessment) met with biologists, witnessed workshops and summer planning sessions, and interviewed preceptors and faculty during the project. His insights were keen, and because he knows us all well, he was able to offer helpful suggestions in context. Dr. Wiseman also guided us to document our project’s assessment so as to highlight our work within our accreditation documentation for the Southern Association of Colleges and Schools (SACS).

External Evaluator’s Assessment
Dr. Michael Reder of Connecticut College was our external evaluator during the NSF-funded period of the project to create Biological Inquiry. His first visit occurred at the project outset as we shared our early excitement and anxiety upon receipt of NSF funding. During his second visit in early December of 2009 (near the end of the first semester the course was taught), he conducted hour-long interviews and focus groups with groups of biology professors, top College administrators, Bio 150 students, preceptors and lab assistants; and he compiled a report that underscored our successes and uncovered the challenges that helped guide changes to the course for 2010. Returning in late November 2010 near the end of the second round of Bio 150, Dr. Reder came again to assess the project’s outcomes. He debriefed with the biology professors, interviewed the Dean of the College, and held focus group discussions with STEM faculty outside the biology department as well as with seven classes of Bio 150 students (in the absence of the professor).

Award Criteria

Criterion 3: Analyzing Assessment Results
Describe how your institution analyzed assessment results to identify, select, and implement improvements. Address the following issues:
• Who analyzed the data and what level of collaboration existed
• What processes were used to analyze the results
• What the results revealed about student learning, and which learning results were viewed as most significant in terms of success, limited success, and/or lack of success
• How internal or external benchmarking was used (or might be used) to validate the learning or lack of it
• What the results revealed about your assessment tools and methods
• How extensively the results were communicated to faculty, students, and administration

Please limit your response to two pages. The following text box may be increased in size as necessary.
**RESULTS OF DIRECT ASSESSMENTS**

Individual course instructors evaluated their own students’ work using the grading rubrics we had developed as a team, and in grading their own exams, which often included questions shared among colleagues. All seven instructors met once weekly throughout the first two years the course was taught, and again during the summer, to debrief/decompress, share ideas for general course improvement, and compare challenges in using the rubrics and recommend changes to them. For example, the poster-grading rubric (Attachment E) has been updated each year. Similarly, the poster template (Attachment D) was also updated. On the latter, for example, the description the discussion section of the poster originally suggested students include in their discussion any confounding issues that may have affected the results. Unexpectedly, this suggestion led to most teams adding the throwaway comment that the experimental results were likely “compromised by human error,” despite huge sample sizes, tiny standard errors, and extremely low p-values! This type of comment reveals how students are taught to handle “wrong results” in cookbook labs during high school, which inadvertently reinforces the use of easy or pat explanations instead of critical thinking about actual experimental results. A sample of a high-quality student poster is also included as Attachment F for your review. Considering that this represents the work of first-semester freshmen, we are quite pleased with the competencies demonstrated.

**STUDENT RETENTION**

It is noteworthy that of the 293 students that enrolled in Bio 111 from 2007-2008, an average of 24% either failed or withdrew from the course. However, an average of only 6% per year of the total of 714 students who have enrolled in Bio 150 (since it started in 2009) withdrew from or failed the course. Our *indirect* assessment methods suggest that improved retention is due to the diversity of assignments and test questions (which emphasized only recall of memorized material in Bio 111), teamwork that builds friendships among seemingly disparate students, and closer relationships with the professor among all students (which include BA and BS students in Bio 150, whereas only BS students took Bio 111). Importantly, the course appears to provide a structure that better retains students of color and other at risk students from diverse cultural backgrounds (e.g., first generation students), although the numbers of these students is too low to make definitive claims.

It is important to note here that results such as these results are just a friendly phone call away to Raymond Ruff, our Director of Institutional Research, Jason Womick, Vice President of Information Technology, or to Dr. Boyce Lawton, Vice President of Academic Planning, and we are thrilled to have such gifted and supportive technology experts supporting our assessment work.

**STUDENT GRADES**

Although final grades may be a blunt instrument for measuring student learning, they are none-the-less a small but important (especially to the student) piece of the assessment puzzle we’ve constructed. Whereas there was no statistically significant grade inflation in Bio 150 over Bio 111 (the course it
replaced), there was an increase in student retention. On a four-point scale, the average grade (± standard error) in Bio 111 was 2.62 ± 0.07 whereas in Bio 150 it was 2.80 ± 0.05, and final grade distributions were also remarkably similar. This finding suggests that the types of students who were dropping out of the old course not only stay in the new course; they complete it successfully.

**RESULTS OF INDIRECT ASSESSMENTS**

As an indirect self-assessment of learning gains, students respond to the end-of-the-semester SALG survey questions by selecting a score on a Likert scale (e.g., 1 = no gains to 5 = strong gains) and to other questions by providing open-ended responses. Quantitative data from the SALG were analyzed and expressed graphically by Dr. Ellen Goldey by exporting the data from the SALG website into Microsoft Excel™, downloading it into JMP™ for statistical analysis, and graphically displaying the results using Delta Graph™. Because these data include sensitive information about each instructor, Dr. Goldey has taken on this responsibility to preserve collegiality, help us all improve together, and to prevent the information from being used punitively against individuals.

**SALG: Students’ Perceptions of Intellectual Behavior**

One set of SALG questions reflects the Bloom’s Taxonomy of Intellectual Behavior (Bloom, 1956) and is taken directly from the National Survey of Student Engagement (NSSE). Figure 1 shows that Bio 150 students perceived that they used less memorization and recall and more application and judgment/evaluation than their predecessors in Bio 111. We are pleased with this outcome, because we want students to operate in higher cognitive domains. The direct assessments used in Bio 150 (exams and research posters) and other qualitative evidence support student perceptions.

![Figure 1: Students were asked about how much (y-axis) the course emphasized certain types of thinking (x-axis), questions adapted with permission from Question #2 on the National Survey of Student Engagement. Columns represent average student response (± S.E.) to selected questions on our end-of-course SALG survey. Black columns show responses from students who took the old course (Bio 111/Zoology) in 2008 whereas the gray bars represent responses from students who took the new Bio 150 course in 2009, 2010, and 2011, respectively (N = 122, 186, and 233, respectively). Values in adjacent columns with different letters are significantly different from each other (Analysis of Variance followed by LS Means Differences Student’s t-test; p < 0.01).](image-url)
SALG: Students’ Perceptions of Knowledge Gains

Numerous other questions were asked about students’ perceptions of gains in content knowledge, and graphs like those in the following sections are available, but are not included here for brevity. Not surprisingly, the results underscore students’ ability to correlate areas of course emphasis with perceived knowledge gains. For example, students in Bio 111 reported little or no gains in understanding of DNA transcription and translation (topics not covered in Bio 111) but high gains in understanding these topics as a result of their emphasis in Bio 150, findings that are supported by direct assessments. As in Figures 1 and 2, biology knowledge gains also show significant increases each year of Bio 150, reflecting intentional, ongoing course improvements.

SALG: Students’ perceptions of gains in skills

Perhaps the most dramatic results of this project are seen in the student perceptions of gains in skills in Bio 150 compared to Bio 111 (Figure 2). Although gains in teamwork skills did not show an increase, this finding is not surprising since teamwork was also heavily emphasized in Bio 111. Our direct assessment measures support student perceptions here. Guided inquiry sessions in class and lab, research posters, and exams required students to interpret evidence (their own and previously published) relative to their hypotheses, build quantitative skills through data collection and analysis, decipher and apply primary literature, write in disciplinary style, and apply course content to new situations when developing logical arguments; all skills that they practiced regularly and that improved in quality over the course duration as shown from graded assignments.

We are particularly happy with students’ perceived gains in their ability to write in the discipline, and the direct assessments of student work supports their perceptions. Not only is this a course goal, improving writing in the first year is also a college-wide goal and the target of our Quality Enhancement Plan (QEP) for accreditation by the Southern Association of Colleges and Schools (SACS). Students who take Biological Inquiry (over half of each freshman class) are bringing better quantitative and communication skills to their upper-level courses and beyond. The instructors of the 300-level physiology course noted that they spent much less time this year describing statistics or scientific writing to this group of students, because most had practiced these skills as first year students.
SALG: Students’ Perceptions of Attitude Gains

As shown in Figure 3, below, student attitudes declined in Bio 150 (gray bars) compared to the old Bio 111 course (black bars), which successful students loved for its concreteness and predictability. One suggestion was that the lower attitude scores were coming from the BA students. However, this was not born out by further analysis. Instead, the findings represent significant instructor differences. Analysis of the data by professor reveals that the two professors who had taught Bio 111 continue to get good scores on these questions, whereas a few of the instructors new to teaching first-year students had lower scores. Because such information can generate hurt feelings and anxiety, care was taken so that individual instructor scores remained confidential and were not used punitively. Instead, faculty members were self-motivated to sit in on each other’s labs to learn from their colleagues ways to build rapport with students and develop other skills.

INTERVIEWS, FOCUS GROUPS, AND OTHER QUALITATIVE ASSESSMENTS

One of the questions that Dr. Reder (our external evaluator) asked each focus groups of 20+ students was “What assignment was the most challenging and why?” This questions is similar to the open-ended SALG question “How did the assignments in this course challenge you in ways that were different from high school?” In both assessments, the vast majority of students chose the two team-based research posters as the most unique and challenging assignments of Bio 150. One student’s response does a particularly good job of summarizing the vast majority students’ sentiments:

“The assignments in this class were above anything I expected. While I hated with a passion working on the research posters, they were a great help. I know so much about the topics we did our posters on. This was one major change from high school; working with a group…Also, I have studied more for this class than any other science class. In high school, I was used to not studying until the night or morning of a test and making A’s. In this class I have learned to study a little each day and know the material inside and out. The assignments were much more challenging and required an actual thought process rather than just a regurgitation of facts” (Anonymous, 2010).

And while we hope to improve students’ attitudes toward the assignment, we believe that the antipathy to the posters reflected here indicates that we are moving students from being passive recipients of knowledge, the comfort zone of most young learners (Perry 1970), to higher levels of intellectual development.
Criterion 4: Making Improvements
Describe your institution’s effort to identify needed learning and methods improvement projects following the analysis of assessment data. Address the following issues:
• What learning improvement projects your institution selected, including high-impact, active learning strategies, and/or faculty development activities
• What assessment method improvements your institutions selected (if needed)
• What outcome statement improvements/adjustments were made (if needed)
• Who collaborated on targeted learning or methods projects and at what level of activity
• What level of institutional support exists for the improvement projects, such as funding, personnel, and faculty development
• What plans exist to follow up on targeted improvement projects to check for improvement
• What results have been collected following the improvement efforts (if they have been collected)
• What lessons were learned from the improvement process

Please limit your response to two pages. The following text box may be increased in size as necessary.

One of the reasons that we believe our project is worthy of consideration for AGLS recognition is the broader impact it has had on our campus. Since the Biology department undertook its high-profile, evidence-based reform effort, all the science departments have become more involved in the national dialogue on STEM reform. The Psychology and Environmental Studies departments each have a new “150” course on the books for first year students, our Chemistry professors are implementing Process Oriented Guided Inquiry Learning (POGIL) in their courses, and the Physics department has applied for funding to overhaul its introductory courses, seeking to implement their version of studio physics (see http://gallery.carnegiefoundation.org/collections/keep/jbelcher/index.html). While biology doesn’t deserve any credit for the creativity of our colleagues in other departments, Dr. Reder’s focus group discussions with administrators and other STEM faculty members reveal that our leadership, and willingness to assume the risk that comes with change, has inspired our colleagues in other disciplines to consider reform and to view their work as important for student learning at both the institution and national level.

There is a high level of institutional support for the improvement projects that are occurring across campus. The work described in this application was instrumental in encouraging the Trustees to approve establishment of Wofford’s new Center for Innovation and Learning, directed by Dr. Dennis Wiseman, which provides a venue for extending the faculty development workshops that were vital to the success of this project, and which were funded in part by our NSF grant. As another example of support, Biology was given two new tenure-track positions, and these new faculty members have been key players in the implementation of Biological Inquiry and a second course, Evolution and Development (Bio 151). The latter course, while not described here, represents yet another, completely new course for second-semester students, and is targeted to students who have indicated their desire to continue in biology as their major.

What we recognized early on in our work on Bio 150 is that if we changed the first course, we would
have to completely change the second course, too. In addition, important content that was no longer covered in the two “old” first year courses, Zoology and Botany, would have to be considered for inclusion in upper-level courses. For instance, we consider an understanding of photosynthesis to be important for biology majors, so this topic is now investigated in Cellular Biology in the sophomore year.

It is easy to see why a traditional course sequence can remain in place too long – change can create multiple layers of new challenges, and we have done a good job of communicating regularly with all constituents to ward off potential problems and to deal quickly with those that do arise. For example, Biological Inquiry is taken by so many Wofford students that one particularly important constituency to keep in the loop was freshman advisors. We developed handouts with new language about the course and who should take it, and we met with the advisors during summer and pre-semester orientation.

One of the most rewarding aspects of this challenging three years has been the support we’ve received from faculty members from across the college, administrators, and even some Trustees. In many different ways our faculty colleagues, in particular, let us know that they were proud of us, and their support was particularly important during that first semester of Biological Inquiry, when each day felt like our first day of a new job – wanting to make a good impression but not completely confident that our performance would be our best.

We learned from this extensive assessment process is that none of us were at our best that first year, and that we had to struggle through that difficult period and rely on each other for support. But we survive it, and all seven instructors agree that it took until the third year before each of us started feeling really good about our “performances” in Biological Inquiry. Now we are enjoying our continuing work of revising and refining the course, which we will continue to do based on student feedback and discussions among the instructors of outcomes on our direct assessments.

We believe that our process and outcomes will inform and inspire those seeking to undertake a similar, evidence-based process of reform, and we hope AGLS will help us disseminate this work.
Attachment A: Background for reform efforts

To share our belief that the new biology curriculum represents a true transformation of our curriculum, it is important to understand the context of the change. For at least thirty years prior to 2009 (the year we implemented Bio 150), the required core curriculum for all biology majors consisted of a four-semester sequence of courses that spanned the freshman and sophomore years. Zoology (Bio 111) was followed by Botany, Genetics, and then Cell Biology. Incoming first-year students took the first of these, Bio 111, if they intended to pursue a BS degree. Students pursuing a BA degree could instead take two lab science courses designed specifically for non-science majors (one in a life science and one in a physical science) to satisfy their GE requirements. These courses, designated Biology 104, Chemistry 104, etc., are intended to introduce non-science majors to the concepts and methods of the discipline.

The majors’ course, Biology 111, was a traditional, textbook driven, phylum-by-phylum survey course. This course was popular, and on course evaluations students praised it for its concreteness, clarity of lectures and notes, adherence to the sequence of material in the textbook, and predictability of material for exams. However, the very characteristics that students praised about the course are often criticized in the literature on cognitive research for failing to require higher-order thinking, such as the transfer of knowledge to novel situations (Bransford et al., 1999). In addition, the course made no attempt to engage students in scientific inquiry as professional biologists practice it.

The non-science major’s courses, including Bio 104, had received particular attention and innovation beginning in 2002, when Wofford received another NSF grant (DUE CCLI #0126788) to create interdisciplinary learning communities (Goldey, 2004). In fact, the outcomes assessment of the learning communities program helped fuel the drive to change the majors’ courses so as to adopt the interactive, interdisciplinary, and inquiry-based approaches prevalent in the learning communities and advocated for in Bio 2010 (NRC, 2003), among other publications (e.g., AAMC and HHMI, 2009). The non-majors science courses, including Bio 104, had been the object of creative reform efforts over the past decade, especially as a result of a 2001 grant from NSF to develop interdisciplinary learning communities, which integrated two courses, a science 104 course with the first-semester, GE seminar in the humanities. A serendipitous complaint emerged from science majors who noted that they didn’t have the opportunity to do the “cool stuff” going on in the learning communities.

But another impetus to reform the science courses for BA students was the common perception that these courses were supposed to be easy, and it was common in our culture for students, faculty advisors, and even some science faculty members to refer to the 104-level courses as “baby science,” inadvertently setting low expectations, even before students set foot in the door. The fact that this tone was set at a crucible moment in students’ academic careers, when they arrive fully expecting increased rigor in College, is all the more problematic. Assessment evidence (results not shown) comparing grade distributions among first year science courses for BA and BS students indicates that the perception of decreased rigor in 104-level courses is likely well-founded. This was unacceptable to many of us. In addition, the unintended consequences of separating biology majors and non-majors includes reinforcing the fear of science held by many BA students as well as eliminating the rich interactions and
interdisciplinary sharing of knowledge and habits of mind that occur when students from all disciplines interact – as they do in all other GE courses and many of our capstone courses.

For these and other reasons, the new course, Bio 150, combines BA and BS students together and targets the development of valuable GE competencies for all students while engaging them in a rigorous engagement with biology content and performing research as scholars in the discipline do it. Thus all students finish the course with an excellent sense of the scientific process and how it differs, and is complemented by, humanistic inquiry and the social sciences. Such is the true value of a GE program.


Attachment B: **Three categories and targeted outcomes for biology students in Bio 150**

<table>
<thead>
<tr>
<th>Canonical Knowledge (Know)</th>
<th>Skills (Do)</th>
<th>Affect (Care About)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core theories of natural world (e.g., evolution/natural selection)</td>
<td>Manage time effectively and practice effective study skills.</td>
<td>Increased (not inflated) self-confidence of ability to succeed in course/college</td>
</tr>
<tr>
<td>Foundational content (e.g., organism diversity, ecology, population genetics, DNA structure/function)</td>
<td>Effectively observe, document, collect data, analyze, and evaluate.</td>
<td>Greater appreciation &amp; awareness of scholarship</td>
</tr>
<tr>
<td><strong>Functional numeracy</strong> (orders of magnitude, interpret graphs, statistics, concentrations, molarities, applied mathematics)</td>
<td>Design a good experiment or model and/or use computational methods to test hypotheses.</td>
<td>Motivation (take action, learn more than required, seek justice)</td>
</tr>
<tr>
<td>“Credentialing” of a scientist, the role of peer review process, primary research, etc.</td>
<td>Use precision in measurement and dissection.</td>
<td>Honesty – Integrity</td>
</tr>
<tr>
<td>How new findings remodel accepted interpretations (e.g., <em>Hox</em> genes and phylogenetic relationships)</td>
<td>Think critically (use evidence, evaluate credibility, critique bias in self and others), practice open-minded skepticism</td>
<td>Responsibility for peers and others – civic engagement</td>
</tr>
<tr>
<td>The power and limitations of science (and scientists). Moral, ethical, economic, historical, &amp; religious norms influence scientific practice. Learn beyond STEM.</td>
<td>Integrate an apply knowledge from other disciplines. Transfer knowledge to novel and/or real world situations, predict/create/innovate.</td>
<td>Self-reflection and improvement; constructive criticism and support of peers.</td>
</tr>
<tr>
<td>Complexity and ambiguity are more the norm than fact and proof.</td>
<td>Communicate in oral and written forms practiced in the discipline. Paraphrase and cite others' ideas appropriately.</td>
<td>Sense of belonging that is shared with other learners</td>
</tr>
<tr>
<td></td>
<td>Work well in teams and individually</td>
<td>Committed to institution &amp; to teachers</td>
</tr>
<tr>
<td></td>
<td>Make meaning of complex issues in context (Values/ Ethics/ Morals)</td>
<td>Seeks to understand diversity of perspectives, backgrounds, etc.</td>
</tr>
<tr>
<td></td>
<td>Utilize multidisciplinary knowledge and skills to investigate complex and ambiguous topics.</td>
<td>Enthusiasm and/or appreciation for discipline.</td>
</tr>
</tbody>
</table>
Attachment C: Making NSSE results actionable by the faculty.

Data were pooled for the NSSE senior survey from 2007 – 2010 and parsed by department for the five NSSE Indices and for individual NSSE questions. An example (question 9a from the NSSE survey) from among the 60+ questions is shown below, ranked from highest to lowest score. Our faculty has found the format to be particularly helpful in directing action plans. Each department was assigned a code letter to protect confidentiality, and departments were encouraged to decide what topics from among their results inspired action. The green line (Wofford) represents the College mean. This question generated a rich discussion. Because a typical course load is 15 hours and the rule of thumb is that it is fair to expect 2 hours of study for each hour of class time, most faculty members across the College feel that we can expect more time from our students devoted to their academic work. For this question, biology students are spending about 13 hours of study per week in all their courses, which ranks above the mean but below several departments.
Attachment D: Poster Template

Title (should be descriptive of the work)
Your Names Here (typically in alphabetical order unless first author did most of the work)
Wofford College, South Carolina

Introduction

This section should provide background information (with citations from the primary literature) about your topic. Narrow your literature review of the topic (it takes time to find relevant articles!), and tell the reader how your study is similar and/or adds something new to what is already known about the topic. Avoid plagiarizing the work of other authors by summarizing (in your own words) their findings and citing them (Smith, et al. 2009) within the text and in the Literature Cited section. Your introduction should move from general to specific and end with your hypothesis (not all research is based on hypothesis testing, but that is what you’ve been doing in labs 2 - 4).

Methods

This section includes information on how the experiment was performed. It should be brief but descriptive (a list of supplies and steps is not appropriate). Consider using photos or diagrams (each would have its own figure caption) if they would help the reader understand what was done. Remember that the reader should get the gist of the experimental protocols here. A research poster doesn’t give as much detail as a full article, but it should provide an overview with enough detail for a peer (naive to the experiment) to understand what you did. Be sure to name/describe the statistical tests that you used to analyze your data.

Results

This section should be dominated by results that appear in graph or table form, but will also typically have a descriptive paragraph. Each figure should have below it a descriptive caption that begins with Figure 1, Figure 2. Each Table should be numbered (Table 1, Table 2, etc.) with a descriptive header across the top. The figure captions should include information important for interpreting the figure (sample size, t-statistic, p value, etc.). Statistics should be displayed appropriately; mean values should be shown relative to sample variance (e.g., standard error values can be calculated using JMP). Your results SHOULD NOT include raw data and you should not interpret your results in this section.

Other hints for preparing your poster:
1. Just type over the text in each section if you want to use the template as is. If you want to change the background, logo, etc., then go to “slide master” under the edit tab.
2. If you have room, consider adding relevant photos to your poster – they capture the eye and draw people to your poster.
3. This font size is 48 point, and the overall poster dimensions are 4’ X 6’. Stick with this, as it makes your poster easy to read from a couple feet away and you can still read it when you print an 8.5” X 11” size copy. You may use a smaller font for figure captions and references.
4. Brevity is key – write out a draft of your text and then remove as many words as possible. None: You are looking at too many words on this poster template!
5. Get many people to critique your poster. Remember that peer-review is a hallmark of good scholarship.
6. Use example research posters on the walls of Milliken Science Center. Think about which ones are most effective and why.
7. Use past tenses when describing your experiment. Use of first person is deemed appropriate by some professors – ask yours for his/her preference.

Discussion

In your discussion you should interpret the results but not restate them (we can see the results section). Reflect back on your introduction (do the results support your hypothesis and/or stated purpose?). Do your findings support or refute the findings of other scientists (be sure to cite them appropriately)? Are there alternative explanations for your results? Remember, you should interpret the results you get, not the ones you wanted or expected. Getting results you don’t expect doesn’t mean your results are wrong – you may be onto something interesting! But do consider how our experimental methods may have affected the results – is there a change in protocol that you would recommend?

At the end, you need to try to link the work you’ve done to the “bigger picture.” This is the “So What?” part of your poster. How might your work inform future studies? One common way to end this section is to suggest future studies that you or other researchers should do as follow-up. Keep your focus here and design a “next step” experiment to address a follow-up question that emerges from your experiment.

Literature Cited

Use the appropriate format for your citations (you can use the format from the references/literature cited section of one of your primary sources or go to http://irsm1.nsm.iup.edu/rgendron/citation.shtml for guidance). It is not OK to list a bunch of web sites. Your literature cited must include at least four primary sources (published articles from refereed journals that you have read) related to your topic.

Acknowledgements

Use this space to thank those who helped you. It is optional, but nice.

This research poster template was prepared by Ellen Goldey and colleagues at Wofford College. You are welcome to modify it for your own use, but be sure to list your use of our NSF grant project (EGLR 0903453) please let us know if you find it useful. 864-597-4622 or egoldey@wofford.edu. Reminders: you should delete this note from your poster!
### Attachment E. Poster Grading Rubric (page 1)

**Attachment E: Biological Inquiry Research Poster Grading Rubric.**

<table>
<thead>
<tr>
<th>Explanation of grading of performance</th>
<th>Inadequate: Performance not acceptable (F)</th>
<th>Below average: Performance not up to minimum standards but shows marginal grasp of concept (D)</th>
<th>Average to above average: Performance met all minimum standards (C)</th>
<th>Good to very good: Performance representative of good to noteworthy achievement (B).</th>
<th>Particularly strong to exemplary: Performance demonstrated that this team moved beyond expectations and came up with original ideas that provided unique insight (A).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Introduction</strong></td>
<td>Intro is not present, is incoherent, or is unrelated to experiment.</td>
<td>Intro disorganized, or lacks reference to relevant primary literature, or missing purpose/hypothesis.</td>
<td>Background info too broad or too narrow, or weak/missing purpose or hypothesis, or lacks sophistication and/or may contain fallacies of logic.</td>
<td>The intro smoothly pulls reader into topic. It is well organized, flows from general to specific, and makes clear the purpose of experiment.</td>
<td>Intro is uniquely well written and is crafted in such a way (e.g., relevant examples from 1st lit) as to educate the poster audience in a noteworthy and effective way.</td>
</tr>
<tr>
<td><strong>Appropriate use of primary literature: including Literature Cited section</strong></td>
<td>No 1st literature cited or it was plagiarized and/or citations missing or inadequate.</td>
<td>Attempts at paraphrasing border on plagiarism, or cited literature seems random and/or irrelevant to topic, and/or literature cited section inadequate and improperly formatted.</td>
<td>Use of reference literature perfunctory without clear context, and/or attribution inappropriate or misplaced, and/or literature cited section is inadequate.</td>
<td>Background information used in context (esp. in intro and discussion). Citations are appropriate and correctly located within text, with literature cited in appropriate format.</td>
<td>Creative and effective use of 1st literature, which is cited appropriately. Paraphrasing of other works represents noteworthy grasp of referenced articles applied to poster’s context.</td>
</tr>
<tr>
<td><strong>Methods</strong></td>
<td>Methods absent or blatantly inaccurate.</td>
<td>Reader would have a tough time knowing what happened in the experiment and/or the methods was a list of materials and steps (style of H.S. lab report)</td>
<td>Methods gave general view of experiment but were incomplete or imprecise (e.g., only described single team’s work rather than combined work across all sections)</td>
<td>Clearly states how experiment was conducted, and how data were collected and analyzed.</td>
<td>Methods are sophisticated, clear, and concise, giving particularly good insight (perhaps with visual aids) into how the study was performed and how the data were analyzed.</td>
</tr>
<tr>
<td><strong>Results</strong></td>
<td>No results, no figures, or what is presented is grossly inaccurate.</td>
<td>Results are misleading or un-interpretable for reader due to mistakes or omissions (e.g., no figure captions).</td>
<td>Graphs/tables don’t conform to minimum standards (e.g., contain raw data), or captions are incomplete, axes are misleading, or supporting text is inaccurate.</td>
<td>Figures &amp; tables provide useful information for discussion. Captions are complete and accurate (include N, p-value, etc.), and supporting text is informative.</td>
<td>Results demonstrate effort beyond the norm, e.g., evidence that authors worked extra hard to create visually appealing, clear, and concise figures and supporting text.</td>
</tr>
</tbody>
</table>

Funding supporting Bio 150 came from NSF grant 0836851. For additional information about the above document, please contact Dr. Ellen Goldey (goldeyes@wofford.edu).
Attachment E. Poster Grading Rubric (page 2)

Attachment E: Biological Inquiry Research Poster Grading Rubric.

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Score</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discussion</td>
<td>Discussion is not present, is incoherent, or is unrelated to experiment.</td>
<td>Poor</td>
<td>Communicates original synthesis of evidence in a way that is complex and free of logical fallacies. Future study recommendations are specific and reasonably follow from this study. Findings are discussed (i.e., so what?) in broader context. Sections are well integrated and interdependent (e.g., topics of intro are resolved in discussion) with smooth transitions. Discussion reflects back on other sections to provide novel, even exciting, insights. Be careful here!</td>
</tr>
<tr>
<td>Overall unity of poster</td>
<td>Sections vary widely in quality and accuracy, resulting in a confusing hodgepodge.</td>
<td>Poor</td>
<td>Demonstrates generally coherent and unified writing across sections providing a unified whole.</td>
</tr>
<tr>
<td>Title, authors, &amp; acknowledgements</td>
<td>Missing</td>
<td>Poor</td>
<td>All present, title is descriptive and accurate.</td>
</tr>
<tr>
<td>Sentence structure, grammar, punctuation, spelling</td>
<td>Several problems with sentence structure, spelling, grammar and punctuation make poster unprofessional.</td>
<td>Poor</td>
<td>A few errors in grammar, punctuation, or spelling do not detract too much from overall poster quality. Sentence structure is generally good, but may still contain waste words.</td>
</tr>
<tr>
<td>Creativity</td>
<td>Poster is visually unappealing; use of template not apparent, and/or extraneous clutter completely hides the poster’s purpose.</td>
<td>Poor</td>
<td>Poster is free of errors in grammar, punctuation, or spelling, and sentences are well structured. Poster demonstrates authors’ careful editing. Vocabulary is notably sophisticated.</td>
</tr>
</tbody>
</table>

Funding supporting Bio 150 came from NSF grant 0836851. For additional information about the above document, please contact Dr. Ellen Goldey (goldeyes@wofford.edu).
Oviposition of Callosobruchus maculatus is Unaffected by Natal Experience and Antennal Ablation

Karl Cochran, Lauren Heaton, Kayla Johnson, and Nick Napier
Wofford College, South Carolina

Introduction

Insects lay their eggs selectively in order to increase the survival rate of their offspring (Ward et al. 1999). Possible stimuli that serve as markers for this ovipositing behavior include the natal host experience, attractant or deterrent odors, and the topography of the oviposition sites. For example, Culex mosquitoes will lay their eggs in skatole water (normally a deterrent) if they were reared in that odor (McCall et al. 2001). Sambaraju et al. (2008) found that when wheat extract (an attractive odor) is added to non-host sites, Indianmeal moths, Plodia interpunctella, will lay their eggs on these sites. Additionally, deterrent odors have been linked to toxic seed coats and therefore reduce ovipositing frequency (Souza et al. 2011). Finally, yellow dung flies utilize topography by laying their eggs on hills rather than on points or in depressions to avoid desiccation or drowning, respectively (Ward et al. 1999). We tested to see which of these factors influenced the ovipositing of Callosobruchus maculatus. We predicted that bean beetles would lay their eggs on their natal hosts and that they would use their antennae to detect attractive and deterrent odors innate present in each bean to determine which bean species to lay their eggs on.

Methods

We conducted two choice experiments to test oviposition of the bean beetle C. maculatus (See Figure 1). Both studies were analyzed through the use of Chi-Squared Statistical Analysis.

In the first choice experiment thirty-six mung and thirty-six adzuki beans were placed into each petri dish. One female bean beetle was added to each dish. In 44 of the dishes, this was a beetle raised on adzuki beans and in 42 of the dishes this was a beetle raised on mung beans. Forty-eight hours later the beetles were removed and we counted the number of beans with at least one egg.

For the second experiment, female bean beetles received one of three treatments. After exposing the beetles to Fly Nap for one minute, we used microsurgical scissors to cut off the whole antennae of 201 beetles, half of the each antennae of 224 beetles, and performed a sham-operation on 196 beetles. We filled the bottom of each petri dish with eleven of each type of bean (mung bean, adzuki bean, black bean, and black-eyed pea, see figure 2), and then added one female bean beetle from each treatment group. As in the first experiment, forty-eight hours later the beetles were removed and we counted the number of eggs on each bean type.

Results

Natal bean host had no effect on oviposition site (results not shown), therefore, we pooled the data from the two treatment groups (Figure 3).

In the second experiment, there was no effect of antennal treatment on oviposition (results not shown), so we used only the sham-operated group in order to test bean preference (Figure 4).

Discussion

Contrary to our prediction, preference of natal oviposition sites was not shown by C. maculatus. C. maculatus preferred the adzuki bean for ovipositing regardless of which bean it was reared on. Therefore, other explanations must be considered. One possibility is that the beetles prefer to lay their eggs on larger beans. The works of Sambaraju et al. and Messina et al. supported this possibility because moths chose larger-sized beans, and beetles chose larger beans, respectively (Sambaraju et al. 2008, Messina et al. 2003). However, host size alone cannot fully explain our results, as the larger black-eyed pea was not favored by the beetles. Souza et al. (2013) found that toxic compounds in the seed coat deterred beetles from laying their eggs. This suggests that the adzuki bean may have a less toxic seed coat or the coats of the black bean and black-eyed pea may be more toxic than the others. To test this we could apply the procedures of Souza et al. (2011) and test the toxicity of the coats of seeds used in our experiment. Further investigation into the effects of odors on ovipositing also seem to be required. Magali et al. found that more odorous tomatoes elicited increased egg-laying from Tuta absoluta, which, when applied to our results, suggests that the adzuki bean had a more attractive odor (Magali et al. 2011). We could test the effects of such an attractive odor using the procedures of Sambaraju et al. (2008). Also, while antennae did not appear to have any effect on ovipositing in our experiment, Mbata (1994) and Parr (1998) suggest that both the antennae and the palps play roles in chemical signal recognition. Thus the roles of olfaction could be further tested by repeating our ablation experiment with both the antennae and the palps.

If we were able to discover why the beetles choose to lay their eggs on some hosts and not others, this information could be used along with genetic engineering to protect crops from this pest.

Literature Cited


Souza, Alexandre; Parent, Jean-Luc; Santos, Maria T. F. P.; Proffit, Brian; Sassaki, Pedro T.; Witzgall, Hereina; Berehman, Tierry P. C.; Reis Jr., Ronaldo. 2013. Smaller and more nutritious seeds support adaptation by Callosobruchus maculatus. Crop Protection. 30: 651-657.


Acknowledgements

The authors of this poster are indebted to Dr. Ellen Goldy for her assistance throughout this experiment.