

## Scaffolding the Development of Students' Research Skills for Capstone Experiences: A Multi-disciplinary Approach

### Introduction

Inquiry, investigation, discovery, and communication are central to undergraduate education. A growing body of literature (Brewer and Smith 2011; Kenny et al. 2001) documents the effectiveness of research-based approaches in supporting undergraduate learning and creating opportunities for undergraduate students to actively engage in research and inquiry. Studies have shown that students who engage in undergraduate research activities pursue graduate education and additional research activities at higher rates than other students (Hathaway, Nagda, and Gregerman 2002; Lopatto 2003; Russell, Hancock and McCullough 2007), attain higher retention rates (Nagda et al. 1998), increase academic achievement and graduation rates (Bauer and Bennett 2003; Craney et al. 2011), and develop fundamental intellectual skills (Hunter et al. 2006; Kardash 2000; Lopatto 2007). Capstones are one way to provide these kinds of opportunities for research within the undergraduate curriculum and to scaffold the development of intellectual skills.

At Florida Atlantic University (FAU), a large public university serving approximately 25,000 undergraduates on six campuses across South Florida, we have made strides in expanding opportunities for undergraduate research and inquiry. As part of our institution's reaccreditation, the faculty, staff, and students at FAU developed a Quality Enhancement Plan (QEP) in 2013 entitled *Distinction Through Discovery*. The program aims to expand a culture of undergraduate research and inquiry within the institution and across all disciplines. A key feature of the plan centers on integrating undergraduate research experiences into the curriculum at all levels by scaffolding student development through three stages: 1) *exposure* to research skills and content; 2) targeted *skill building*; and 3) intensive independent work, particularly through capstone experiences.

The *Distinction Through Discovery* initiative is intended to develop research skills in curricula across all of FAU. Thus, we adapted a definition of research from the Council of Undergraduate Research (CUR) to focus more broadly on scholarly forms of inquiry. We define undergraduate research as "an inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline or practice" (Chamely-Wiik et al. 2013). Examples of such processes

include questioning existing ideas, identifying approaches to unstructured problems, thinking creatively, developing new technologies and applications, exploring new ideas, and examining the processes by which knowledge is discovered. These contributions can result in exhibitions, performances, works of art, presentations, publications, and other forms of scholarly communication.

The primary purpose of FAU's QEP is to enhance student learning and produce students capable of successfully engaging in scholarly inquiry. Therefore, we established a set of six core student-learning outcomes (SLOs) that cover the research cycle. We also articulated potential indicators to guide the development of course-based measures of learning outcomes. Although these learning outcomes and indicators are presented in numbered form in Table 1, the order does not reflect any preconceived priorities, nor do we conceive of the inquiry process as necessarily linear. Research and inquiry may begin and end at any point, and may take many forms depending on the discipline and the developmental stage of the student.

These learning outcomes were established by consulting the Association of American Colleges and Universities' VALUE rubrics (AAC&U 2007); research-related student-learning outcomes identified by other institutions with quality-enhancement plans for undergraduate research (e.g., the University of Houston, the University of North Carolina Chapel Hill, George Mason University, and Embry Riddle Aeronautical Institute); and Jenkins and Healy's (2009) taxonomy for research in the curriculum. We articulated three pedagogical stages at which curricula could be conceptualized to scaffold incrementally the development of student research and inquiry skills:

- **Research and Inquiry Exposure:** Students acquire basic knowledge about current practices, literatures, and methodologies of research and inquiry in the discipline. Learning is guided through discussion and assignments that introduce concepts, processes, and techniques involving research and inquiry. Student work generally focuses on identifying and articulating fundamental research and inquiry content, knowledge, ethical conduct, and skills.
- **Research and Inquiry Skill-Building.** Students develop intermediate-level, discipline-specific research and inquiry skills and more in-depth knowledge of

methodologies. Learning is guided through advanced experiences such as research discussions and critiques, writing components of scholarly work with some scaffolding, studio or laboratory training, peer review, and development of project proposals. Student work at this level emphasizes the refinement of novice-level knowledge and skills.

- **Intensive Research and Inquiry:** Students learn to apply and implement the entire cycle of research and inquiry skills to develop and explore an original question or problem. Learning is guided through mentored independent study, thesis projects, assembly and presentation of portfolios, performances, and exhibitions, or the completion of other capstone or comprehensive activities. Student work at this level documents the identification of new questions, problems, or approaches; develops a scholarly rationale and design for the approach taken in refining the questions or problems; implements the designed plan; critically reviews and reflects upon the results or outcomes of the work; and coherently communicates the design and results of the work.

## Pilot Project in Accounting

FAU's Distinction Through Discovery initiative began with a pilot project in disciplinary honors programs during the year prior to the official start of the QEP. Two pre-existing honors programs, in accounting and biology, and a new honors program in political science were selected from across the university. The small group of proposals allowed us to collaboratively create and evaluate materials, procedures, and infrastructure on a limited scale before implementing the QEP university-wide. Each pilot program received support for the redesign of the curricular components of a capstone course in the honors program and to develop student-learning outcomes and course-based activities to serve as direct measures of those outcomes (see Table 2). The pilot programs also adapted a rubric for assessing student performance developed for the Distinction Through Discovery program. It was designed to collect and report how well students performed relative to selected learning-outcomes benchmarks. Individual faculty members were given the flexibility to identify outcomes and indicators appropriate for their courses. In many cases, not every student-learning outcome was measured for each course in the pilot program. In what follows,

**Table 1. FAU's Student-Learning Outcomes (SLOs) and Indicators**

Student Learning Outcome	Indicator
<b>SLO 1:</b> Knowledge. Students will demonstrate content knowledge, core principles, and skills.	<ul style="list-style-type: none"> <li>• Vocabulary/Basic Skills</li> <li>• Theoretical Framework or Genres</li> <li>• Information Literacy or Sources of Information</li> </ul>
<b>SLO 2:</b> Formulate Questions. Students will formulate research questions or scholarly or creative problems with integration of fundamental principles and knowledge in a manner appropriate to their discipline.	<ul style="list-style-type: none"> <li>• Relevant Issues or Content</li> <li>• Rationale</li> </ul>
<b>SLO 3:</b> Plan of Action. Students will develop and implement a plan of inquiry to address research and inquiry questions or scholarly problems.	<ul style="list-style-type: none"> <li>• Methods of Exploration</li> <li>• Design</li> <li>• Implementation</li> <li>• Observations or Data Collection</li> <li>• Technical Skills</li> </ul>
<b>SLO 4:</b> Critical Thinking. Students will apply critical-thinking skills to evaluate information, their own work, and the work of others.	<ul style="list-style-type: none"> <li>• Analysis</li> <li>• Interpretation</li> <li>• Sources of Error</li> <li>• Conclusions</li> </ul>
<b>SLO 5:</b> Ethical Conduct. Students will identify significant ethical issues in research and inquiry and/or address them in practice.	<ul style="list-style-type: none"> <li>• Academic Integrity</li> <li>• Safety</li> <li>• Ethical Treatment</li> <li>• Ethical Issues</li> </ul>
<b>SLO 6:</b> Communication. Students will convey all aspects of their research and inquiry (processes and/or products) in appropriate formats, venues, and delivery modes based on the conventions of their disciplines.	<ul style="list-style-type: none"> <li>• Clarity and Organization</li> <li>• Quotation, Attribution, and Citation</li> <li>• Formatting, Level of Audience</li> </ul>

Source: Florida Atlantic University Distinction Through Discovery Quality Enhancement Plan

*Scaffolding the Development continued***Table 2. Pilot Program's Student-Learning Outcomes, Adopted and Measured as Outcomes by Course**

SLO	Intermediate Accounting Theory I	Cost Accounting	Accounting Information Systems	Biology Honors Research	Biology Honors Thesis	Political Science Honors Senior Thesis
1. Knowledge	x		x	x	x	x
2. Formulate Questions		x		x	x	x
3. Plan of Action		x	x	x		x
4. Critical Thinking		x	x			x
5. Ethical Conduct						x
6. Communication	x	x	x		x	x

Source: Florida Atlantic University Distinction Through Discovery Office of Undergraduate Research and Inquiry Assessment Data File

we describe the process each of our pilot programs followed to integrate research and inquiry into its undergraduate curriculum to prepare students for successful completion of a capstone experience.

### Pilot Project in Accounting (College of Business)

A typical path for high-achieving undergraduate accounting students is to pursue a master's degree, obtain professional licensure as a certified public accountant (CPA), and pursue a career in public and/or private accounting. Accordingly, undergraduate accounting students are engaged in activities to further their professional research skills. The accounting program:

- Includes four distinct phases introduced over three to four semesters of study, with scaffolded instruction
  - First semester: Provides a greater understanding of the profession and an awareness of the skills essential for professional success.
  - Second semester: Requires students to review the professional literature to research basic accounting problems and provide professional reports of their research, analysis, and recommendations.
  - Third and fourth semesters: Introduces new areas of the profession (e.g., tax and audit) and requires the use of additional sources of professional literature.
- Includes a capstone case competition, which requires students to work in teams to identify and evaluate possible solutions for an accounting problem for which no

clear solution exists. After evaluating the alternatives, students must propose and defend the solution they believe to be the best of the available alternatives, using only professional literature to support their decision. The deliverables are a professional report and an oral presentation to faculty and accounting professionals.

The results of the pilot program demonstrated increased student learning on all the student-learning outcomes that were measured. Fall 2012 data demonstrated that 15 out of 18 students were assessed as "competent" in the desired outcome involving disciplinary knowledge. The desired learning outcome related to communication was assessed multiple times, using several indicators. For instance, in assessing the clarity of purpose and overall organization, only 6 percent of students in the first semester demonstrated an "exemplary" level of student performance. By the second semester, however, 62 percent of the same students achieved "exemplary" performance on the same measure. This semester-to-semester change emphasized the need for course assignments to build upon each other, with an increasing level of rigor as students progress through the program.

Assessment of sentence structure and punctuation also occurred across two semesters, and it showed that while 80 percent of the student work was assessed as "developing," that is demonstrating limited elements of competency within the student-learning-outcome standard in the first semester, only 25 percent of the same students' work was assessed as "developing" in the second semester. At the same time, the proportion of students assessed as being "competent" on this measure rose from only 13 percent in the first semester to 75 percent in the second semester. Figure

1 presents the aforementioned assessment data on the desired student-learning outcome involving communication for the accounting program.

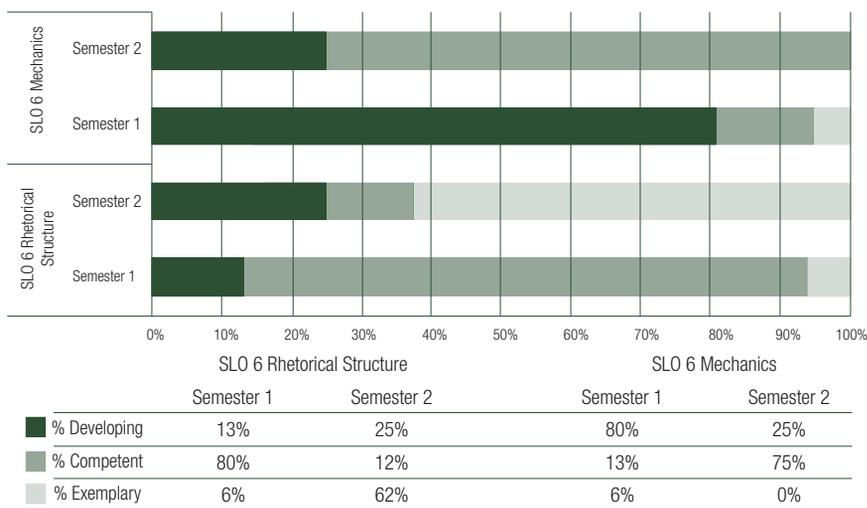
### Pilot Project in Biology (College of Science)

Biology students often pursue graduate education or work in fields that require independent research skills and experience. The honors program in biology, initiated in fall 2011, was developed as part of an NSF Undergraduate Research and Mentoring Program grant to biology faculty from 2009 to 2013. The grant was aimed at promoting skills needed by biology students to pursue their goals for careers and/or advanced education. This upper-division honors program aims to provide opportunities for high-achieving students to engage in research, to create a research mentality among all undergraduates, and to attract additional students into research laboratories throughout the university. The biology program:

- Includes two courses -- Honors Research taught in the fall and Honors Thesis taught in the spring the aforementioned. In addition, admission to the program requires a student to have conducted research during the previous summer with biology faculty, and to have lined up a biology faculty member to mentor the student throughout fall and spring.
- In the first semester, the students meet weekly and, under the supervision of their research mentor, work to prepare a research proposal using the data obtained during the previous summer within a research laboratory.
- In the second semester, students meet weekly and work on producing a manuscript and a research poster based on the students' summer research at the research laboratory (including preliminary results).
- Uses a research presentation, manuscript, and poster as the capstone. Students present their poster at the FAU Undergraduate Research Symposium and other scientific meetings. In order to complete this course successfully, students must defend their research manuscripts in a public seminar and then be evaluated by a committee of two or three faculty members, including their research mentors.

The assessment data on the 13 students in the biology pilot

**Figure 1. Change in Accounting Students' Performance on Communications Learning Outcome Between Fall 2012 and Spring 2013**



*SLO 6 is the student-learning outcome involving communication. Assessments were of work by the same students (with the exception of two students who left the program) across two semesters of work. Assessment of developing, competent, and exemplary student work determined by the instructor of record via rubrics in LiveText, an online assessment system.*

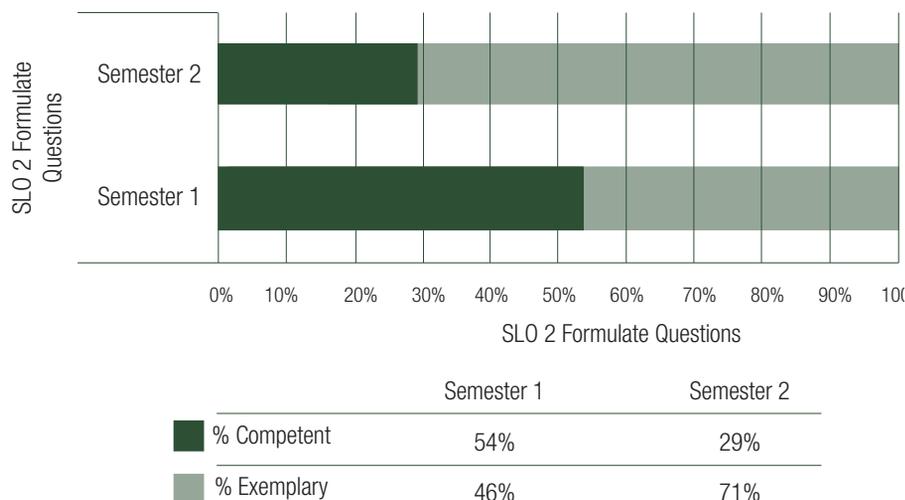
program showed that their performance was strongest on the first learning outcome, related to knowledge, where 70% of them were assessed as "exemplary" and 30 percent as "competent" in the fall term. Student performance on the second learning outcome, involving the ability to formulate research questions, was measured over two semesters. Some evidence of student learning is displayed in Figure 2, (page 22) which presents data on this learning outcome over two semesters on the same cohort of students.

### Pilot Program in Political Science (College of Arts and Letters)

High-achieving political science graduates pursue graduate education, professional degrees, or work in government; these positions require advanced research and communication skills. The honors program in political science began in the 2012-2013 academic year and thus represented the only new program in the QEP pilot. The program aims to provide students with a cumulative experience focused on research, independent inquiry, and communication skills. It involves two semesters of work for high-achieving seniors who major in political science, and it focuses on the production of original research through a senior thesis supervised by the program director and a faculty advisor. The program targets the development of students' research skills through scaffolding and repeated feedback from faculty and peers. The political-

*Scaffolding the Development continued*

**Figure 2. Change in Biology Students’ Ability to Formulate Research Questions Between Fall 2012 and Spring 2013**



*SLO is student-learning outcome. Assessments were of work by the same students across two semesters. Assessment of developing, competent, and exemplary work determined by the instructor of record via rubrics in LiveText, an online assessment system.*

science program:

- Includes two courses a senior research seminar and a senior honors thesis.
  - In the first semester, students enroll in the Senior Research Seminar, which addresses all six of the desired student-learning outcomes as students begin the draft of an honors thesis. The outcomes focus on demonstrating knowledge, developing a plan of action, constructing conceptual frameworks, analyzing results, recognizing ethical behavior, and applying communication skills. In the first semester, students complete much of the analysis, demonstration of knowledge, and plan of action needed as the basis for carrying out original research in the second semester.
  - In the second semester, students complete the honors thesis outlined in the previous semester. Research and inquiry skills are refined and applied as students carry out their research designs, engage in ethical behavior, apply existing knowledge to new research, and collect and analyze information.
- Uses a research presentation, manuscript, and poster as the capstone. Students present their research at a political science research day and other research events.

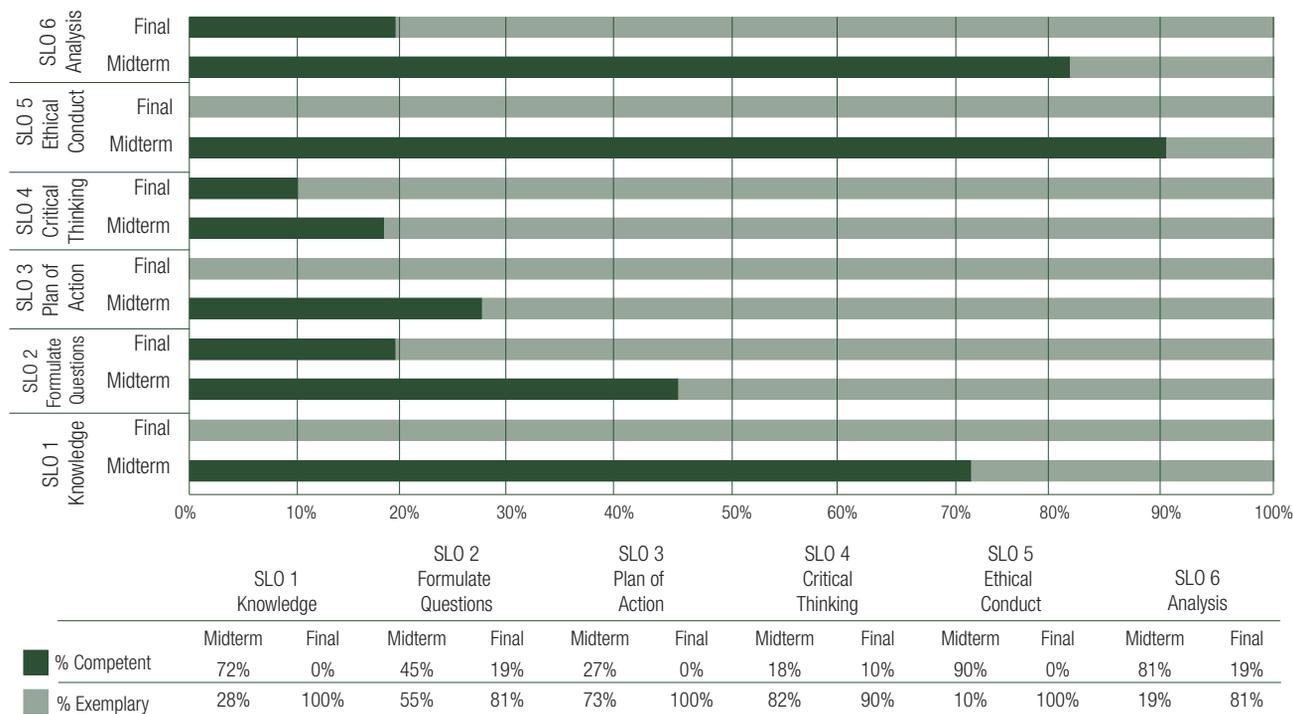
The pilot program in political science showed increased student learning on a variety of the desired learning outcomes. Figure 3 (page 23) presents data from the assessments of student performance at the beginning and end of the pilot. The students’ performance data demonstrate that 28 percent (11 students) were assessed as “exemplary” in the learning outcome related to knowledge at the midterm draft prospectus stage and 100 percent earned the “exemplary” designation by the time of the final draft thesis. This trend was seen across each of the six outcomes measured. The approach of using repeated assessments within one term served to expedite skill-building through concentrated feedback in the same semester. The spring 2013 term projects were enhanced by the emphasis on the outcomes measures.

### Moving Forward

As faculty in the pilot program explored the best ways to embed undergraduate research and inquiry in their programs, they developed a network for support that facilitated the sharing of ideas, best practices, and examples. Data from focus groups of these faculty members identified five themes essential to successful implementation of an increased emphasis on student research and inquiry (Table 3). The feedback resulted in useful changes to program components, including pedagogies (e.g., drawing students’ attention directly to specific research and inquiry skills), assignments (e.g., modifying them to better attain and measure intended student-learning outcomes), and QEP materials and procedures (e.g., the student-performance rubric).

The pilot test of FAU’s Distinction Through Discovery program successfully demonstrated students’ achievement of desired learning outcomes as they were assessed in honors capstone experiences. Therefore, we moved ahead with plans for a full-scale implementation of the curricular-enhancement initiative. For the next two years, our efforts will continue to focus on greater integration into upper-division courses of pedagogies for research and inquiry; we will also expand the initiative to include conventional, non-honors programs. Expanding the focus on curricular research in this way allows us to examine the differential effects of providing undergraduates’ with experiences in research and inquiry in a wider range of senior-level capstone courses, as well as providing them to a broader undergradu-

**Figure 3. Change in Political Science Students' Performance on Measures of Student Learning, Spring 2013 Term**



Source: FAU Distinction through Discovery Database, 2012-13

SLO (student learning outcomes) were measured as assessments of work by the same students over one semester. Using a rubric, course instructors assessed work as developing, competent, and exemplary and recorded rubric scoring in an online assessment system, LiveText.

ate audience and in more disciplines across the university.

In academic year 2013-14, FAU selected eight curriculum-redesign projects for support through our Distinction Through Discovery Curriculum Grants Program, which is financed with internal funds. These projects involve six colleges, including four new disciplines from diverse fields. Seven involve conventional, non-honors programs, and all the programs selected for this cohort include a variety of implementation plans. Three programs will focus on specific student-learning outcomes within one course. Another will implement a two-course skill-building assignment bridging to an intensive research experience. Four programs will use a sequence of research-enriched upper-division courses that provide skill-building over multiple semesters and culminate with an intensive, course-based capstone experience. One joint project spans the College of Engineering and Computer Science and the Charles E. Schmidt College of Science. It will use student-centered research experiences based on active learning to help students achieve designated learning outcomes in the capstone courses in four programs, two in each of the

respective colleges. The program includes:

- A multidisciplinary course at the junior level to provide students with the best practices necessary to properly conduct undergraduate research, and
- A complementary, intensive, industry-mentored or peer-mentored course requiring an undergraduate research project.

Using a continuous-improvement framework, the faculty, student mentors, and students in this joint project will be trained in how to better incorporate student-centered components of undergraduate research into coursework, and how to embed research-rich activities throughout the curriculum, in line with the quality-enhancement plan's objectives.

### The Takeaway

The three pilot programs in FAU's Quality Enhancement

*Scaffolding the Development continued***Table 3. Faculty Recommendations to Improve Program to Enhance the Undergraduate Culture of Research and Inquiry**

Theme	Noted Elements
Planning Time	Map what students will learn
	Customize a rubric to an assignment
Integrating Undergraduate Research and Inquiry	Need for flow of skills
	Understand and meet learner readiness
Assessment	Value of formative assessments
	Professional development essential
Curriculum	Mapping the curriculum
	Direct examples of student-learning outcomes
	Matching faculty to course and research needs
Support Needed	Sharing best practices
	Developing assessment rubrics

Source: FAU Distinction through Discovery Database, 2012-13 Focus Group Analysis

Plan have demonstrated success in designing curricula that intentionally scaffold the development of undergraduates' research skills to help achieve designated student-learning outcomes in senior capstones. We have learned at least six lessons from the pilot experiences that we believe may assist other programs in adapting our model to their own capstone courses and undergraduate research experiences. They are:

1. *Know what you are after.* Identify the knowledge and skills you want students to demonstrate upon graduation. Design your program to intentionally build these skills, culminating in a capstone experience that evaluates these elements. In the pilot study, faculty members were reluctant to include ethics as a formally assessed learning outcome. It would be helpful if faculty had access to existing examples of best practices for integrating and assessing ethics assignments.
2. *Start small, then go big.* Choose a manageable number of courses or programs to start with, and then scale up as you develop materials and collect information to inform your work.
3. *Map learning goals across your curriculum.* Once you have identified student-learning outcomes for your program, define where students should be learning those things in your curriculum. Then determine how you can directly observe whether student learning is being achieved.
4. *Collect information along the way.* Assess students' acquisition of knowledge and skills at developmental points throughout your program. For deeper understanding of how and when students are achieving the learning goals, consider collecting evidence of student performance more than once in the same semester in key courses. Redesign courses and curricula to address gaps in program structure and learning. Routinely reflect on successes and challenges for purposes of continuous improvement.
5. *Create stakeholders.* Involve students, alumni, employers, and other stakeholders in continuous improvement of the program to meet their needs.
6. *Celebrate successes.* Communicate accomplishments to students, faculty, programs, the university as a whole, and the surrounding community. 

**Acknowledgements:**

The authors wish to acknowledge the contribution of biologist Evelyn Frazier for this article's material related to the biology honors program. They also wish to thank Edward Pratt, dean of undergraduate studies, and the faculty, staff, and students at Florida Atlantic University for their support of the Distinction through Discovery initiative.

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