121st ASEE Annual Conference & Exposition
Indianapolis, IN
June 15-18, 2014
Paper ID #9834

# Scaffolded Structuring of Undergraduate Research Projects

**Dr. Dirk Colbry, Michigan State University**
**Dr. Katy Luchini-Colbry, Michigan State University**

Katy Luchini-Colbry is the Director for Graduate Recruiting at the College of Engineering at Michigan State University, where she completed degrees in political theory and computer science. A recipient of a NSF Graduate Research Fellowship, she earned Ph.D. and M.S.E. in computer science and engineering from the University of Michigan. She has published nearly two dozen peer-reviewed works related to her interests in educational technology and enhancing undergraduate education through hands-on learning. As a volunteer for Tau Beta Pi, the Engineering Honor Society, Luchini-Colbry facilitates interactive seminars on interpersonal communications and problem solving skills for engineering students across the U.S.

# Scaffolded Structuring of Undergraduate Research Projects

Dirk Colbry, Katy Luchini-Colbry

Michigan State University
East Lansing, MI, USA

## Introduction

Mentoring undergraduate research assistants is both difficult and rewarding. Students come to the project with different backgrounds, motivations and work ethics. While engaging in undergraduate research can be a powerful learning experience for students,[1] expending resources to train undergraduates does not always translate to increased research output or academic credit for faculty mentors.[2–5]

This paper presents a three-stage, scaffolded approach to training undergraduate research assistants, based on experiences and lessons learned in mentoring more than 50 undergraduates in engineering research projects. This three-step methodology reduces faculty effort while preserving the learning experience for new undergraduate researchers, and helps faculty quickly assess the interests and skills of new student assistants.

## Background

The research training methodology described in this paper is grounded in two complementary educational frameworks: **constructivism** and **socioculturism**. At its core, constructivism is the idea that learning is an active process where students create meaning from information and experiences.[6,7] Similarly, socioculturism is founded in the idea that "learning is enculturation, the process by which learners become collaborative meaning-makers among a group defined by common practices, language, use of tools, values, beliefs, and so on."[8] In the context of scientific research, this enculturation includes background knowledge of the data, terminology, tools and research methods of the discipline; analytical and technical skills for developing and evaluating experiments; and meta-cognitive skills to review progress, assess challenges and plan future explorations.[9,10]

Both constructivism and socioculturism are rooted in the social constructivism theory developed by Vygotsky,[11] who argued that knowledge and meaning-making activities cannot be divorced from the context in which the learning takes place. Building on the idea that knowledge is constructed in a sociocultural context, undergraduate research provides **inquiry- and problem-based learning activities that immerse students in the theory, content and practice of the scientific process.** Inquiry-based activities may include making observations, developing hypotheses, using reference materials, generating and analyzing data, and communicating results.[9] Engaging in inquiry-based activities helps students learn the content of the problem area they are exploring, as well as essential skills for effective investigation processes.[12–15] Problem-based learning approaches challenge students to focus their efforts on understanding and solving a specific problem by synthesizing existing knowledge, applying investigative processes, testing possible solutions and evaluating results.[16–21]

Since 2004, the lead author has personally mentored more than 50 undergraduate researchers, resulting in dozens of undergraduate research posters and several workshop,[22] conference,[23,24] and journal[25–27] publications. The author's expertise in computational science and image analysis has led to collaborations in Engineering, Zoology, Biology, Psychology, Linguistics and Medicine, and the lead author has mentored undergraduate researchers majoring in many disciplines. The co-author directs the Engineering Summer Undergraduate Research Experience (EnSURE) program at Michigan State University (MSU), which engages students in 10 weeks of full-time research with Engineering faculty, along with weekly professional development activities to help students prepare for graduate studies. EnSURE serves approximately 100 students annually, and culminates in a regional symposium[28] that allows students to share their undergraduate research experiences with faculty, students, graduate school recruiters and community members. The co-author also has experience in mentoring students' research[29] and has co-published several studies related to undergraduate research experiences.[30–34]

With experience, mentors often develop tricks and techniques for streamlining their efforts when working with undergraduate research assistants.[35] The three-step methodology described here for working with undergraduates in Engineering research developed over time, and was formally implemented in the last two years. During this time, the lead author mentored 20 undergraduates from 8 different institutions, all of whom spent time at MSU working on research related to the analysis of image data. Many of these undergraduates also participated in the EnSURE program, and for simplicity the three-stage methodology is presented in this paper in the context of a 10-week summer research project. However, this method has also been successfully used to manage part-time undergraduate researchers working during the academic year, and as part of an undergraduate research class where students received course credit for their effort.[36] Table 1 and Table 2 summarize the undergraduate research projects supervised by the lead author during the summers of 2012 and 2013, while

Table 3 summarizes the research projects completed during an undergraduate course taught by the lead author during the 2012-13 academic year. This information is included to provide context for the reader, and to demonstrate that the approach described here has been used successfully with students from a variety of backgrounds.

Table 1: Summer Undergraduate Research Projects Mentored by the Lead Author in 2012

| **Research Project** | **Home Institution** | **Gender** | **Ethnicity** |
|---|---|---|---|
| Aiding Manual Image Annotation using a Kinematic Model | Morehouse College | Male | African American |
| Automated Color Space Exploration in Image Processing | Michigan State University | Male | Caucasian |
| Automated Image Measurements | University of Maryland-Baltimore | Female | African American |
| The Variation of Accuracy and Precision in Ground Truth Points | Spelman College | Female | African |

| | | | |
|---|---|---|---|
| | | | American |
| Using reinforcement Learning with SIFT to Track Objects in Videos | University of Michigan | Male | Caucasian |

Table 2: Summer Undergraduate Research Projects Mentored by the Lead Author in 2013

| **Research Project** | **Home Institution** | **Gender** | **Ethnicity** |
|---|---|---|---|
| Toolbox for evaluating algorithms that detect anchor points in images | University of Texas at El Paso | Male | Hispanic |
| Automated Image Segmentation System for use in Research Workflows | University of Michigan | Male | Caucasian |
| Improving the Accuracy and Efficiency of Image Phenomics | Clemson University | Female | Non-Hispanic |
| Avida Checkpoint Restart Implementation | Boise State University | Female | Afghan |
| Research Centered Design: A Case Study in Building Usable Image Analysis Tools for Researchers | Michigan State University | Male | Caucasian |
| Interpolation of Identifier Points of Landmarks that Create Stitched Images with Varying Levels of Focus | Michigan State University | Male | Caucasian |

Table 3: Undergraduate Research Projects Completed as part of an Honors Research Seminar for First- and Second-Year Students at MSU, taught by the Lead Author in 2012-2013

| **Research Project** | **Major** | **Gender** | **Ethnicity** |
|---|---|---|---|
| Healthy vs. Unhealthy: Analysis of FMRI Images In Relation to Food Choice. | Human Biology | Female | Caucasian |
| Background Subtraction | Chemistry | Male | Caucasian |
| Facial Expression Analysis | Neuroscience | Female | International |
| Optimizing CMEIAS A Novel Computing Tool for Microbial Ecology. | Electrical and Computer Engineering | Male | International |
| The Automation of Chestnut Grading | Civil Engineering | Female | Caucasian |
| Improving Chamview Software Though Python Programming | Engineering - No Preference | Female | Caucasian |
| Correlation Between Brain Volumes and Age in People with Alzheimer's Disease. | Electrical Engineering | Male | Caucasian |
| Speed Dating Technology: Finding the Right Program For Analyzing Audio and Video Data | Political Theory and Constitutional Democracy | Male | Caucasian |
| An Analysis of the Workflow in Studying the Biomechanics of Equine Circular Locomotion | Animal Physiology | Female | Caucasian |

## Overview of Undergraduate Research Mentoring Process

The undergraduate research mentoring method described here involves three stages, each of which combines inquiry- and problem-based approaches to immerse students in the theory and practice of science and engineering research. The hands-on projects in Stage 1 give students a foundation of essential skills and concepts that they can build on during Stages 2 and 3, when they engage in a domain-specific project with their research mentor. Two major evaluation checkpoints are built into the system, at the end of weeks 1 and 3. Students' progress at each of these checkpoints determines how the research process proceeds, and provides a clear "exit strategy" for instances when students are not reaching minimum performance standards and the mentor wishes to minimize additional time and energy spent on this student.

Figure 1 outlines the three-stage process for mentoring undergraduate researchers. In order to encourage students to develop independence, each stage includes a series of problem-based activities that include educational scaffolding (supports) to assist students in building skills. As students gain experience, they are challenged with more difficult tasks – yet this process also allows research mentors to customize the experience for students. By giving students individual expectations and goals, they are able to work at their own pace – whether they spend the summer mastering basic skills or quickly progress to more challenging activities. The appendix shows an example welcome letter sent to students (via email). The welcome message is designed to introduce students to the three stages of our mentored research process, and what they will be doing in each of the stages.

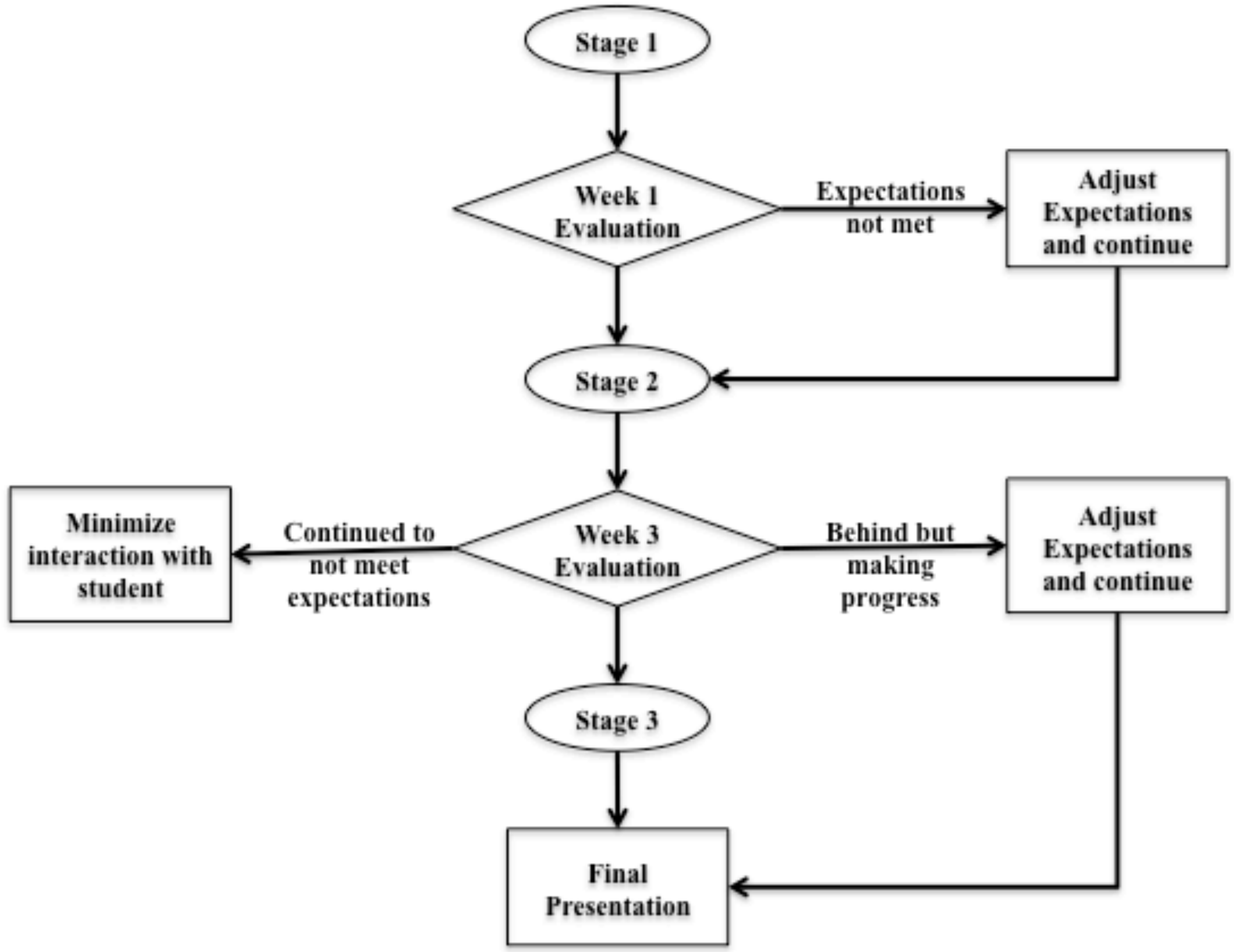


**Figure 1: Flowchart of Research Mentoring Process**

## Stage 1 – Introductory Tasks

In the first stage students are assigned a specific task to complete, with basic instructions for getting started. An example task for this first stage is downloading and installing software to support their project. While the first stage tasks are meant to be simple, in reality it often takes students extra time to get things working because there are "start up" costs: allocating office space and computer resources, setting up accounts, obtaining keys and IDs, getting familiar with the lab, etc. If students can get through this first stage quickly, they can move on to the second stage – and ultimately will have more time spend in the later stages of the project. If the first stage task takes longer than a week, the mentor will sit down with the student and re-evaluate the project to make sure the goals are reasonable, adjusting as needed.

The goal of Stage 1 project is to immediately engage students by getting them ready to do research, while also providing the mentor with a baseline assessment of students' independent problem solving abilities. For example, students might receive detailed instructions for completing tasks similar to the following:

- Download and install software tools used by the research lab

- Download the testing dataset from a project website
- Use software to annotate a testing dataset (following the directions provided) and email annotation results to the mentor
- Go though an introduction tutorial to gain familiarity with a research tool and conduct a basic tutorial experiment using the tool

Projects in Stage 1 should be chosen so that a novice student can complete this type of project in 1-5 full days of work. A good rule of thumb is that a first stage project should take an experienced researcher only 15-30 minutes to complete on his or her own; giving inexperienced students 1-5 days to complete this task should provide sufficient information for the mentor to estimate whether students will be able to take on harder tasks.

After completing Stage 1, students sit down with their research mentor and evaluate their project. Careful consideration of the student's abilities must be made at this point. If the student was not able to complete Stage 1, the mentor must decide how much time he/she is able to put into mentoring the student. Generally it is not recommended that a student be terminated after their first week of work. However, it is important that the mentor talks to the student and sets clear expectations for progress expected during the next two weeks. If termination is a possibility, the student should be properly warned at this evaluation and clearly understand that a decision will be made at the next evaluation.

**Stage 2 – Small Project**

During the second stage, students will have a small (but complete) project that they can see through from start to finish. Examples include analyzing a small dataset or doing initial benchmark tests. More experienced students can often finish a Stage 2 project in a week or two, although the pace will vary depending on the project and what skills students need to learn. If it takes more than two weeks for a student to complete stage 2, the mentor can sit down with the student and re-evaluate the project goals and adjust the pace if needed.

The goal of Stage 2 projects is to give students more practice with the research methodologies and workflows used in the lab, while also providing the mentor with further opportunities to evaluate the students' abilities. Stage 2 projects should be designed such that students who are not able to progress to the third stage would be able to present the results of their Stage 2 project by the end of the 10-week experience. Example projects for stage two include:

- Re-evaluate an existing dataset for a new treatment
- Use evaluation machine or program to explore a new area of research
- Write a simple program to automate the workflow
- Write a simple program to visualize some data

Projects in Stage 2 should be chosen so that a good student can complete this type of project in 1-2 full weeks of work. A good rule of thumb is that a second stage project should take an experienced researcher a maximum of 2-4 hours to complete on his or her own.

After completing their third week of the program, students sit down with their research mentor and evaluate their progress. Students need to be evaluated at the third week (or sooner) regardless of whether they have completed the second stage project. At this point, mentors should be able to separate the excellent students from those who are average or poor research assistants. Excellent students are those that are able to complete the Stage 2 projects on time and are ready to move forward. Average students may not have completed the Stage 2 project, but should be making strong progress. At the week 3 evaluation, poor students may not even have completed the project from Stage 1 – and it may be necessary for the research mentor to determine whether to continue working with poor-performing students at this point.

**Terminating or Minimizing Interactions with Poor-Performing Students**

Mentors who accept unpaid interns or who hire student research assistants themselves may be able to terminate poor-performing students after the third week evaluation. Mentors who do need to terminate a student should approach the process thoughtfully, with the goal of making this a "teachable moment" for the student. While being fired from an undergraduate research position may be traumatic for the student, the long-term career impact is likely to be minimal and hopefully the student will learn from the experience. Mentors should take the time to provide written feedback for the student, noting both strengths and areas for improvement, and ensure that the student understands how they fell short of the initial expectations.

In other cases, it is not possible to terminate a student (either firing or zero class credit); for instance, students may be on campus for a specific summer research experience funded by someone other than the mentor. In this case, it is recommended that the mentor conduct the three week interview as if the student was being terminated and then try to minimize further interactions with a poorly performing student. Obviously, this can be difficult – particularly in situations where students continue to be compensated – but is important for mentors who do not want to waste resources on students who are unprepared, uninterested, or otherwise incapable of meeting basic expectations for the research experience. Minimal contact might include having the student continue to participate in weekly group meetings and submit progress reports, but discontinuing one-on-one meetings. For some under-performing students, the shock of being "dismissed" by their mentor is sufficient motivation to improve their performance, while other students will welcome the reduced "face-time" and consequently reduce demands on the mentor's time and resources.

**Stage 3 – Final Project**

Most students will make adequate progress by the third week review, and after completing Stages 1 and 2 they will have established a good foundation of skills for working in the research lab. When students are ready for an additional challenge, they will work with their research mentor to extend their project in a direction that builds on their experiences, interests and capabilities. This open-ended project is the core of Stage 3, and the mentor should help the student estimate how much can be accomplished in the available time and establish appropriate goals for this stage. In the best case, students can complete their project from start to finish and contribute enough of their own ideas to lead to a research publication.

It is important that students formally present their work, and many research programs conclude with a poster presentation or other forum for students to share their experiences. Other options might include presenting a poster or giving a talk at a campus or regional symposium, or even giving a formal presentation to the research group or department. Distilling their experiences into a poster or oral presentation gives students valuable experience in communicating technical content, and encourages students to reflect on the their contributions to the larger research project.

**Example Projects**

This three-step method for mentoring undergraduate researchers is easy for faculty to implement and scaffolds students' introduction to the research domain. Highly motivated students have the opportunity to gain skills and responsibility as they move through the three stages of this mentoring plan. For students with less experience or interest, the first two stages offer a valuable learning experience – even if the students never progress to the final stage of the project. Overall, this approach minimizes faculty time and effort while providing appropriate, scaffolded learning experiences for undergraduate research assistants.

The following examples demonstrate how this approach has been effective when working with students whose motivation and skills vary. These examples are based on the authors' actual experiences, although identifying details have been changed.

**Example 1 – Slow Progress**

As part of a formal, 10-week summer research experience, a student with fairly extensive programming experience was hired to help develop some algorithms for a code used in digital image analysis. The mentor designed the following three-stage plan and explained it to the student at the beginning of the summer:

> **Stage 1:** Download and install two software tools (git and python) on the student's local machine, then pull the latest build of the lab's digital annotation software. Get the software up and running using the provided test images, following the full step-by-step instructions provided.
>
> **Stage 2:** Rewrite part of the algorithm to use a very basic physics model. The entire program can easily be written in 10-15 lines of code. The student is provided with a complete pseudo-code showing how the algorithm will work and indicating where in the existing code the modifications can be made.
>
> **Stage 3:** Explore other, more complex physics models and compare results to the basic model. The mentor will provide a number of ideas, but the student is also encouraged to explore options based on their own creativity and experience.

The student was able to complete the Stage 1 project with minimal intervention from the mentor. However, at the one week review the mentor mentioned that it was worrisome that it took the entire week for the student to get up to speed, and that the student did a poor job reporting progress and asking questions. The mentor continued to notice problems during Stage 2, when the student failed to grasp the algorithm that need to be implemented, despite discussing and diagramming it multiple times during group meetings. At the three-week evaluation meeting, no real progress had been made and it was clear that the student was not ready to move on to Stage 3. Instead, the student continued working on the Stage 2 project until the end of the summer.

After the week-three evaluation meeting, the mentor limited face-to-face interactions with this student to the weekly group meetings, and instead encouraged more advanced students to help guide the underperforming student. This approach not only preserved the mentor's time, but also allowed the more advanced students to gain mentoring experience. Peer-mentoring worked well for this student, and by the end of the 10-week program the student had completed the original Stage 2 project and met some additional goals. The resulting code was of good quality and is still being used in the main branch of the research codebase.

**Example 2 – Change in Plans**

In this case, the student had fairly extensive parallel programming experience and previous research experience, and was matched with the mentor as part of a 10-week summer research program. The mentor outlined the following three stages for the student at the beginning of the summer:

> **Stage 1:** Download, install, and complete tests using existing digital evolution software.
>
> **Stage 2:** Get the software working on a high-throughput Condor (HTCondor) cluster.
>
> **Stage 3:** Identify and develop new research workflow tools to allow researchers to take advantage of various high performance computing resources and research methods to scale digital evolution codes on modern computational platforms.

The mentor did not have a lot of experience with the digital evolution software, and it turned out that the campus expert was not available for consultation early in the summer. So, the student changed focus in the first week to instead learn as much as possible about HTCondor and quickly managed to get some fairly complex Python examples working in HTCondor. By the third week evaluation, the student had demonstrated substantial programming competence and had written a number of different workflows for HTCondor including: MATLAB, Java, Python, and R. In the third stage of the project, the student was able to take on a much more difficult project of getting the digital evolution software to run on the local High Performance Computing resource using a Checkpoint/Restart Library called BLCR. This project far outreached the initial goals and resulted in the submission of a paper. The student's work also had a much broader impact, by allowing researchers using the digital evolution software to take advantage of a wider range of high performance computing resources, which enabled explorations of new kinds of research questions.

**Example 3 – Minimum Technical Expertise**

This final example is also of a student participating in a 10-week summer research program, but in this case the student had little to no programming, engineering or technical experience (which is not uncommon when working with younger students). Here is the 3-stage project as described to the student at the beginning of the summer:

> **Stage 1:** Download, install, test and evaluate two existing segmentation tools.
>
> **Stage 2:** Use existing tools and manual tools to segment a small baseline testing dataset, making sure that the resulting foreground and background mask data are easily accessible by other programs (which you will help develop in stage 3).
>
> **Stage 3:** Annotate a variety of larger datasets to prepare for segmentation testing. Work with team to develop a tool to compare automatically generated foreground and background masks to ground truth masks. Develop tools to graph the results of the comparisons in meaningful ways.

This project was specifically designed to allow the student to contribute to the lab's research, even without learning any programming. Working with other students in the lab, this student was easily able to complete the first two stages within the allocated three weeks. The student became an expert at segmenting user interfaces using existing tools, and was able to generate annotated datasets for ongoing experiments. Ultimately, this student was able to organize the datasets in a way that made it quick and easy for other members of the research group to test their algorithms, and the student learned valuable research skills by participating in the program.

**Concluding Discussions**

One key feature of the research examples described above is that they were projects tangential to the mentor's main research thrust. While it would be great if students are able to finish the projects, the main research will not stall if the undergraduate research assistants do not meet expectations. For students with limited skills, data visualization projects may be ideal: giving students existing research results and having them generate graphs and movies that could be added to the mentor's presentations and publications, but are not essential. For more experienced students or those who have a lot of potential, it may be helpful to start them on exploratory experiments for research projects that are 6-12 months away. If students are successful, their exploratory work can jump-start the research; yet only minimal time is lost if the students are not successful.

Compensating students, whether through payroll or course credit, is an important part of most successful undergraduate research experiences. While there is certainly value in the research experience itself, unpaid volunteers may be less motivated and drain mentors' time and resources. This three-stage model can be adapted to help mentors manage a motivated volunteer: meet with the student once to develop a small project they can complete on their own time, such as background research or a programming task. Establish a deadline and encourage the student to present their results to the group, if appropriate. If the student completes the project and meets the deadline, then the mentor may find value in spending more time working with the student to develop a more challenging project. Effectively managing volunteer efforts can be a good way for mentors to identify promising students, who may move into compensated roles after gaining volunteer experience.

The three-stage, project-based approach to mentoring undergraduate researchers allows students to develop skills and gain responsibility over time. This methodology also minimizes the risk that mentors will be "stuck" with an underperforming student who requires a lot of time and resources without producing valuable results. This approach requires some up-front effort from the mentor to select and sequence projects that will allow the exceptional students to excel, help the average students move forward, and quickly identify poor-performing students so the mentor can choose to separate early, before expending significant time and resources.

## References


1. Kuh GD. High-impact educational practices: what they are, who has access to them, and why they matter. Association of American Colleges and Universities; 2008. 50 p.
2. Dolan EL, Johnson D. The Undergraduate–Postgraduate–Faculty Triad: Unique Functions and Tensions Associated with Undergraduate Research Experiences at Research Universities. CBE-Life Sci Educ. 2010;9(4):543–53.
3. Zydney AL, Bennett JS, Shahid A, Bauer K. Faculty perspectives regarding the undergraduate research experience in science and engineering. J Eng Educ. 2002;91(3):291–7.
4. Nyden P. Academic Incentives for Faculty Participation in Community-based Participatory Research. J Gen Intern Med. 2003;18(7):576–85.
5. Thomas E, Gillespie D. Weaving together undergraduate research, mentoring of junior faculty, and assessment: The case of an interdisciplinary program. Innov High Educ. 2008;33(1):29–38.
6. Loyens SMM, Gijbels D. Understanding the effects of constructivist learning environments: introducing a multi-directional approach. Instr Sci. 2008 Sep 1;36(5-6):351–7.
7. Phillips DC. Constructivism in Education: Opinions and Second Opinions on Controversial Issues. Ninety-Ninth Yearbook of the National Society for the Study of Education. Yearb Natl Soc Study Educ. 2000 Jan;
8. Soloway E, Jackson SL, Klein J, Quintana C, Reed J, Spitulnik J, et al. Learning Theory in Practice: Case Studies of Learner-centered Design. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems [Internet]. New York, NY, USA: ACM; 1996 [cited 2014 Jan 4]. p. 189–96. Available from: http://doi.acm.org/10.1145/238386.238476
9. Council NR. National science education standards. National Academy Press; 1996.
10. Bransford J, Brown AL, Cocking, National Research Council (Estats Units d'Amèrica), Committee on Developments in the Science of Learning. How people learn: brain, mind, experience, and school. Washington, D.C.: National Academy Press; 2000.
11. Vygotsky L. Mind in Society: The Development of Higher Psychological Processes. 1978.
12. Linn MC, Songer NB, Eylon BS. Shifts and convergences in science learning and instruction. Handb Educ Psychol. 1996;438–90.
13. Luchini K, Quintana C, Soloway E. Design guidelines for learner-centered handheld tools. Proceedings of the SIGCHI conference on Human factors in computing systems [Internet]. New York, NY, USA: ACM; 2004 [cited 2012 Feb 14]. p. 135–42. Available from: http://doi.acm.org/10.1145/985692.985710

14. McGilly K. Cognitive science and educational practice: An introduction. Classroom lessons: Integrating cognitive theory and classroom practice [Internet]. MIT Press; 1996 [cited 2014 Jan 4]. Available from: http://books.google.com/books?hl=en&lr=&id=YyiywUE-M0YC&oi=fnd&pg=PR7&dq=%E2%80%9CCognitive+science+and+educational+practice:+An+introduction,%E2%80%9D+mcgilly&ots=hsx7tDRdU7&sig=FZDyQ2fop4CST7tDfGlULVprYYo

15. Olson S, Loucks-Horsley S. Inquiry and the National Science Education Standards: A guide for teaching and learning [Internet]. National Academies Press; 2000 [cited 2014 Jan 4]. Available from: http://books.google.com/books?hl=en&lr=&id=m7gOqWwq0scC&oi=fnd&pg=PR11&dq=%22Inquiry+and+the+National+Science+Education+Standards:+A+Guide+for+Teaching+and+Learning%22&ots=88nfhYPT4u&sig=0iek3p0RseOBZfTWj8pkP-PRvZc

16. Camp G. Problem-based learning: A paradigm shift or a passing fad? Med Educ Online [Internet]. 1996 [cited 2014 Jan 4];1. Available from: http://med-ed-online.net/index.php/meo/article/viewArticle/4282

17. Loyens SM, Magda J, Rikers RM. Self-directed learning in problem-based learning and its relationships with self-regulated learning. Educ Psychol Rev. 2008;20(4):411–27.

18. Norman GR, Schmidt HG. The psychological basis of problem-based learning: a review of the evidence. Acad Med. 1992;67(9):557–65.

19. Savery JR, Duffy TM. Problem based learning: An instructional model and its constructivist framework. Educ Technol. 1995;35(5):31–8.

20. Schmidt HG. Problem-based learning: Rationale and description. Med Educ. 1983;17(1):11–6.

21. Schmidt HG. Foundations of problem-based learning: some explanatory notes. Med Educ. 1993;27(5):422–32.

22. Ingle N, Door T, Colbry D, Dyer F. Coordination of Vision and Action in Chameleons. 49th Animal Behavior Society Annual Meeting,, Albuquerque, NM. 2012.

23. Hayden D, Colbry D, Black Jr JA, Panchanathan S. Note-taker: enabling students who are legally blind to take notes in class. Proceedings of the 10th international ACM SIGACCESS conference on Computers and accessibility [Internet]. 2008 [cited 2014 Jan 4]. p. 81–8. Available from: http://dl.acm.org/citation.cfm?id=1414488

24. Colbry D, Oki F, Stockman G. 3D face identification: experiments towards a large gallery. SPIE Defense and Security Symposium [Internet]. 2008 [cited 2014 Jan 4]. p. 694403–694403. Available from: http://proceedings.spiedigitallibrary.org/proceeding.aspx?articleid=834970

25. Pickett R, Colbry D, Sagert I. Computational science education through multiple approach parallelization for supernova simulation development. Submitt J Comput Sci Educ. 2012;

26. Stockman G, Payne J, Sadler J, Colbry D. Error analysis of sensor input variations in a 3D face surface matching system. Sens Rev J. 2006;26(2):116–21.

27. Krishnan NC, Juillard C, Colbry D, Panchanathan S. Recognition of hand movements using wearable accelerometers. J Ambient Intell Smart Environ. 2009;1(2):143–55.

28. Mid-SURE - URCA - MSU URCA [Internet]. [cited 2014 Feb 27]. Available from: http://urca.msu.edu/midsure

29. Luchini-Colbry K, Ortega-Knight T, Chen C, Lynch D, Fitzsimons K, Alton C, et al. Exploring the Experience of Undergraduate Research: A Case Study Using facebook. Proceedings of the 2013 ASEE National Conference. Atlanta, GA; 2013.

30. Luchini-Colbry K, Steinke-Wawrzynski K, Mangiavellano R, McCune E. Guiding Them to Graduate School: Professional Development for Undergraduates Participating in Engineering Research Programs. Proceedings of the 2012 ASEE National Conference. San Antonio, TX; 2012.

31. Jackson-Elmoore C, Steinke-Wawrzynski K, Luchini-Colbry K, Boucher-Niemi J. Undergraduate Research: Blending the Scholarship of Discovery, Teaching, Application and Integration. In: Fitzgerald H, Primavera J, editors. Public: Civic and Community Engagement, the Scholarship of Practice. MSU Press; forthcoming.

32. Luchini-Colbry K, Gonzalez T. Finish my Research! Find a Job! Feel Better! Seminars to Support Engineering Graduate Students' Professional and Personal Goals. Proceedings of the 2014 ASEE National Conference. Indianapolis, IN; 2014.

33. Luchini-Colbry K, Shannahan M, Steinke-Wawrzynski K. Feeling Like a Grad Student: A Survey of Undergraduate Researchers' Expectations and Experiences. Proceedings of the 2013 ASEE National Conference. Atlanta, GA; 2013.

34. Luchini-Colbry K, Steinke-Wawrzynski K, Shannahan M. The Mentoring Experience: Finding Value in Guiding Undergraduate Researchers. Proceedings of the 2014 ASEE National Conference. Indianapolis, IN; 2014.

35. Coker JS, Davies E. Ten time-saving tips for undergraduate research mentors. J Nat Resour Life Sci Educ. 2006;35(1):110–2.

36. Colbry D, Luchini-Colbry K. STEM inSight: Developing a Research Skills Course for First- and Second-Year Students. Proceedings of the 2013 Conference of the American Society for Engineering Education. Atlanta, GA; 2013.

# Appendix

Welcome!

This summer, you will be working together as a research group with me on a wide variety of projects. I have mentored undergraduate research assistants for many years, and am looking forward to working with you this summer. We have a pretty large group (8 students) this year, which is exciting because we can learn from each other and collaborate to accomplish some really interesting projects. Communication and coordination are very important, particularly in a large group, so I wanted to take some time to let you know what to expect this summer.

This summer, each of you will be assigned to a specific project. While you will have ownership of this project, you will also work collaboratively as a group to solve problems, share ideas, and support each others' work.

To help you get started, I am structuring the individual projects into three stages:

**Stage 1 (1 week)**: In the first week, you will be assigned a specific task (like downloading and installing software to support your project). While the first stage tasks are meant to be simple, in reality it often takes extra time to get things working at first (set up accounts, figure out what you need to do, get familiar with your co-workers, etc.). I like to give new students up to a week to finish the stage one project. It is not a race, but if you can get though this stage quickly you will have more time for the more fun projects in the later stages. If stage one takes you longer than a week, we will re-evaluate your project to make sure the goals are reasonable and adjust as needed.

**Stage 2 (2 weeks):** During the second stage, you will have a small (but complete) project that you see through from start to finish. Examples include analyzing a small dataset or doing initial benchmark tests. More experienced students can often finish a Stage 2 project in a few days, although the pace will vary depending on your project and what skills you need to learn. If it takes more than two weeks for you to complete stage 2, we will re-evaluate the project goals and adjust the pace if needed.

**Stage 3 (7 weeks):** This is your main project for the summer, and in most cases this project will be open-ended. We will work together to see how much you can accomplish during the summer program - the pace and goals for this stage will vary depending on your projects, skills and interests. In the best case, we hope to achieve some results that can lead to a publication.

In the final week of the summer program, each of you will present a poster about what you have accomplished during the summer.

The best way to get in touch with me is via email. I expect that you will check your email account regularly (at least twice a day during the work week), as I will use email to communicate with you. We will discuss specific schedules once you're on campus, but typically you should expect to be in the office working during normal business hours (between 8am and 5pm) Monday through Friday.

I hope that this overview is helpful as you make plans for this summer. Let me know if you have questions.

I look forward to working with you!

- (Your Mentor)