Designing Undergraduate Research Projects That Benefit Both Students and Faculty

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Abstract

In any discipline, providing research experiences for undergraduate students is known to enhance their learning experiences. However, faculty research advisors sometimes fail to get much scholarly achievement in return for their efforts in working with such students, mainly because the students’ lack of experience limits their ability to contribute to the research advisor’s scholarly work. Additionally, students sometimes miss out on enhanced learning opportunities because of the obstacles involved in providing an ideal learning environment. This essay provides strategies to improve the potential for faculty gain when working with undergraduate students while simultaneously enhancing the learning experience for the student.
Motivation

A research experience is one of the most meaningful learning opportunities for an undergraduate student. The myriad benefits that result from such an experience have been elegantly summarized by the Undergraduate Research Advisory Committee at Winthrop University (2006) in a proposal to increase support of undergraduate research. Their proposal is supported by documented findings: undergraduate research experiences enhance critical and analytical thinking skills (Ishiyama, 2002; Lopatto, 2004; Merkel, 2001; Seymour, Hunter, Laursen & DeAntoni, 2004); improve students' abilities to acquire, process, and communicate information (Bauer& Bennett, 2003; Kardash, 2000); promote learning (National Conferences on Undergraduate Research/Council on Undergraduate Research, 2005), student success (Nagda, Gregerman, Jonides, von Hippel & Lerner, 1998), and self-confidence (Seymour et al., 2004); and help students solidify career plans (Lopatto, 2004; Seymour et al., 2004). While the benefit to students is substantial, the benefit to faculty research advisors may be less so. Undeniably, research advisors thrive on watching young researchers learn, grow, and become more independent critical thinkers. Yet, in terms of advancing meaningful scholarship relevant to an advisor's research interests, there is often little payoff to working with undergraduate students in a research setting.

For a research experience to be symbiotic, both the student and the research advisor must receive some benefit. For the student, the benefits are those listed above, but most importantly the development of critical thinking skills. For the faculty advisor, aside from the gratification associated with teaching in this capacity, an added benefit should be increased productivity of scholarly work, which in turn becomes a motivating factor for a faculty member to truly invest in cultivating a student researcher's analytical skills.

In this essay, I will outline a project design that provides the best opportunity for student contributions to an advisor’s scholarly goals while simultaneously offering the best opportunity for student learning. This design is followed by a variety of disciplines, particularly the natural and physical sciences; however, it is not broadly utilized across all fields. Nonetheless, its incorporation in any undergraduate research setting could dramatically influence both student learning and the scholarly advancement of the research advisor in a positive way.
There are significant obstacles for the implementation of the proposed project design and impediments for the meaningful advancement of an advisor's work. These will be addressed along with some proposed strategies for their resolution. The goal is that the application of these techniques for research with undergraduates in any field will enable faculty to increase potential for scholarly productivity while providing a mutually beneficial experience.

**Project Design**

For students to positively contribute to the scholarly activities of a research advisor, they must possess certain analytical skills. However, very few undergraduate students have the skills necessary to critically analyze at the appropriate level when first beginning a project. Instead, they must follow a growth trajectory that takes them from mere technicians toward becoming independent researchers. These stages of development parallel the categories of the cognitive domain of Bloom's taxonomy (Anderson & Krathwohl, 2001) as depicted in Figure 1. As a student moves through the developmental stages from technician to observer to analyst to research designer, they will require the skills described by the cognitive domain: remember, apply, understand, and evaluate/create.

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**Figure 1. A schematic comparison of the categories in the cognitive domain of Bloom's taxonomy and the developmental stages of a researcher. The figure of Bloom's taxonomy was adapted from Anderson and Krathwohl (2001).**
At the start of a project, undergraduate researchers are, at best, technicians because they can follow directions and remember steps or sequences, but their abilities beyond this are limited. However, the more exposure to research techniques they have, the better able they are to apply what they've done before to new situations. They become better observers of their own experimental processes, even if they can't necessarily put all the pieces together. While it is unlikely that a student will progress all the way to become a designer of a complete research project in just a few semesters of work, the goal of the advisor should be to bring the student to at least the beginning stages of an analyst, where a student truly understands the project and can start making his/her own conclusions.

Research advisors are the true designers of research projects, and it is unreasonable to think that an undergraduate student could independently create his or her own project. However, with guidance from an advisor, he or she could work toward that goal via the cognitive apprenticeship model. This model, developed by Collins, Brown, and Newman (1989), is a natural fit for a student research setting since this environment allows students to actually practice what they've been taught (Lave, Smith, & Butler, 1988). The methodology proposed in the model involves a progression from modeling, coaching, and providing scaffolding for learning to student articulation, reflection, and exploration (Collins, et al., 1989). Applied to an undergraduate research setting, the advisor is ever-present, guiding the student during the early stages of a project, but the presence fades over time, and the student becomes more independent. The overarching goal is to bring the student through the developmental stages of a researcher described above.

The strategies for working with undergraduate researchers described in this essay dovetail nicely with the cognitive apprenticeship model and are therefore at the heart of successfully imparting critical thinking skills to student researchers. However, the research project must be designed with this philosophy in mind. This is best achieved by developing a project that is both closely related to a faculty member's scholarly pursuits and original in nature.

Helping students choose projects that overlap with the faculty advisor's interests is one of the best ways for a student to potentially contribute to an advisor's scholastic goals. The student's experience is also enhanced because the advisor will have a vested interest in the research outcomes, which leads
to a closer student-advisor relationship, a critical component of any undergraduate research experience (Laursen, Hunter, Seymour, Thiry & Melton, 2010; Thiry & Laursen, 2011; Thiry, Laursen & Hunter, 2011).

As research advisors, it is often our instinct to let students choose their own research topic, and there are some advantages to this approach. This method is an excellent exercise in the use of the scientific method. After all, refining a research question is an important skill that should be nurtured. However, when students choose their own project, they may not be taking full advantage of a research advisor’s expertise if the project is different than the scholarly work of the advisor. Additionally, this choice potentially negates the opportunity for students to contribute to the advisor’s scholarly work.

Allowing students total freedom in choosing a project can lead to other challenges with the project as well. Most students are not familiar with the whole of their discipline and will not fully grasp the potential complications of a project of their choice. They are also unfamiliar with what resources will be available to them, and any shortage of required resources would limit their success. Finally, they will most certainly need the guidance of the research advisor for any project they pursue, and advisors will have difficulty providing support if they are not already well versed in the topic of choice.

The choice of an original project (versus an exercise with well-established results) instantly exposes students to a more realistic view of research where they will encounter uncertainty, failure, and real challenges without immediate answers. Also, original projects are likely to be more difficult and can therefore provide more advanced training to student researchers. Lastly, students will have a greater sense of ownership of their project if they feel they are working on something meaningful rather than a mundane exercise such as simply searching the literature.

While the ideal research setting has just been described, many obstacles exist for creating such an experience for students and research advisors. The obstacles related to these aspects of implementation and some potential solutions are described below. Many proposed strategies for handling these obstacles fit well with the cognitive apprenticeship model (Collins, et al., 1989), and their connections to this model are also described.
Obstacles

Students May Not Be Passionate About an Advisor's Work
The main concern associated with limiting students' choices when it comes to project design is that the student may not be interested in the available topics. Ideally, students could choose their own projects, and they would be passionate about them, thereby creating a vested interest in the outcomes. However, there is a high probability that the students' choices would be outside of an advisor's area of expertise. This not only minimizes the opportunities for an advisor's scholastic productivity, but also increases the level of difficulty for the student since he or she is not taking advantage of the advisor's expertise as a resource for success.

Original Projects Cannot Be Completed in a Short Period of Time
Most research projects are unending. While publication may result, signifying completion of a certain aspect of the work, in the big picture, there is always more to be done. It is difficult to imagine chopping a researcher's life's work into small pieces that could be completed by a student over the course of one or two semesters. Yet, students should experience a "beginning-middle-end" for their project rather than jumping into the middle of a project or having unfinished work at the end of their term.

Students Aren't Prepared for Difficult Projects
The primary reason research advisors have for putting students on simple, independent projects unrelated to their own work or projects that are unoriginal is that their own personal, original projects are too difficult for students to comprehend. This analysis makes perfect sense because researchers typically have a minimum of several years of graduate-level training, and many have decades of research experience. How can undergraduate students work on advanced projects when their exposure to the field includes only a few semesters of undergraduate coursework?
Faculty Don’t Have Enough Time to Work with Students One-on-One

To provide students with the best opportunity for learning, particularly in an apprentice-style model, the research advisor must invest a large amount of time engaging with the student. However, time is a precious commodity in an academic setting and frequently not available for one-on-one interactions. Often, other priorities (usually those with deadlines and especially those that directly impact the advisor’s own professional development) take precedence, and research students are unable to make significant progress without the advisor’s guidance.

Strategies for Overcoming Obstacles

Create a Prerequisite Course

To prepare undergraduates for the rigors of research, a prerequisite course could be developed to introduce students to the various aspects of research related to his or her discipline. The course could include literature searching techniques, miniature projects or term papers, or a review of critical concepts required for success. Anything that a research advisor routinely tells each undergraduate researcher could be covered in such a course so that precious time is not wasted relaying such information on an individual basis. This strategy not only reduces the amount of individual attention required by students, even during the first semester of research, but also helps to prepare them for the challenges of advanced projects by teaching problem solving, control and learning strategies. These skills comprise the content component of the ideal learning environment described by the cognitive apprenticeship model (Collins, et al., 1989).

Encourage Students To Start Research Early in Their Careers

Students should be encouraged to start research early in their careers and work with an individual advisor for multiple semesters. This approach has obvious benefits to the student in that he or she has more time to work through the developmental stages of becoming a researcher. However, it also gives the faculty advisor more opportunities to bring the student through the method described in the cognitive
apprenticeship model (Collins, et al., 1989). The student has greater potential to reach the exploration step if he or she works long enough on the project. For instance, the initial semester may be devoted to the investment of training the individual on the basics of research through modeling and coaching. Then, in following semesters, students may become more independent and could go on to produce more and more fruitful contributions to a project over time, thereby improving the scholarly productivity of the project.

Provide a Limited Choice of Projects

The concern of a student not being passionate about an advisor's work is a valid one. After all, if the student is uninterested, he or she certainly won't be devoted, and there will be little productivity for the advisor or learning for the student. The best compromise is to provide some limited choices to students. Most researchers work on more than one project at a time, and there is likely more than one researcher in an academic program, so the combination of multiple researchers working on multiple projects means there are many options available to students that lie within the expertise of an advisor. The diversity of a student's interests can be surprising and at least one project is likely to spark his or her curiosity.

Students can still choose the project that is most appealing to him or her, and the interest level of the student in any available project is likely sufficient enough to cultivate the desired ownership of the chosen project.

Additionally, when students work on a project that overlaps with the advisor's, they are placed in a "situated learning" environment that embodies a "culture of expert practice," as described in the cognitive apprenticeship model (Collins, et al., 1989). These are two components of the sociological aspect that give the student a sense of what real-world research experiences are like.

Create Narrow Projects with Small Achievable Goals

Despite the breadth of most research projects, small manageable goals can usually be defined. Narrowing the scope of a research question or simply researching the background and history of an idea are two ways to turn a large project into a smaller one which will make the project doable in a semester or two and perhaps make the experience less difficult for the student.
Another option is to break the project into small pieces. For instance, initial work for new students could involve fundamental literature research. The investment of training students in proper searching techniques can generate useful readings. Usually this background work will not provide new information for the research advisor in the beginning, but sometimes students will find articles that the researcher hasn't seen simply because the students' unique, inexperienced perspective allows them a wider view of the field. Literature searches can serve to enhance the student's critical thinking skills if there is an associated assignment such as providing a list of relevant publications, writing one page summaries or a list of questions related to an article, or simply creating a vocabulary list with definitions. (The results of such assignments can also be passed on to new students, thereby reducing the burden of training.) These are all manageable tasks for a beginning researcher with limited expertise, and such activities provide students with a sense of project ownership and training in literacy. Meanwhile, the advisor has increased the potential for finding new information relevant to his or her field.

**Choose an Appropriate Project Difficulty Level**

While it is true that students will undoubtedly struggle with difficult problems, they will be able to cope with the challenges they face if the faculty advisor ensures that the difficulty level is appropriate for the student's level of preparedness. While the project as a whole may be quite challenging for undergraduates, a senior-level student will be able to cope with the challenges better than a sophomore. So upper-level students should be given more difficult problems than beginning students. At first it may appear that inexperienced students lack the ability to significantly contribute to a project. However, these students in particular may become the best contributors over time because they are able to pursue a multi-semester research experience and can be trained from the most basic level. The increase in complexity of a project over time follows the method described by the cognitive apprenticeship model (Collins, et al. 1989). Consequently, at the end of their research experience, they will have improved critical thinking abilities and positive contributions may become the norm.
Provide Opportunities for Teamwork

One semester, or even two, is not a very long time for an individual to complete a research project. However, a strategy for accomplishing more work in a shorter amount of time has always been teamwork. For the faculty advisor, the colloquial expression "many hands make light work" adequately describes the opportunity for enhanced productivity when many students work on the same project. For students, much evidence exists to support the benefits of collaborative learning accomplished through group work (McKinney & Graham-Buxton, 1993; Topping, 2005; Windschitl, 1999). Also, part of the socialization aspect of the ideal learning environment described by Collins, et al. (1989) is the exploitation of cooperation. Cooperative learning is both a motivational tool for students and a mechanism for the development of problem-solving skills. In most fields, whether the student pursues research as a career or not, successfully working as a team will be critical to his or her success.

Having students work together will increase their own productivity since tasks can be divided among team members. However, an even greater gain will be their ability to learn from one another and the consequent rapid development of their critical thinking skills. The faster they learn a research strategy, the more quickly they can contribute to the advancement of the project. Finally, having students with varied levels of experience on the same project can reduce the research advisor’s one-on-one training time since more experienced students can work hand-in-hand with new students.

Provide One-on-One Interactions with Students

Although one-on-one interactions with students require a large investment of an advisor’s time (in fact, that’s an obstacle listed above!), these meetings should be considered an investment, especially if the student is working on a multi-semester project. The investment results in students becoming more independent workers that require less faculty involvement as time passes, and the payoff, in terms of both student growth and scholarly achievement, is well worth the expense of faculty time.

This strategy mimics the method described by the cognitive apprenticeship model (Collins, et al., 1989) where students are given extensive modeling and coaching at the beginning of the project. This approach not only provides important student-faculty interactions that can have a tremendous positive impact on student development (Astin, 1993), but also vastly improves the student’s understanding of the
project. The better a student’s understanding of a project, the better able he or she is to positively contribute new ideas.

Often, students will encounter stumbling blocks (e.g. an experiment didn’t work, an article didn’t answer the question, something doesn’t make sense, the next step is not obvious). During these times, it is especially important to work with the student one-on-one to avoid student frustration and help students exercise their critical thinking skills.

This approach proves to be quite challenging since research advisors often seek quiet seclusion to analyze results or work out their own stumbling blocks. At times, it may be necessary to dismiss the student, work out the issue, and then explain the thought process for working out the solution at a later time. Ultimately, whether to choose this approach or not will depend on the complexity of the issue. However, students will gain valuable insight into the critical thinking process if they can observe the researcher’s methodologies for solving complex problems, regardless of whether the explanation comes in real time or is delayed. If the problem is truly so complex that the advisor needs to struggle with it (perhaps independently), then all the better! This means the student has brought forth an issue in the advisor’s project that needed to be addressed, and the student has made a positive contribution to the project.

Host Group Meetings

Group meetings are a way for students to articulate and reflect on their progress, which fits with the later stages of the cognitive apprenticeship model (Collins, et al., 1989). All students will benefit by communicating with their peers about the challenges they are facing, and they can learn from each other. As they discuss their problems and potential solutions, they are simultaneously enhancing their problem-solving skills. Meanwhile, the advisor gets to meet with all the students at once, which may alleviate some of the time required for one-on-one meetings. If students are working as a team, they will also be reminded of how their aspect of a project fits into the big picture.
Require Weekly Progress Reports

In addition to reporting to a group, individual students could be asked to produce weekly progress reports detailing what they have done over the week and what they plan to do the following week. This exercise shifts some of the burden of planning and consultation to the shoulders of the students and helps them to constantly consider their end goals. It also keeps the students focused on the tasks at hand, provides opportunities for reflection and articulation, and helps to keep the project moving in the forward direction.

Require Summary Reports

Periodic assignments should be created in which students provide a summary of not only what they have done but also how they have done it. These documents not only serve to help students reflect on the big picture of their project and develop their communication skills, but can also act as a standard operating procedure to be passed on to future generations of students, saving the advisor from having to explain repetitious details.

Conclusion

Undergraduate research provides many benefits to student learning, but a symbiotic relationship between research advisor and student does not always exist. The type of project that provides the most potential for both the student and the advisor to benefit is one that is original and is aligned with the advisor's research interests. Designing a project in such a manner can be a challenge for several reasons: (1) students may not be passionate about the work, (2) such projects require a significant time commitment on behalf of both the student and the advisor, and (3) the project may be too difficult for the student to comprehend. Many of these obstacles can be overcome by assuming a cognitive apprenticeship style of teaching (Collins, et al., 1989) and applying some of the strategies presented in this essay such as matching the level of project difficulty with the student's experience; having students work for multiple semesters, especially in group settings; providing adequate opportunities for student-faculty interactions; and having students summarize their own progress and sharing it with others. These methods will not only improve the student's research experience, but also increases the opportunity for advancement of an advisor's scholarly interests. In this manner, the experience can ultimately become mutually beneficial.
References


