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Tips for New Faculty: Engaging Your Graduate Students in Independent Thought

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Abstract

This contribution describes certain strategies and lessons-learned which have proven effective at improving the independent thought and problem-solving skills of graduate students. In particular, we highlight two specific interactions: advisor / student, and student / student interactions during three main venues. The first venue is written communications such as email, daily or weekly research summaries, literature review / discussions, and papers. The second venue is oral communication via face-to-face meetings in an office or in the classroom. The third venue is demonstrative communication via laboratory training, and side-by-side data analysis on computers. Each mode of communication plays a key role in helping students grow into professional researchers with skills in independent problem solving.

Introduction

The New Engineering Educator has many challenging tasks ahead of them as they progress towards tenure. One of these challenges is establishing a fully functional and efficient research group quickly[1]. Unique research results need to be obtained almost immediately in order to incorporate them into manuscripts since the peer-review process can take over a year before publication. The new faculty likely has well-developed project plans for the beginning graduate student; however, the student also needs to be educated more extensively as they progress towards their degree on independent problem solving and generation of ideas. While there is no substitute for experience in this endeavor, following certain guidelines can allow the new faculty member to optimize the development of their graduate students in these areas. To be as inclusive as possible, we also discuss the development of undergraduate research students as well.

Skills that graduate students need to develop include: literature review, laboratory procedures, design of experiments, data analysis, problem solving, written communication, oral communication, and personal interaction skills. Regular, organized efforts to strategically develop these skills in students can go a long way to helping develop their independent thought, and thus optimizing their effectiveness as a researcher. While research productivity is still highly dependent on the quality of the graduate student, the strategies outlined in this paper will help new engineering educators mentor and train graduate students to successful project completion and at least one publication. Advice is offered in the form of managing tips to improve written and oral communication skills, experiment planning and documentation, and problem solving skills. Experiences are summarized briefly followed by a discussion of strategies that were found to be effective.

The goal of this paper is to offer practical advice in the form of technique tips that new faculty can easily implement in a research group comprised of young graduate students and undergraduate students. A structured and multifaceted approach has advantages for graduate students of all learning styles and can potentially improve a graduate student's research productivity. The authors combine their experiences developing independent thought skills in their graduate students. These experiences have developed from observing and strategically influencing two different student interactions: advisor / student and student / student interactions. The three main venues with which an advisor can influence the graduate student's development are outlined below: written communications, oral communication, and demonstrative communications. This paper concludes with a brief discussion that new faculty can implement in their own research groups.

Written Communications

Written communication is an important venue for advisors interacting with their research students. However, it should be well balanced with oral and demonstrative communications to most effectively guide the research student to research proficiency and independence. The written venue of communication includes email, daily or weekly research summaries, maintaining a laboratory notebook, literature review guidance prior to oral discussions, and writing abstracts or articles.

The key advantage of written communication is that the student can re-read over material at their own pace. This is particularly helpful for open-ended questions, understanding of fundamental theory, or strategies for testing a hypothesis. Each of these examples requires intense thought and the student needs time to contemplate before answering – an attribute that is more difficult with oral and demonstrative communication. It should also be noted that written communications are a valuable tool when permanent documentation is important or when specific expectations or deadlines need to be articulated. A few examples of venues of written communication are discussed below.

For a young graduate student, an advisor can help plan out experiments (in writing) and define smaller research objectives. Once the student begins the research, the student can initiate written communications via email to quickly report exciting results, via daily or weekly summaries that help keep the students encouraged with their progress and keep the advisor abreast of the progression of the research, or via documenting controls and variables for an experiment in their laboratory notebook. All of these forms of written communication can help the advisor to most effectively provide timely and effective direction. From the student's perspective, experience writing short documentations of research steps, data, or progress are great learning experiences that teach the student to become proficient in terminology in their research area and to effectively communicate in writing their results for technical audiences.

As the student's knowledge and skill set grows and the body of research results they have produced grows, they can move onto writing abstracts for consideration at conferences as well as onto writing articles for publication. At this stage, the advisor needs to resist the urge to take over outlining or writing the first draft of the paper to save time; the process of iterating with a student is important for their growth as a professional. In fact, it is advisable for a more experienced graduate student in the group to read abstract or paper drafts to provide experiential guidance and language / grammar edits to the younger students. This first review can be less stressful for the new author, provide experience for the senior member, and save the advisor valuable time with low level edits.

In general, most students struggle with writing their first paper and frequently do not include essential information. One approach is for the student to only work on one section at a time. For experimental research, writing the materials and methods is a good starting point. Having the student write short summaries of each article they read in their literature search can become a good resource for them as they write their introduction and background. In order to write the results and discussion section, one author has found it useful to have the student prepare a PowerPoint presentation of their results, tape-record the student's discussion of the figures and then have them type their words in as the first draft. This can serve as a good starting point for either iterative editing between the student and the faculty or for the student to sit with the faculty and edit the paper together. In the latter approach, a graduate student can directly see where and why such editing is made as it happens.

Whatever the case many be, when students receive the first edits back on their rough draft, it can be rather difficult because the paper may "bleed" with marks. It can be important to forewarn the student in advance that almost all papers require significant work to get them to publication quality. Training students to be proficient in written communication is a key skill that simply requires practice. Smaller essays are beneficial learning tools that simultaneously develop the student's independence such that they feel qualified to write bigger bodies of work.

A final approach to foster independent thought of a graduate student is to have them participate in the peer-review process. For example, prior to any work being submitted by the group for publication, students in the group not affiliated with the paper can serve as reviewers. They should provide written reviews of the submission in the same manner as would occur at professional journal. Such student-student interaction allows them to establish a formal professional relationship with the colleagues in their group.

As a final example, students can benefit from learning to write professional correspondence regarding committee meetings, abstract submissions, or requests for papers. It may be necessary to instruct the student on email etiquette (carbon copying advisor on lab correspondences, paper submissions, etc.) including salutations and signatures. All venues of written communication are important once the student enters the workplace.

Oral Communications

The advisor/student meeting in an office or a classroom provides a great training ground for students to demonstrate the results of independent thought. When working with a student, be it a Ph. D. candidate almost ready to graduate or a Freshman undergraduate, the temptation might be to take their results and do the appropriate analysis yourself with them in the room or even suggest next steps in the research. However, this removes a key time for students to cultivate their growth towards being a critical thinker capable of independent thought. One strategy that has found success is to let the student guide the flow of the meeting. Rather than offer advice on an issue, ask "how do you think we should approach this problem?" If their ideas are poorly-formed, this now becomes a teachable moment. However, if the ideas only need some refinement, this can provide them with the encouragement to, hopefully, think ahead and anticipate these types of questions from their advisor in future meetings (or from their supervisors once they graduate).

A great opportunity to promote independent thought and critical thinking for students is when listening to oral presentations, either internal to the group or at a larger function. When students are presenting their work, whether it is simply to update their advisor on their research progress or when practicing for a conference, other students (undergraduate and graduate) should be in the room listening to this presentation. Of course, emphasizing to the students that this is a professional development opportunity for them should be done in order to prime the students to be ready to critically consider the contents of what they are to about to hear.

A few days prior to a technical conference where students are presenting their work, it is beneficial to have the students practice their presentation in front of the research group. During this practice session, the audience is asked to analyze each slide individually and provide comments about each one. At the conclusion of the presentation, the group goes through the slides one-by-one and each audience member will provide feedback on what they have seen and heard during that particular slide. Positive comments, of course, are encouraged where warranted. Note that it is expected, however, that this practice presentation is not the first time the student has delivered this presentation. The time length of presentation, obvious font size issues, etc., should be addressed prior to this more-formal practice session. Videotaping of the presentation is encouraged so that students can better grasp the audience feedback.

Demonstrative / Interactive Communications

The third venue is demonstrative communication via laboratory training, and side-by-side data analysis on computers. Since the advent of video games and increased emphasis on using computers, students tend to be visual learners. This places faculty with some additional challenges within the classroom and within their offices in mentoring both undergraduate and graduate students. This is especially the case considering the traditional lecture style format or office discussion. As such, the ensuing discussion will focus on integration of computational methods into the curriculum (and research program), and afterwards discuss experimental methods.

One of the authors is at an institution that is attempting to make a large growth in its graduate and research programs. However, the majority of graduate students are recruited from the department's undergraduate pool. Furthermore, many of these same students can be recruited into undergraduate research. Thus, it is of benefit to the faculty member to nurture a certain set of tools within their courses that will likely be used by any student in the research group either as an undergraduate or a graduate student.

One particular area in which this can be accomplished is in the use of computational software, which happens to be an active research area for one of the authors. In the required undergraduate course taught by the faculty member, they can assign computation problems that the students solve with their own computer algorithms. This can progress to a more intensive project which, while still at the fundamental level, can serve as a platform to develop a more rigorous model for computational research. Graduate students can be given computational problems as independent study, which train them to develop algorithms they may use in their research projects.

In concert with this development, the faculty member can integrate third-party software into the course. As an example, in his course, one of the authors typically has a simple problem that is solved step-by-step using the software. The program can then be compared to analytical solutions or to the student's own computational results discussed in the previous paragraph. Then, with this understanding, the student can solve a more complex problem using the software. This structure promotes the students to practice independent and innovative problem solving strategies. Again, with this training the student is familiar with tools that may be utilized by a computational researcher.

It is clear that assigning problems and projects of this nature can help identify students that are skilled enough to recruit as an undergraduate research student, and possibly for graduate school as well. However, these types of assignments come at a disadvantage. Some students will struggle with the assignment. They can rebel and not turn the assignments in, and fall behind in the material. They can also be so lost that it requires additional faculty time in getting the students acquainted with what they actually need to do. The faculty member should be prepared to edit computer code on-the-fly. On a more positive note, the faculty member can also enlist the help of current graduate students, who are more experienced at solving the problems but need to develop their teaching skills. As a final comment, the assigning of computational projects can promote student-student interactions within a team environment.

Within the laboratory there are more teaching opportunities readily available. Some students are very hands-on and some are very hands-off. Either student can be good with technical theory. Careful attention and supervision is required to get students up to speed on experimental methods.

Video technology can help in this instance. Recordings of current undergraduate researchers, graduate students, and the individual faculty member can be easily integrated into the course. They can serve as simple training mechanisms for students and also help students appreciate how difficult it is to obtain experimental data, such as physical and/or material properties, many of which are not found in the back of the book.

A lot of up front effort is required by the beginning Assistant Professor, but it can reap significant long-term benefits. If the faculty is diligent in teaching proper experimental techniques, step by step, and for lengthy periods of time, they have trained their first graduate student and/or undergraduate researcher the skills which that student can pass onto others. Of course the faculty member should observe these student / student interactions but will not need to invest several days retraining students, freeing up time for other scholarly activities. It is noted that with undergraduate students it is ideal to recruit both senior and junior level students, so there is some continuity of knowledge and experience within the research group, so that adequate progress can be made towards publication and/or future research proposals.

Demonstrative interactions are of extreme importance for beginning graduate students. Many of these students have only worked in laboratories during their undergraduate curriculum and are not prepared for experimental laboratory work. In many cases they do not have much exposure to laboratory safety. As an example within the Department of Chemical Engineering at Michigan Technological University, there is a one-credit graduate safety course that all students must take. Students learn appropriate safety procedures and learn to follow prescribed departmental regulations with regards to laboratory safety. There are two interactive components. The first is to perform laboratory inspections to build up their experience of possible dangers in the laboratory before they begin working ion their research projects. The second is to fill out a Job Safety Assessment (JSA) form for a piece of equipment. These forms are required for new equipment or new procedures. With proper safety training, the students can then focus their efforts on their experimental research.

The Merits of a Multi-Dimensional Communication Strategy

Every graduate and undergraduate student is different. The process of guiding each student's research is thus different and requires flexibility. Studies have shown that students have preferences in their learning styles [2,3]. Some learn from external input while others need time to contemplate; some do this visually, some verbally. Communication is the crucial tie that guides the student along and focuses a research group to a common goal of research productivity. Since students do not usually arrive with an innate ability to perform research, they must learn and refine their skills. By practicing and developing skills in written, oral, and demonstrative communication, an advisor can effectively train and mentor all their students. Furthermore, by exposing the researcher to all these modes of communication, they can develop their own skills in each venue.

A few key habits are important to encourage in a research group. One of these is for the students to work hard and push themselves to obtain results. An advisor can help reinforce healthy work habits. A second is to maintain open lines of communication between the advisor and the student and between students. When the students receive positive reinforcement for their ideas and for helping each other, the whole group benefits. The last is consistency and fairness. Discord and problems can develop if students are paid fairly / consistently or if any time of favoritism exists. While mentoring is tailored for the individual student, group level management should be consistent.

When considering adopting a new activity, new faculty should critically assess whether the activity supports their efforts for tenure and if it adds to their existing workload. While it is difficult to quantify time spent mentoring graduate students, successful mentorship results in many rewards for the faculty and student alike. Mentoring is typically a skill that is learned via experience. This work has outlined potential strategies that a new faculty may choose to adapt in their own group.

Conclusions

Within this contribution to the New Engineering Educators Division of ASEE, the authors outline communication strategies to strategically guide the professional development of members of a research group. The modes of communication discussed were written, oral, and demonstrative. In each of these venues, student / advisor as well as student / student interactions were discussed. Also in these venues, the author's advocated guiding the student to critically examine research scenarios (technical writing, data analysis, and problem solving) to develop independent thought. A number of additional benefits for the advisor and for the student arise from promoting independent thought including improved written prose, improved oral expression, unique problem solving skills, and improved teaching skills.

References

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