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Creating and Sustaining Productive Research Groups in Engineering Departments: Results from a Faculty and Future Faculty Workshop

Abstract

In July 2011, 45 engineering graduate students, postdoctoral researchers, faculty members and administrators from 33 universities across the country met to discuss how to foster successful engineering graduate research groups. This paper summarizes the recommendations and conclusions from this meeting. Analysis of workshop discussions yielded four major themes: clarity of expectations, attending to community, organization for group and peer learning, and structuring student development towards independence. In this paper, we provide an overview of the workshop organization and expand on the findings from the workshop, presenting detailed examples and recommendations across a wide range of disciplines, types of universities, and levels of faculty experiences. Specific findings centered on the idea that expectations should be made clear to students as early as possible. We conclude with the implications for the graduate engineering community and offer recommendations for faculty members interested in continuing this discussion at their institution.

Background

Despite ongoing research in higher education, the basic model of doctoral education has remained unchanged for several decades. How the training of doctoral students is conducted, however, reflects distinct disciplinary patterns. This research training is central to transforming the student into a producer of knowledge, so much so that departments design specialized training programs to meet the needs of individual disciplines.

The majority of engineering graduate students spend their graduate school years as part of a research group. These groups are generally organized around the research specialty of a primary advisor, or collaboration between faculty advisors, depending on the size of the research group. Doctoral students, master’s students and post doctoral researchers work together under the guidance of these faculty advisors, often in shared laboratory and office spaces. It’s this group environment where the majority of student learning and development occurs, through shared interactions and experiences with other graduate students as well as faculty advisors. Characterizing the structure, or in some cases the absence of structure, in the research group learning environment is key to better understanding how we train engineering graduate students. Research-focused graduate programs (thesis master’s and PhD) are meant to transform students into independent researchers with critical and analytical thinking skills who can set goals, collaborate with others and communicate their ideas orally and in writing. Students’ experiences in these research groups, both positive and negative, influence the extent to which they learn these skills, as well as their satisfaction and intention to complete their degrees.

Within this structure, graduate engineering education is highly individualized and can be greatly influenced by a student’s relationship with his or her advisor. In engineering education, we often
lament that faculty receive little to no training in pedagogy and tend to fall back on their own experiences. This is doubly true in the case of graduate advising and mentoring.

The workshop we report on is part of a larger research project focused on understanding and improving the experiences of engineering graduate students in research groups. Funded by a National Science Foundation grant, the workshop was intended as a dissemination mechanism for our research findings. We developed and administered an online survey to graduate students at four universities across the United States. Guided by the results of this survey, we developed a two day workshop centered on creating and sustaining productive research groups in graduate engineering departments. Details on the survey development and results are published in other sources and will only be considered in this paper when framing the format and discussion questions for the workshop. Our primary findings could be summarized as emphasizing the importance of clarity and communication regardless of the details of the expectations. This led us to design an interactive workshop featuring active group discussion of values.

The workshop was organized into two sessions focusing on research group organization and development. Using case studies, select survey results, and their own experiences, participants focused on the workshop questions with the aim of developing guidelines for creating and sustaining successful engineering research groups. At the end of the workshop, we collectively established a set of guidelines and practices to inform development of research groups at their respective universities.

Workshop Structure

Participants

A call for participants was sent out via engineering professional society listservs and distributed at engineering education conferences. Administrators, faculty members, postdoctoral researchers, and graduate students interested in faculty careers were encouraged to apply. More than 100 applications were received, from which we selected 40 participants representing diverse academic backgrounds and engineering disciplines. Participants represented 14 engineering disciplines and 30 universities from across the United States. There were 14 graduate students, 18 untenured faculty members, 7 tenured faculty members (including 2 department heads), and 1 assistant dean. Appendix A lists the participants, who contributed to the ideas presented in this paper. Facilitators for the workshop included three engineering graduate students, one faculty member from engineering education, one faculty member from educational psychology, an assistant dean in engineering, and one graduate school dean.

Workshop Sessions

The workshop was organized into two four-hour sessions. The first discussed what is meant by successful research groups and the second focused on a specific case study to make concrete recommendations for fostering success. These sessions were organized using a series of small and large group breakout sessions as shown in Figure 1. Examples of the workshop agenda can be found in Appendix B.
**Figure 1:** After the topic introduced, each workshop session consisted of focused small group discussions, presentations of each groups’ results to the larger group and then the large group gave feedback/added to the findings of the small groups. The sessions concluded with the large group determining the fundamental outcomes of the discussions.

**First Session: Characteristics of Productive Research Groups**

In the first workshop session, participants worked in small groups to define characteristics of productive research groups and to begin grouping these into overarching concepts. The first small group session was used to brainstorm. Participants used note cards, sticky notes, colored markers, and large sheets of paper to generate characteristics and concepts. Facilitators kept the discussion focused by asking probing questions to encourage discussion. Once the group had finished brainstorming characteristics, participants grouped these into categories or themes that could be presented to the large group. During the large group meeting, each smaller group presented their categories and characteristics and facilitators synthesized the small group responses into broad themes. These themes included: clarify expectations, attend to community, structure development toward independence, and organize the group for mentoring and peer learning.

**Second Session: Creating Productive Research Groups**

During the second workshop session, participants met in (different) smaller groups to apply the themes developed during the previous session to work with one of three research group case studies. The case studies featured either a small research group, a multidisciplinary medium sized research group, or a large research group with multiple faculty advisors (details were based on our research findings anonymized to protect research subjects’ identities). Participants were assigned to the case study that most closely matched the size of the research group they were currently working with at their home institution. The goal of the case studies was to allow participants to devise a plan for managing this research group based on the themes determined in...
the first session and the current organization and resources available to the research group. Participants often cited examples from their own experiences, but the case studies gave a common anonymized foundation for the discussion. The questions listed in Table 1 were used by the facilitators to guide the discussion. The first three questions applied to all case studies, while questions four and five were tailored to address characteristics specific to the particular case study. The prompt for each case study can be found in Appendix C.

**Table 1:** Guiding Questions for Case Study Activity. All groups considered questions 1-3, while different groups considered question(s) 4-5 depending on the specific case study assigned.

<table>
<thead>
<tr>
<th>General Questions For All Research Groups</th>
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<tr>
<td>1. What characteristics distinguish this group from other engineering research groups?</td>
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<td>2. How does the size of this research group impact:</td>
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<td>a. Overall group management?</td>
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<tr>
<td>b. Student learning and development?</td>
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<tr>
<td>3. What suggestions would you make for advising a research group with these or similar characteristics?</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Multidisciplinary Research Group</th>
<th>Small Research Group</th>
<th>Large Research Group</th>
</tr>
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<tbody>
<tr>
<td>4. This group has more than one research advisor. How might this influence group management and student learning?</td>
<td>This group has students working in separate locations (e.g. offices). How might this influence group management and student learning?</td>
<td>This group has a highly internationally diverse population (students from more than two countries). How might this influence group management and student learning?</td>
</tr>
<tr>
<td>5. This group is subdivided into smaller “project” groups. How might this influence the climate for student interactions within the group?</td>
<td></td>
<td>5. How might the frequency of group and individual meetings influence students’ learning?</td>
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</table>

Following the small group breakout sessions, we met again as a complete group to share what each case study group discussed. During this session, we considered several follow-on questions, including: what are the similarities based on group size and what are the differences? What differed across groups that had the same case, and finally what are the barriers to creating these environments? At the conclusion of both sessions we continued the discussion as a large group to summarize the events of the meeting and create a plan for disseminating the results.

**Synthesis**

Photographs of all presentation materials were taken and each poster was collected for future analysis. Other materials generated during the course of the event were also photographed to ensure all comments and ideas from the participants were recorded. Finally several graduate student research assistants attended the small and large group breakout sessions and took notes on participant ideas and responses to be used for later analysis.
Data analysis for this workshop occurred in two stages. Preliminary analysis of the characteristics of productive research groups was accomplished “real time” during the large group meetings to synthesize the findings and create working themes which could be used in subsequent activities. In the second round of analysis, the research team used the materials gathered during the workshop, including photos of the presented materials, the actual documents generated by each group, and field notes from the sessions to further expand on the working themes to include more details and examples for each theme. An example of these documents is shown in Figure 2. These themes are presented and discussed in the Results and Discussion section.

**Figure 2:** Examples of Participant Generated Responses. These were analyzed both during the workshop and again following the workshop to generate the themes.

The four themes used to organize the results in the next section align with those suggested by the participants in the workshop. These were determined using an inductive analysis while the workshop was in progress. At the completion of the meeting, the authors and an additional graduate student (whom helped organized the workshop) reviewed all of the data that was collected and confirmed that these themes captured the results well using a deductive approach. In addition, this paper was circulated among the workshop participants as an additional means of validating the findings. This process validates both the results and the organization that we present in this paper. Additionally, feedback on the final recommendations will aid in the process of generalizing and disseminating the results from this workshop, and in organizing future meetings.
Results and Discussion

Analysis of workshop discussions yielded four major themes: clarity of expectations, attending to community, organization for group and peer learning, and structuring student development towards independence. Specific findings centered on the idea that expectations should be made clear to students as early as possible. As groups increase in size, it becomes less efficient for one advisor to individually mentor and develop expectations for each student. Postdoctoral researchers or more advanced graduate students can contribute to mentoring while developing their skills for future positions. Time should also be spent developing community among research group members to increase the chances they will approach each other for help and support. Faculty members should use scaffolding techniques with students to require increasing responsibility and creativity over time. Finally, setting concrete and challenging but achievable goals can also help motivate students. Specific findings from each of the four themes are discussed in the proceeding sections.

Clarify Expectations

Discussing expectations allows both the advisor and students the opportunity to clarify what is required of a group member, to become more effective and better gage success. A method that was suggested for starting this discussion was to have students evaluate themselves. Self-evaluation of strengths and weaknesses can open the door to discussion of what is expected of a group member (lab hours, presentation skills, mentoring responsibilities, professional behavior, etc.). However, participants emphasized that it is important to have the same general expectations for all of the students within the group and to avoid treating individual students differently. Since group membership may change continuously, advisors should periodically readdress expectations to prevent miscommunication among both students and faculty members.

Table 2 highlights some of the specific areas recommended by the participants that advisors should discuss with their students.

Table 2: The participants recommended the following as possible discussion points for the expectations for a graduate student.

<table>
<thead>
<tr>
<th>Examples of expectations include the advisor’s/groups philosophy on:</th>
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<tr>
<td>• Giving and accepting feedback from peers and mentors</td>
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<td>• Work-life balance, hours spent in the lab or office and amount of vacation time</td>
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<td>• Competitive or collaborative culture</td>
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<td>• Expectations for graduation and degree progress</td>
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<tr>
<td>• Expected level of writing and presentation skills</td>
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<tr>
<td>• How students will be evaluated</td>
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<tr>
<td>• Professionalism in interactions with others, especially support staff</td>
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Clarifying expectations to potential students can also increase recruiting success. Workshop participants emphasized that undergraduates often do not have enough information available to them when trying to select an advisor or research group. They proposed that a guide to selecting an advisor should be developed, complete with specific questions the undergraduates should ask their prospective advisors. However, simply discussing expectations and work preferences
openly during recruiting phases can give students and advisors better information on which to base their decisions. Another tool that participants suggested was to hold a seminar series about graduate school as part of an undergraduate capstone course. Prospective students will then understand what is expected of them before beginning a research project with the advisor. Knowing what is expected of the student before beginning research will limit the number of cases where they subsequently leave the group due to a mismatch between student and advisor expectations. Participants also suggested that even if advisor and group expectations are made clear during the recruitment process, they should also be reinforced to new students upon entry into the group.

Attend to Community

The workshop participants emphasized that sense of community can lead to an open environment that fosters collaboration and interest in other students’ projects. The goal for developing community is for students to have a sense of belonging to their research group. Developing community takes attention and effort by both the advisor and the students. A sense of community can be attained through common activities (both academic and social) in which all members of the research group can participate.

The first steps towards developing a community are providing a common space for students to work together and building a set of guidelines for student interaction. The participants advised that common workspace will naturally foster group member collaboration on both research and other aspects of life. Students will be able give and receive feedback on their research, which will in turn foster interest in each other’s research projects. If assigned group space is not a possibility, then the activities listed in Table 3 are doubly important. One of the issues that arose during the case study discussions for the small start-up research group was whether or not to give undergraduates office space. One of the groups comprised of new faculty concluded that not providing space for the undergraduate students would hinder the mentorship of the undergraduates by the graduate students. However, several other groups felt that undergraduates should be separated from graduate students in order to preserve the research momentum of the graduate students. These groups thought that the mentorship of the undergraduates would distract the graduate students from their research and that it is especially important to build research momentum for newer research groups. It is also important for the research group to develop guidelines for behavior within the common workspace and research group. For example, members should respect cultural differences and work-life balance. Advisors may need to discuss inclusive rules for when to use English or other native languages in the lab (participants could not reach an agreement about whether or not it was necessary for students to use English in American lab groups). The guidelines should insist on professional behavior, respect for others and fair treatment of all students. The participants emphasized that the advisor should also follow these guidelines and serve as a role model for the students.
Community building activities:

- Journal clubs
- Student organized social activities
- New students take classes together
- Meetings outside the office/labs
- Have current students take prospective students out for a social activity
- Group retreats
- Force collaboration on side projects within groups
- Get lab member’s opinions before hiring a new graduate student
- Celebrate awards and milestones by member together

Community should also be promoted through group activities outside the common workspace. Table 3 lists some of the suggestions put forth during the small group discussions. Community can be fostered through social events, such as group lunches, and celebrations of birthdays and research milestones (conference best papers, passing qualifying exams). Academic activities can be planned to promote community, such as group meetings, retreats, journal clubs and taking courses together. Advisors should consider “branding” their labs with a name and identity, logo and even t-shirts.

Participants also concluded that the development of the research group’s community is aided by increasing the diversity of the lab group. This conclusion was prompted by the discussion of the multidisciplinary group during the case study break-out session. The group in the case study was comprised of entirely of male graduate students from either the United States or India. The discussion groups thought that the research group’s make-up would have two main effects on the research group’s community. First, it could lead to the development of separate cliques of students from the United States and India. Second, it would hinder the recruitment of female students and male students from other countries. When recruiting new students to the lab, it is important to be mindful of the group’s make-up and to ensure that the structure is not conducive to the development of cliques. The participants also suggested that holding regular lab meetings or rearranging students’ offices could prevent the formation of cliques as well.

Organize the Group for Mentoring and Peer Learning

Group organization is important for efficient learning and effective communication. Participants concluded that the building blocks for developing a group organization were mentoring and peer learning with frequent opportunities for group communication, assessment, and feedback. The participants believed that feedback opportunities are dependent on common workspaces and meetings with the group’s mentors. The participants stated that group meetings should have clear and focused goals in order to maximize mentoring and feedback. However, groups (especially larger groups) should consider other means and forums for accomplishing various group-meeting related tasks such as updating the advisor, reporting progress, providing positive peer pressure, troubleshooting, practicing presentation skills and learning about each others’ work. The consensus among the participants was that the best solution may be a combination of
emails, subgroup meetings and individual meetings, along with clear mapping of tasks to formats.

The participants in this workshop felt that a single advisor cannot effectively mentor more than about five students singlehandedly. Therefore, larger groups should utilize postdocs and senior students as mentors (this is also an opportunity to develop the senior student’s professional skills). Subgroups or smaller project-based groups can also be an effective tool for managing larger groups. However, large groups should retain their identity through group expectations and common practices (e.g. maintain a list of group expectations and ask students to archive common lab procedures for group reference). The participants emphasized during the discussion of the large research group case study that advisors of large groups should clarify to whom students should report and where they can get feedback or training in specific skills. A clear group organization will reduce student confusion about where and when they can receive mentoring from their advisors and thus lead to more efficient mentoring practices (not to mention satisfaction with mentoring and progress).

To develop an organization that is optimal for the group, there should be frequent opportunity for reflection on group processes. In order to facilitate group feedback, the participants emphasized that advisors should be approachable, even in large groups. The advisor should include (and mentor) students in all aspects of research. When students are reporting their progress and challenges, advisors should do the same. The workshop participants explained that advisors updating the group on their research will not only inform the members about their advisor’s research (and build community), it will also serve as a model for what is expected during a research report and it will give the students an opportunity to give the advisor feedback. The participants concluded that peer evaluations and group feedback can help the group function more effectively. The advisor should reflect on both group feedback and the successes and challenges of each individual in order to guide their adjustments to the group organization when necessary.

**Structure Student Development Toward Independence**

The goal of a graduate research program is to prepare students to complete independent, productive research. The fundamental suggestion of the participants for this theme was that an advisor should provide structure or “scaffolding” to new students, which is gradually removed over time so they develop more creativity and independence. The workshop participants suggested that an advisor should begin determining the structure to be provided to the student through an evaluation period. It is important that the advisor analyze a graduate student’s abilities in order to tailor their guidance to the student’s abilities. Participants suggested using a small research-related task as a tryout to evaluate fit and determine individual students’ strengths and weaknesses. Table 4 shows the tasks that were suggested as good evaluation tools for new and/or prospective students. The faculty and more advanced graduate students emphasized that prior experience with other students sensitizes an advisor to potential student weaknesses, but one should not make assumptions about students’ characteristics (e.g. based on nationality) without evidence.
Table 4: Suggested projects that can be used to evaluate the strengths and weaknesses of new and prospective graduate students.

**Evaluation Tools:**
- Application process for joining group
- Analyze an article and present its results
- Weekly research meetings (with frequent presentations)
- Frequent individual meetings
- Small side projects

The workshop participants stated that it is important to define the mentorship relationships between students and advisors clearly. All students should give and receive mentoring either from the advisor or other student-mentors. The new student can be trained in basic lab procedures by other students in the lab; however, participants emphasized that high-level skills should always be taught by the advisor. It is also important to ensure that the mentoring responsibilities of the upper-level students do not overwhelm them; this will hinder their own research progress. When graduate students make good progress, the participants suggested using conference travel as a reward and to expand students’ professional networks.

Once an advisor has determined the student’s abilities, participants emphasized that the student should be paired with a project that matches his or her career goals. They suggested that the advisor and student jointly set short (6 months), medium (1-2 years) and long (4-5 years) term goals. Throughout the process of developing the student’s goals, the advisor should keep in mind that student motivation stems from well-defined, challenging projects aligned with the student’s career goals. The participants emphasized that the advisor and student should work together to meet the jointly developed goals for the student. However, the participants advised that the students will make greater strides towards independent learning if the advisor allows students to take calculated risks and learn from their own mistakes. It is important for advisors not to micromanage; they should gradually allow the student to set their own goals and make decisions independently.

While guiding students through their research projects, advisors should involve students in all aspects of research, including proposals, decisions and planning. The participants believed that this experience will be invaluable to the student’s development as an independent researcher. The advisor should also continue to evaluate and give feedback on the student’s growth and development as a researcher. The advisor and the student should engage in frequent communication, such as weekly progress reports and feedback cycles. Professional development plans and annual reviews should be used to facilitate frank discussions of strengths and opportunities for growth.

**Conclusions and Recommendations**

Research groups are a fundamental tool for training graduate engineering students in research master’s and doctoral programs. In this paper, we have discussed several recommendations faculty advisors can use to create and sustain productive research groups in graduate engineering programs. Workshop findings centered on the idea that expectations should be made as clear as
possible, and discussed frequently during the students’ graduate study. Along with an open flow of communication regarding expectations for both students and faculty advisors, there should also be frequent opportunities to provide feedback and evaluation for students on both the peer and faculty level. Finally developing community, whether through shared office space, group activities, and interaction guidelines, will help students establish a sense of belonging and responsibility to the group.

One of the most important action items that resulted from the workshop was that engineering faculty should continue this discussion at their respective institutions. The last session of the graduate portion of the workshop focused on how to disseminate the results from the meeting. An easy to read summary of the recommendations resulting from the workshop is found in the two page handout in Appendix D. In addition to this paper, the handout and the case studies (found in Appendix C) can be used to generate discussions about how to effectively guide research groups through graduate school. The participants suggested that discussions begin in both faculty meetings and lab group meetings. Faculty meetings and department-level discussions can focus on sharing best practices and some materials such as evaluation forms. Participants in the workshop suggested that departments could set up a wiki or a discussion board where faculty can post common issues and good practices. The wiki (or a similar forum) would provide an arena for faculty to discuss and set goals, give feedback, share forms and reflect on their experiences. Research group discussions should focus more on clarifying values and expectations, providing feedback and reflecting on how to improve. These discussions need not be formal in nature; however it is important that faculty and graduate students to consider and openly discuss the issues presented in this paper.

Like teaching, graduate advising is a critical activity for engineering faculty members, but one in which they receive little to no training. This project demonstrates that with some basic attention, reflection and communication of values, engineering faculty members can build research groups that will transfer their technical knowledge and promote student success.

Acknowledgements

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References


**Appendix List**

Appendix A: Participant Listing  
Appendix B: Eight Hour Workshop Agenda  
Appendix C: Case Studies  
Appendix D: Workshop Summary Handout  
Appendix E: Sample One Hour Workshop Activities
## Appendix A

### Workshop Participants and Institutions

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
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<tbody>
<tr>
<td>Maura Borrego</td>
<td>Virginia Tech</td>
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<tr>
<td>Kevin Cassel</td>
<td>Illinois Institute of Technology</td>
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<tr>
<td>Ryan Comes</td>
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<tr>
<td>Lydia Contreras-Martin</td>
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<td>Monica Cox</td>
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<td>Erin Crede</td>
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Appendix B
Workshop Agenda (8 Hour)

Workshop for Developing and Sustaining Productive Graduate Research Groups in Engineering

Session 1:

12:00 – 12:30  **Introductions**  
Research team, advisory board members, and participants

12:30 – 12:45  **Review the objectives of the workshop**  
- Establish characteristics of productive graduate engineering research groups  
- Determine ways to foster these characteristics in existing research groups and academic departments

12:45 – 1:45  **Small Group Breakout**  
Participants brainstorm characteristics of successful and productive research groups.  
- Give participants post it notes and paper to write individual ideas on notes and group them into larger themes.  
- Assign a scribe and reporter.  
- Some discussion questions to get things moving:  
  - What are the overarching factors and common areas?  
  - What contributes to commonalities and differences between different groups?

1:45 – 2:00  **Break**

2:00 – 2:45  **Small Group Discussion**  
Attempt to generate “larger” themes from the collection of notes.  
- Create single set of “themes” using the previously determined characteristics.  
- Use new paper and regroup post it notes to present to large group  
- Discuss results: Be prepared to present in large group

2:55 – 4:00  **Large Group Discussion**  
Combining the Small group Results  
- Have each reporter give a 3-5 minute summary with major themes and characteristics.
• Gather all posters and create “bigger picture” from small group results
• Discussion Points:
  o What are the similarities between each group (focus on sizes); what are the differences?
  o What has your program done to address some of the issues presented?

4:00 – 4:15  **Summarize Findings (Multipurpose Room)**

**Session 2**

8:00 – 8:30  **Review**
Summarize key characteristics from first session.

8:30 – 10:00  **Small Group Breakout - Case Study Activity (individual room)**
Each participant will have had a chance to read the case study ahead of time.
• Assign a scribe and reporter.
• Have participants work in groups to come up with a “plan” for establishing a research group for given students.
• Discussion questions are attached to each case study
• Give groups paper, post its and markers to make notes, create lists etc.

10:00 – 10:15  **Break**

10:30 – 11:30  **Large Group Discussion**
• Have groups present their plans to the large group.
• What are the similarities based on group size, what are the differences?
• What differed across groups that had the same case?
• What are the barriers to creating these environments?

11:30 – 12:00  **Final Remarks**
• What do new faculty members need to know about creating and maintaining a successful research group?
• Next steps, dissemination, how to share information
• Distribute and collect evaluation forms for those leaving early.
A Start-Up Research Group

This research group is advised by a new faculty member in aerospace engineering. It comprises two Chinese PhD students (one male and one female) in the first year of their programs and two American male undergraduate members. The graduate students share office space with other aerospace engineering students, but they do not have official “lab” space. This office contains several desks, chairs and computer equipment, along with whatever furnishings were supplied by the inhabitants (e.g., a microwave). Undergraduate students are not allocated space. In addition to the size and newness of the group, their focus on advanced materials research, not as equipment-intensive as other engineering research areas, is another reason they do not have a lab like other groups in the department. The majority of the research is conducted using students’ personal computers. Both graduate students have research assistantships funded from current projects for at least the next two years, and the undergraduate students are using this research experience to satisfy a technical elective course as part of their degree programs. Neither graduate student attended a conference during their first year. Every other week, meetings alternate between group (all students and the advisor) and individual (one graduate student and the advisor) formats. The undergraduate student researchers meet individually with the faculty member as well, although on a less frequent basis. All meetings are held in the faculty member’s office.

Discussion Questions:

1. What characteristics distinguish this group from other research groups?

2. How does the size of this research group impact:
   a. Organization and management?
   b. Student learning and development?

3. This group has students working in separate locations (e.g., offices). How might this influence group management and student learning?

4. What suggestions would you make for advising a research group with these or similar characteristics?
A Multidisciplinary Group

This research group includes 12 students, and is multidisciplinary with students from the electrical engineering and aerospace and ocean engineering departments. This research group has no undergraduate or female students, and all of the members are either from the United States or from India. There is a mix of master’s and PhD students, and every member of the group has a full funding package for the duration of their program. Students in the latter stages of their projects travel to a conference either annually or biannually. This group has been in existence for about five years and has students who are just starting their research through those defending their dissertation.

The students are divided into three main areas that align with three large projects: theoretical applications and two different autonomous systems. The students working on theoretical applications are part of the electrical engineering department and are supervised by a faculty member from electrical engineering, who also serves as the head of the research group. The other two research projects are jointly advised by either an aerospace faculty member or an ocean engineering faculty member in conjunction with the group head from electrical engineering. Altogether, there are 3 faculty members associated with the group.

This research group has a large lab area where students can work together on different aspects of their research. With the exception of the few students focused on theory, the experimental nature of this research group requires a lot of hands-on activity, and much of the lab area is devoted to equipment. This lab is compartmentalized into four rooms. When you enter the lab area there are four desks, which are home to the theoretical students and the computer equipment they use for running simulations. Passing through this smaller room one enters the main lab area which is covered from floor to ceiling in old parts, building materials, construction equipment, parts, work tables and building tools such as soldering irons, drills, and wiring components. Just off the main work area are two additional offices. The first is the group head’s faculty office; the other holds desks for several other students to use when they are not actively engaged in construction, such as creating solid models, running calculations on the designs, or working on class work.

Because of the project based nature of this research group, group meetings are organized around the project teams, and the group as a whole (all students and faculty advisors) does not meet regularly, if at all. The students working on theoretical applications meet with research group head individually, but do not participate in research project meetings. The other students are divided between the two remaining projects, and meet separately in small, task oriented groups. The “surface” autonomous system project (four students), is advised by the research group head and a faculty member from aerospace engineering, and holds weekly project meetings. The “underwater” autonomous system team (three students), is advised by the research group head and a faculty member from ocean engineering, and holds project meetings weekly as well. Project meetings are not held in the lab space, but in a conference room in the electrical engineering department. Individual meetings are scheduled as needed by the three faculty members and students. In addition, much of the work is sponsored by external parties (e.g., companies and federal agencies), who call in regularly and meet with the groups via teleconference.
Discussion Questions

1. What characteristics distinguish this group from other engineering research groups?

2. How does the size of this research group impact:
   a. Overall group management?
   b. Student learning and development?

3. This group has more than one research advisor. How might this influence group management and student learning?

4. This group is subdivided into smaller “project” groups. How might this influence the climate for student interactions within the group?

5. What suggestions would you make for advising a research group with these or similar characteristics?
A Large Research Group

This group has 23 graduate students; 20 male and three female. It has grown rapidly over the past three years since it was started with three students. The members of the group represent a wide range of background experience and diversity, with students from more than seven countries in this research group. The majority of the students in the group are PhD students, with a handful of master’s students as well. There are students who have been members of the group since its inception three years ago, and new students joining each semester. The research focus of this group is in the area of electrical systems, one of eight concentrations within the electrical and computer engineering department. There are four faculty advisors for this group: one that serves as the head of the group, another which serves as a major advisor to the group but also serves in an administrative role in the department, and two other faculty members that have a large role in securing funding, but are less active in the day to day activities of the group.

The group is assigned a lab space which can hold the majority of the students and most of their equipment. There is a square of computer work stations in the center area, and regular tables and chairs line two sides of the room. In one corner area not lined with individual tables, there is a large meeting table that has a white board against the wall that doubles as a projector screen. On the opposite side of the lab there is a small additional office with several desks and wall to wall shelves of books. Research equipment takes up whatever additional space is left in the corners and along the walls of the room and is moved frequently when students are using it. The lab also has a nice kitchen area, much like what one would find at an office break room. There is a microwave and full size refrigerator as well as counter and cabinet space for storing cooking and food items. The group also has a few smaller offices that are used by students working on projects that have proprietary material. These offices are across the hall from the main lab room, and students can come and go as they please. The faculty member that is the head of the group has an office right down the hall, and he is a frequent member in the lab area.

On average, there are between five and ten students in the lab at any given time, either working at their individual work stations or collaboratively on assignments at the large table. Although there are no assigned desks, students tend to “claim” space for themselves and work in the same places every day. Some students are near permanent fixtures in the lab, while others only appear in the lab during the bi-weekly research groups meetings. These meetings are held every other week in the main lab area and last for approximately two hours. In these meetings, new students are introduced, students who are actively working on projects present findings to the group and faculty advisors, and general information from the faculty is passed along to the lab members.

Discussion Questions

1. What characteristics distinguish this research group from other engineering research groups?

2. How does the size of this research group impact:
   a. Overall group management?
   b. Student learning and development?
3. This group has a highly internationally diverse population (students from more than two countries). How might this influence group management and student learning?

4. How might the frequency of group and individual meetings influence students’ learning?

5. What suggestions would you make for advising a research group with these or similar characteristics?
Developing and Sustaining Productive Graduate Research Groups in Engineering

Research-focused graduate programs (thesis master’s and PhD) are meant to transform students into independent researchers with critical and analytical thinking skills who can set goals, collaborate with others and communicate their ideas orally and in writing. In engineering, the setting for this learning is often a research group, or the set of students and research staff advised by one faculty member (or a team of faculty in close collaboration). The following recommendations are offered to faculty advisors to maximize student learning in research group settings.

**Clarify Expectations**
- Advisor and group expectations should be made clear to new students so they can act appropriately.
- Because group membership changes, you may need to periodically discuss expectations.
- Clarifying expectations to potential students can also increase recruiting success.
- Examples of expectations include your philosophy on:
  - Giving and accepting feedback from peers and mentors
  - Work-life balance, hours spent in the lab or office and amount of vacation time
  - Competitive or collaborative culture
  - Expectations for graduation and degree progress
  - Expected level of writing and presentation skills
  - How students will be evaluated
  - Professionalism in interactions with others

**Attend to Community**
- The goal is for students to have a sense of belonging to their research group.
- Developing community takes attention and effort.
- Community can mean an open environment that fosters collaboration and interest in other students’ projects.
- Foster community through social events, such as group lunches, and celebrations of birthdays and research milestones (conference best papers, passing qualifying exams).
- Plan academic activities to promote community: group meetings, retreats, journal clubs and taking courses together.
- Seek space for students to work together.
- Consider “branding” your lab with a name and identity, logo and even t-shirts.
- Require members to respect cultural differences and work-life balance. If necessary, discuss inclusive rules for when to use English and native languages in the lab.
- Insist on professional behavior, respect for others and fair treatment of all students.
- Advisors should serve as role models.
Organize the Group for Mentoring and Peer Learning

- A single advisor cannot effectively mentor more than about five students singlehandedly.
- In larger groups, postdocs and senior students can serve as mentors.
- Subgroups or smaller project-based groups can be a management tool for larger groups.
- Clarify who students should report to and where they can get feedback or training in specific skills.
- Ask students to archive common lab procedures for group reference.
- Group meetings should have clear goals, but consider other ways of accomplishing the various goals of updating the advisor, reporting progress, providing positive peer pressure, troubleshooting, practicing presentation skills and learning about each others’ work. The best solution may be a combination of emails, subgroup meetings and individual meetings.
- Advisors should be approachable, even in large groups. When students are reporting weekly progress and challenges, advisors should do the same.
- Peer evaluations and group feedback can help the group function more effectively.
- The advisor should reflect on successes and challenges to make adjustments when necessary.

Structure Student Development Toward Independence

- The idea is to provide structure or “scaffolding” to new students, which is gradually removed over time so they develop more creativity and independence.
- Jointly set short, medium and long term goals with students; work together to meet them.
- Use professional development plans and annual reviews to discuss strengths and opportunities for growth.
- Allow students to take calculated risks and learn from mistakes.
- Engage in frequent communication, such as weekly progress reports and feedback cycles. Do not micromanage.
- Involve students in all aspects of research, including proposals, decisions and planning.
- Student motivation stems from well-defined, challenging projects aligned with career goals.
- Use a small research-related task (such as analyzing a journal article) as a tryout to evaluate fit and determine individual students’ strengths and weaknesses.
- Prior experience sensitizes an advisor to potential student weaknesses, but do not make assumptions without evidence.
- Use conference travel as a reward for sufficient progress and to expand students’ professional network.

A common theme across all these recommendations is frequent communication and feedback about goals and expectations, which should be developed jointly between students and faculty. Participants in the research studies and workshops associated with this project felt strongly that feedback, reflection and evaluation helps students, advisors and research groups grow and improve over time.
### Appendix E

**Sample 1 Hour Workshop Activities**

**Facilitator Instructions:** These activities and prompts were designed to help you facilitate a mini-workshop version of the two-day meeting for your research group, department or professional association. As in the full workshop, the key is to encourage active participation for attendees to discuss their own ideas. Sample responses are given to help move conversation along as necessary. The first discussion prompt is necessary to get everyone on the same page, but others can be selected as time allows. For example, a one-hour event would include: successful characteristics (5 mins) and one case study (50 mins) or all activities except the case studies (10-15 minutes for each activity, allowing some time for report back).

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<th>Prompt</th>
<th>Sample Responses</th>
<th>Facilitator Notes</th>
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| What are the characteristics of successful and productive engineering research groups? | - Research productivity  
- Student degree progress  
- Effective meetings  
- Feedback and communication  
- Sense of community  
- Mutual respect and professionalism  
- Challenging projects which provide structure  
- Mentoring and supportive culture  
- Student personal characteristics (motivated, good writer, etc) | Depending on group size and total time limit you can use one of the following techniques:  
- Think-pair-share: quietly jot down some thoughts for 2 minutes, then turn to neighbor and discuss responses (groups of 2-3 for 5 minutes), then ask some groups to report back in 2-5 minutes.  
- Assign questions as homework before the meeting/workshop As facilitator for either mode, you should try to synthesize the findings, or at least list them on a visual aid. If a single research group is doing the workshop, more time can be taken to develop consensus around how they define success. If your audience is not talking much, talking in pairs (think-pair-share) is one of the best ways to loosen them up. |
| What are some specific ways to develop community or a sense of belonging among group members? | - Social events (lunches, birthdays)  
- Involve current members in recruiting new students/members  
- Celebrate as a group (awards, articles, degree milestones)  
- Joint projects or mentoring to encourage knowledge of others’ work  
- Participate in dept events as a group  
- “Brand” with lab name and logo |  |
| What are some specific ways to mentor students to develop independence? | - Mutually identify short, medium and long-term goals  
- Use postdocs and senior students as mentors  
  - Clarify who to go to for what advice  
- Facilitate networking and conference travel  
- Professional development plans and annual reviews  
- Faculty should be open to feedback  
- Make it safe to discuss mistakes to learn from them  
- Involve students in proposal writing |  |
| What are your group’s expectations for the following? | - What is required to graduate?  
- Whom to turn to with questions?  
- How competitive or collaborative we are?  
- Required communication skills (written and oral)?  
- How often to check and respond to email?  
- Hours spent working or hours in the lab/office?  
- Vacation time? | This activity should be used when running the workshop for a specific research group, also work with a department group, but loses its value as the workshop attendees increase in organizational diversity. |