Problem Solving Obstacles in the Research Lab: Perceptions of Graduate Students and Faculty

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Abstract

The transition from dependent to independent learner is an important part of the graduate school experience. The transition is overly bumpy for many students (and their faculty advisors). This paper describes a survey of faculty and graduate students administered at Michigan Tech. Twenty-two faculty and thirty-six graduate students from a variety of engineering and science disciplines completed the surveys. The surveys asked respondents to rate the importance of a variety of factors to success in graduate school. Students were also asked to rate themselves on each factor both now and as they saw themselves upon entering graduate school. Factors were grouped into three domains: Knowledge, Attitude/Communication, and Problem Solving. Faculty rated factors in the Problem Solving domain as much more important than the other two while students rated factors in the Attitude/Communication and Problem Solving domains as being nearly equal as most important. Of the three domains, students reported the least amount of improvement in the Attitude/Communication domain, and the most improvement in the Knowledge domain. The importance that students assign to Attitude/Communication factors, especially relative to the faculty, was an unexpected finding from the survey. It is recommended that faculty and the university as a whole find new ways to address this aspect of graduate student experience.

Introduction

The undergraduate curriculum is not necessarily good preparation for conducting graduate research. New graduate students often have difficulty in overcoming problems in the laboratory. Practical problems include things like broken equipment, limited hardware capabilities, and difficulty in isolating a variable of interest. The problems that arise cannot be predicted, and every student encounters unique problems. Students repeatedly get stuck, and many are slow to learn how to solve these types of problems. Our long-term goal is to understand the nature of the learning difficulty and to develop learning experiences that could be implemented at either the undergraduate or graduate level to facilitate the transition from novice to expert problem solver in the lab.

The first step toward this goal is to better understand the nature and extent of the problem. Graduate students and faculty at Michigan Tech were surveyed to gather their perceptions of barriers to success. Thirty-six graduate students and twenty-two faculty from a variety of engineering and science disciplines responded to the survey. Respondents rated a list of factors on a scale of 0-5, with 0 being "not at all important" to success and 5 being "very important." In addition, the student survey asks students to rate their ability with respect to each factor both now and at the time they entered grad school. The surveys (both faculty and student) also asked respondents about their level of experience and the amount of experimental work in their projects.

Statistical Analysis

The survey data were sliced in a number of different ways to make comparisons. For example, faculty responses were compared to students; MS student responses were compared to PhD; etc. Nonparametric statistics are used when assumptions of normality of a data set are not appropriate. Since survey responses are subjective, each person can interpret the response scale differently and a response of "5" is not necessarily five times better than a response of "1." Therefore, appropriate nonparametric statistical tests were used to analyze the survey results. For all statistical tests, a $P \leq 0.05$ was considered statistically significant.

The Mann-Whitney rank sum test was used to determine differences between two different groups, such as students vs. faculty or M.S. students vs. Ph.D. students. This test is analogous to a t-test for parametric data. The dependent variable was the response to the survey question. The Wilcoxon signed rank test was used to assess differences between students' perceptions of their abilities before beginning graduate school and currently. This test is analogous to a paired t-test.

Faculty Responses

Figure 1 shows the most important factors for student success in order of importance. The error bars display +/- one standard deviation.

Amount of Experimental Work

Faculty were asked to rate the amount of experimental work in one of their typical graduate projects on a scale ranging from 0 (none) to 5 (significant). Five of 21 faculty responded in the range 0-3. Their survey responses were grouped as "Low Experimental". The remaining 17 faculty indicated 4 or 5. Their survey responses were grouped as "High Experimental". Figure 1 compares the two groups for all of the factors. However, only four factors showed a significant difference (Mann Whitney U test, $P \leq 0.05$). Only the first factor has an obvious connection to experimental work. However, the other three make sense given that experimental work involves getting the help of technicians, ordering materials and scheduling, and persisting in the face of inconclusive experimental results.

Question	Low Experimental	High Experimental
Hands-on ability	1.40	3.33
Tolerance for ambiguity	2.20	3.93
Time management	1.80	3.31
Ability to work with other people	0.40	1.80

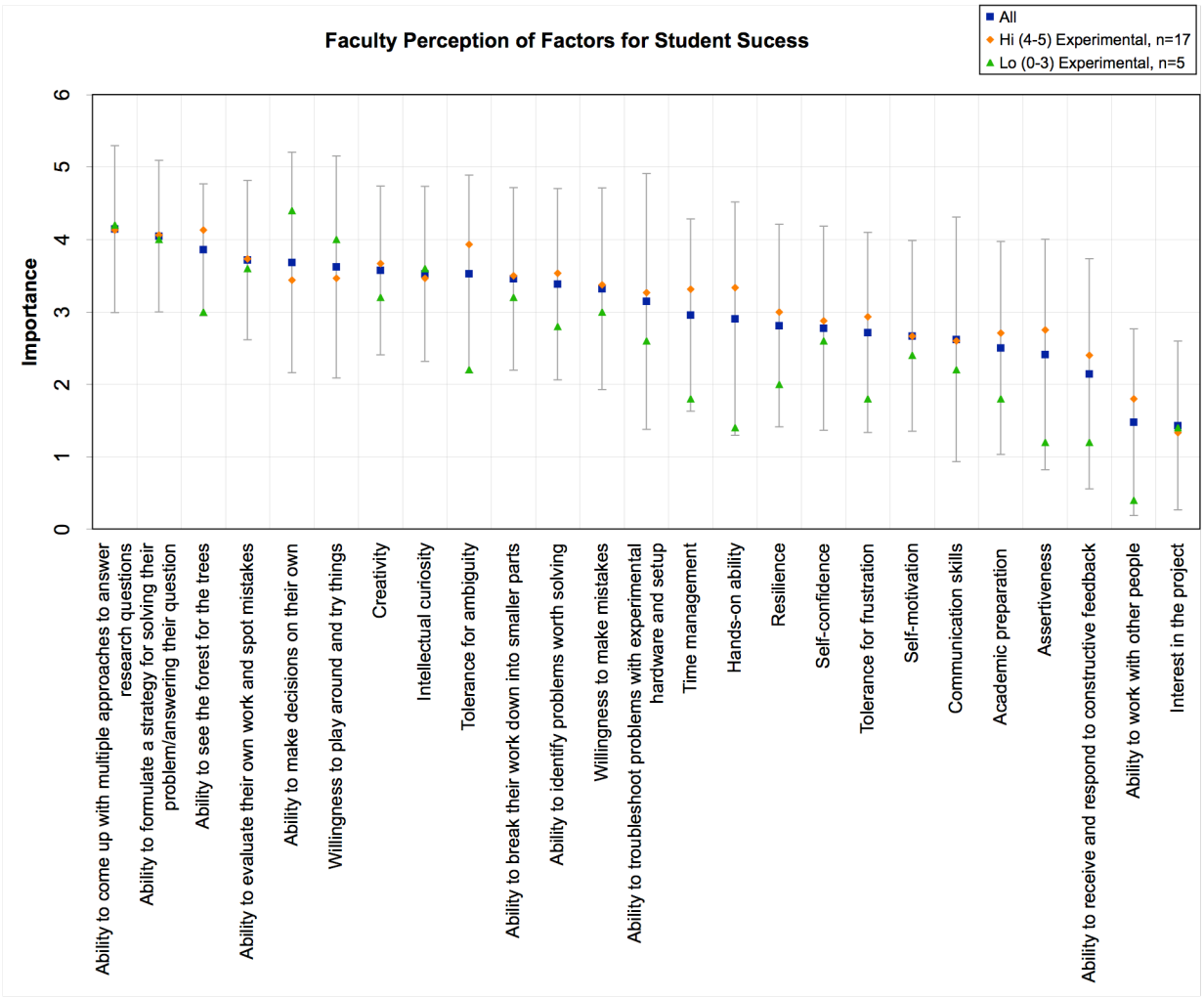

Figure 1: Most important factors for grad student success based on faculty survey responses

Graduate Advising Experience

Faculty responses were compared in terms of amount of graduate advising experience. Faculty who have advised less than 11 students were labeled "low experience" and faculty who have advised 11 or greater students were labeled "high experience." There were 5 and 17 faculty, respectively, in each category. No statistically significant differences were found.

Student Responses

Figure 2 shows factors for student success according to graduate students. The students consider nearly all factors to be important for success.

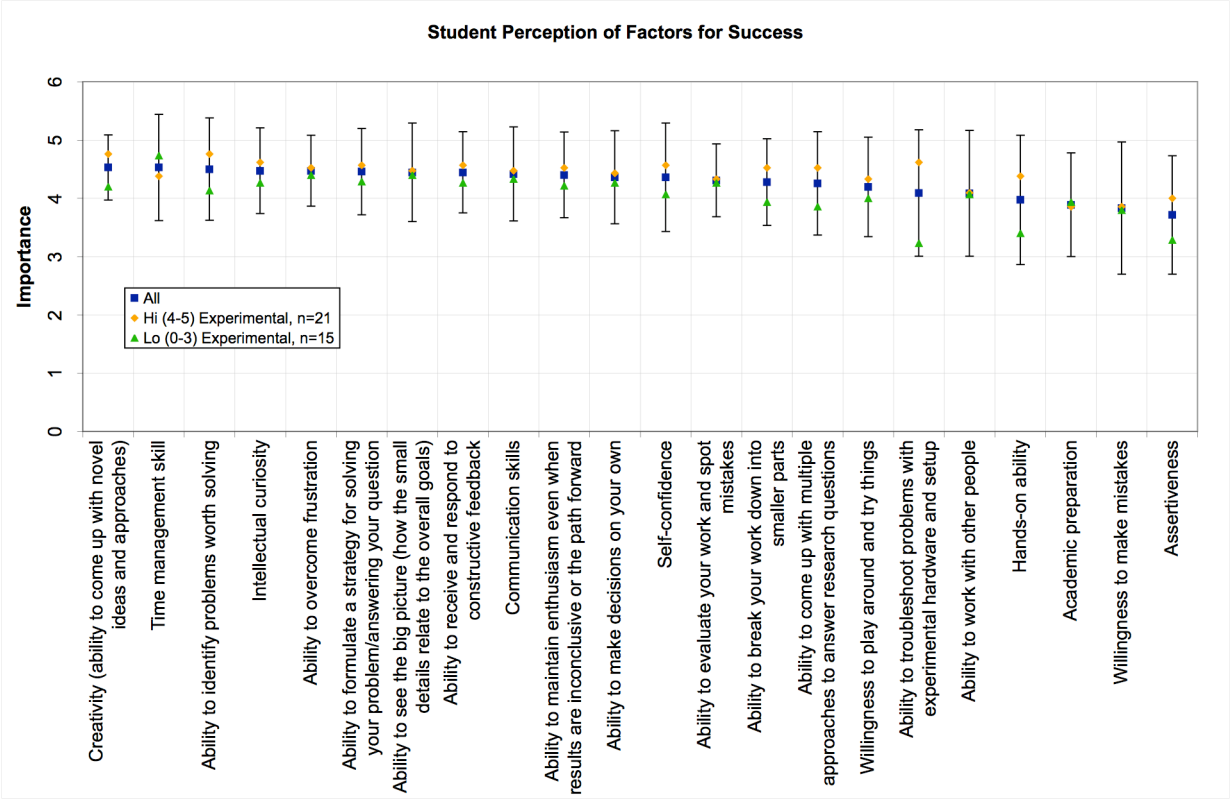

Figure 2: Factors for graduate student success based on student survey responses

Graduate students were asked 6 additional questions about their graduate student experience. Average responses to those are summarized below.

Question	**Avg**
If you were able to fund your own graduate study (or won a fellowship that paid all your expenses), how likely would it be that you would choose a research project similar to the one you are currently working on (0 very unlikely to 5 very likely):	3.80
How rewarding do you find your grad school experience? (0 not rewarding to 5 very rewarding)	3.88
How challenging do you find your research project to be? (0 not challenging to 5 too challenging)	3.74
Do you feel that success on your research project is mostly within your control or does it mostly depend on lots of other factors? (0 in my control to 5 depends on other factors)	2.71
Has the transition to graduate school at MTU been easy or difficult (consider the total experience)? (0 easy to 5 difficult)	2.00
Do you find the atmosphere at MTU to be welcoming and supportive? (0 no to 5 yes)	4.11

Amount of Experimental Work

Students were asked to characterize the amount of experimental work in their projects on a scale of 0 to 5. We have labeled responses of 0-3 as "low experimental" (includes 15 students) and 4-

5 as "high experimental" (includes 21 students). The responses of the two sets of students were compared. The table below summarizes results where there is a statistical difference (Mann Whitney U Test, $P \leq 0.05$). The first two factors have obvious connections to experimental work. The last 2 factors indicate that experimentation requires a high level planning and creativity.

Question/Factor?	Low Experimental	High Experimental
Ability to troubleshoot problems with experimental hardware and setup	3.23	4.62
Hands-on ability	3.40	4.38
Ability to break work into smaller parts	3.93	4.52
Creativity	4.20	4.76

Domestic versus International

The responses of domestic (n=24) versus international students (n=12) were compared, and no statistically significant differences were found.

MS vs. PhD

The responses of MS versus PhD students were compared. In most cases, there were no significant differences between the two groups. The items with statistically significant differences are summarized below. On average, as compared to MS students, the PhD students find their graduate experience to be less rewarding, and the atmosphere less welcoming.

Question	MS Average	PhD Average
How rewarding do you find your grad school experience? (0-5 most rewarding)	4.36	3.57
Do you find the atmosphere at MTU to be welcoming and supportive? (0-5 yes)	4.71	3.73

Time in Grad School

Student responses were placed in 2 groups depending on the amount of time a student has been in graduate school. Less than 2 years is "low", and greater than 2 years is "high." Eighteen students were in each group. The table below summarizes the responses with a significant difference. It makes sense that a new student in the transition of becoming an independent learner would rate these two factors highly.

Question	Low Time	High Time
Ability to make decisions on your own	4.72	4.00
Ability to receive and respond to constructive feedback	4.72	4.17

For each of the importance factors, students rated their ability currently and upon entering graduate school. Figure 3 displays the difference between the two ratings. It also shows a comparison between the "high" and "low" experimentation groups. The greatest improvements are in academic preparation and factors related to problem solving.

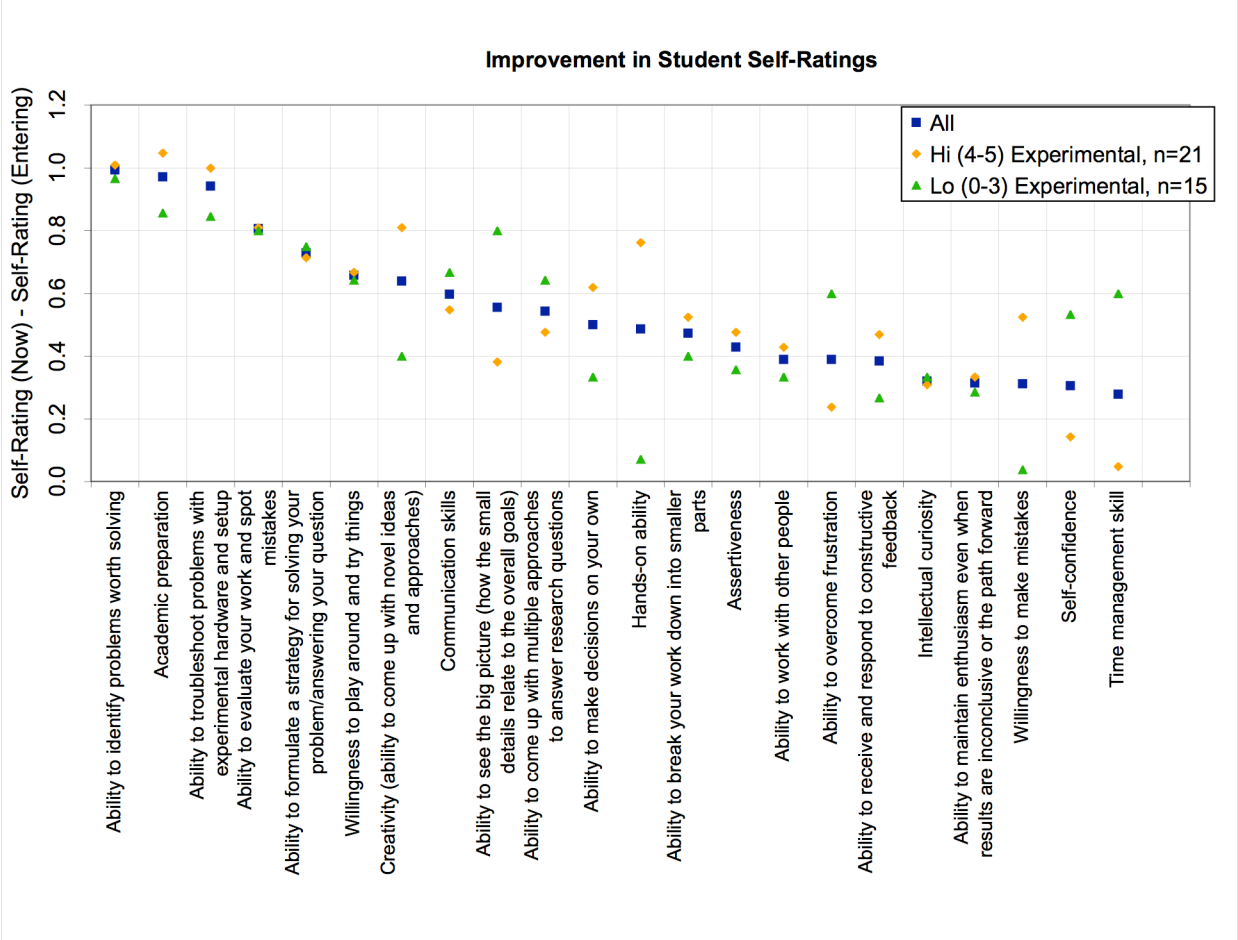

Figure 3: Student perception of their improvement in their abilities

For the group of all students, five factors didn't have statistically significant improvement: time management skill, self-confidence, willingness to make mistakes, ability to maintain enthusiasm when the path forward isn't clear, and intellectual curiosity. These factors tend to relate to a student's emotional life. Comparisons were made between sub-groups of respondents. Generally, as expected, PhD students reported more improvement than MS students, and students in graduate school for more than 2 years reported more improvement than those in school less than 2 years.

Faculty versus Student Perceptions of Important Factors

The table below compares the average responses for students and faculty. Students rated all factors as more important than faculty. The table lists the factors in the order of the biggest difference in averages between the two groups. The largest differences are factors involving communication and emotions.

Factor	Student Avg - Faculty Avg
Ability to work with other people	2.60
Ability to receive and respond to constructive feedback	2.30

Communication skills	1.80
Ability to overcome frustration	1.66
Self-confidence	1.59
Time management skill	1.58
Academic preparation	1.39
Assertiveness	1.30
Ability to identify problems worth solving	1.12
Hands-on ability	1.07
Creativity	0.96
Intellectual curiosity	0.95
Ability to troubleshoot problems with experimental hardware and setup	0.95*
Ability to maintain enthusiasm even when results are inconclusive or the path forward isn't clear	0.88
Ability to break work down into smaller parts	0.83
Ability to make decisions on their own	0.68*
Ability to evaluate their work and spot mistakes	0.60*
Ability to see the big picture	0.58
Willingness to play around and try things	0.57*
Willingness to make mistakes	0.51*
Ability to formulate a strategy for solving their problem or answering their question	0.41*
Ability to come up with multiple approaches to answer research questions	0.12*

*Statistically insignificant, $P>0.05$

Lumped Attributes-Importance

We attempted to simplify the analysis by looking at factors that seemed to go together. Bloom (1956) identified three domains of educational activities: cognitive, affective, and psychomotor. These may be referred to as Knowledge, attitude, and skills. In this case, "skills" are physical. We modified Bloom's scheme to replace physical skills with problem solving skills. In addition, we broadened attitude to include communication skills. Our three domains and the factors that go with them are listed below.

Knowledge	Attitude/Communication	Problem Solving Skills
Academic preparation	Evaluate own work Make decisions Motivation Work with people Intellectual curiosity Interest in project Willingness to make mistakes Respond to feedback Resilience Communication skill Tolerance for frustration Time management Self-confidence Assertiveness Tolerance for ambiguity	Identify problems worth solving Break work into smaller parts Willingness to play and try things See the big picture Hands-on ability Creativity Come up with multiple approaches Formulate a strategy Troubleshoot

The importance ratings for each survey respondent were averaged in these three domains. The results for faculty and students are summarized below. For the lumped attributes, students rate all three as more important than faculty. The differences are statistically significant. Faculty rate Problem Solving skill as being most important and Knowledge as least important of the three domains. The greatest difference between faculty and student perception of importance is the Attitude/Communication domain (with the Knowledge domain having a similar difference). Faculty perhaps underrate the importance of students' emotional life to their success in graduate school. On the other hand, students might underrate the importance of problem solving skills.

	Faculty	Students	Difference
Knowledge	2.50	3.89	1.39
Attitude/Communication	2.87	4.27	1.40
Problem Solving	3.52	4.26	0.74

As was done in earlier sections, we made comparisons between different subgroups looking for statistically significant differences. The faculty high experimental group rates Attitude/Communication as more important than the low experimental group does (3.04 vs. 2.33). MS students rate Attitude/Communication as more important than PhD students do (4.48 vs. 4.13). The student high experimental group rates Problem Solving as more important than the low experimental group does (4.48 vs. 3.92). We found no significant differences in the following comparisons: domestic versus international students, low versus high time in school, and low versus high number of students advised.

Lumped Attributes-Improvement

The self-evaluations of all students indicated statistically significant improvement for the 3 lumped attributes. The mean responses are given below. Note that the greatest improvement is in the Knowledge domain, and the least improvement is in the Attitude/Communication domain.

	Entering	Current	Change
Knowledge	2.91	3.89	0.98
Attitude/Communication	3.31	3.74	0.43
Problem Solving	3.22	3.88	0.66

Interestingly, the MS students tended to rate themselves higher than the PhD students in all three domains both upon entering and currently. We analyzed whether improvement in the three domains was statistically significant for all sub-groups, and in a couple cases it was not. The improvement for the MS students was not statistically significant in all three domains (perhaps because they rated themselves highly upon entering and because they've had less time to improve). Also, international students reported no significant improvement in the Attitude/Communication category.

Conclusions

Faculty perceive Problem Solving skills to be the most important factors for success while students perceive Attitude/Communication to be the most important. At the same time, of the three domains, students report the least amount of improvement in the Attitude/Communication domain. When we began this study, we were looking for evidence that the development of problem solving skills is an important part of transitioning from dependent to independent learner. We did find evidence for that, and we gained more detailed information about particular aspects of problem solving. What we didn't expect was the large difference in faculty/student perceptions of the importance of Attitude/Communication. While it may be more difficult to address, faculty and the university as a whole should pay greater attention to this domain if they want to empower graduate students to be more successful in their graduate work.

References

Bloom, B. S., *Taxonomy of Educational Objectives; The Classification of Educational Goals*, New York: Longmans, Green, 1956.

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