What Makes an Inquisitive Engineer? An Exploration of Question-Asking, Self-Efficacy, and Outcome Expectations among Engineering Students

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Abstract

In order be successful, engineers must ask their clients, coworkers, and bosses questions. Asking questions can improve work quality and make the asker appear smarter. However, people often hesitate to ask questions for fear of seeming incompetent or inferior. This study investigates: what characteristics and experiences are connected to engineering students' perceptions of asking questions?

We analyzed data from a survey of over a thousand engineering undergraduates across a nationally representative sample of 27 U.S. engineering schools. We focused on three dependent variables: question-asking self-efficacy (how confident students are in their ability to ask a lot of questions), social outcome expectations around asking questions (whether students believe if they ask a lot of questions, they will earn the respect of their colleagues), and career outcome expectations (whether they believe asking a lot of questions will hurt their chances for getting ahead at work).

We were surprised to find that question-asking self-efficacy or outcome expectations did not significantly vary by gender, under-represented minority status, and school size. However, students with high question-asking self-efficacy and outcome expectations were more likely to have engaged in four extracurricular experiences: participating in an internship or co-op, conducting research with a faculty member, participating in a student group, and holding a leadership role in an organization or student group. The number of different types of these extracurricular activities a student engaged in correlated with question-asking self-efficacy and positive outcome expectations around asking questions.

The results illustrate the relationship between extracurricular activities and students' self-efficacy and behavior outcome expectations. The college experience is more than just formal academic classes. Students learn from experiences that occur after class or during the summer, and ideally these experiences complement class-derived skills and confidence in asking questions.

1.0 Introduction

Think of the last workplace setting you were in. Now, imagine what that work would be like if you did not feel like you were able to ask anyone any questions. Would you be able to contribute as much to your organization?

As engineers spend more of their time working in large teams to solve complex problems, they must ask their coworkers, clients and bosses questions. The design process evolves through asking questions, and questions help design teams structure their work [1]. Questions help teams with divergent thinking – building upon other team members' ideas to come up with many creative solutions. Questioning also facilitates convergent thinking – analyzing many ideas to

focus on the best solution or to diagnose problems in an existing solution. The process of asking questions at work helps employees contribute more to the organization.

In addition, seeking help and advice through asking questions can have a positive influence on performance. In a study of teams at a large company, asking for personal advice – which often happens through asking questions – leads to sharing of knowledge and improved work quality [2]. Asking for advice can also make the asker appear smarter [3]. However, people may hesitate to ask such questions because of a fear of seeming incompetent or inferior– especially when in male-oriented occupations, such as engineering [4] [5].

Despite the importance of questioning, engineering students' confidence in and perceptions around asking questions in the workplace have received little attention. This paper looks at data from 905 students across a sample of 27 representative colleges and universities to investigate what program characteristics and student experiences are connected to engineering students' perceptions of asking questions [6]. We focus on (1) question-asking self-efficacy – one's confidence in one's ability to ask questions – and (2) outcome expectations around asking questions – one's view that asking questions will lead to desired results. In line with Bandura's self-efficacy theory [7], we conceptualize that behavior is dependent on these two elements, self-efficacy and outcome expectations, and influenced by previous performance accomplishments and vicarious experiences. (See Figure 1, below). Previous research has shown that self-efficacy beliefs influence activity choices, effort and persistence in both work and educational contexts [8-12]. Those with low self-efficacy beliefs are more likely to cease efforts prematurely and fail to have the desired impact [11], whereas those with high self-efficacy beliefs related to a task are more likely to engage in proactive behavior [13][14]. Outcome expectations are also conceptualized to influence task motivation [15].

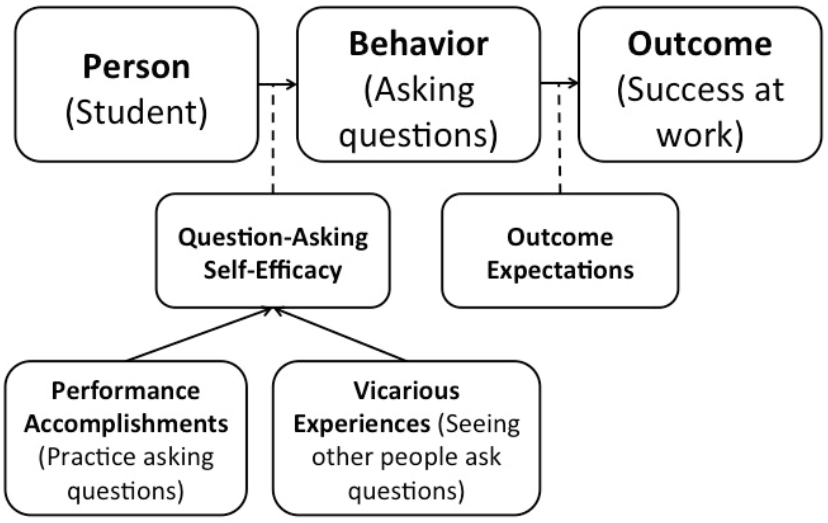


Figure 1: Self-efficacy theory applied to asking questions (model adapted from Bandura [7])

This study investigates: *what is the relationship between students' characteristics and experiences, and students' reported question-asking self-efficacy and perceptions of the outcomes of asking questions? Are higher levels of self-efficacy and outcome expectations*

related to certain attributes or experiences? By answering these questions, we can begin to understand the relationships between student experiences and their confidence and expectations around asking questions in engineering. Ultimately, this line of inquiry can help educators in fostering this essential communication skill.

2.0 Methodology

The current study used survey data from the second administration of the Engineering Majors Survey (EMS). EMS was developed as part of a longitudinal study investigating engineering students' interests and career goals surrounding innovation and entrepreneurship [6]. EMS 1.0, the initial survey, was administered in 2015 to engineering undergraduates across a nationally representative sample of 27 U.S. universities and colleges with engineering programs. EMS 2.0, administered in 2016, was a follow-up to those participants who had permitted contacting them again for a second survey. A total of 1,460 participants completed the EMS 2.0 survey.

2.1 Sample

The EMS 2.0 sample consisted of both current undergraduates and students who had recently received a Bachelor's degree. For this study, we limited the sample to current bachelor's students (N=905) to include only undergraduate experiences in our analysis. The participants were able to skip questions or exit the survey early; our sample includes respondents who answered all three items that are key to the current study, as discussed below. See Table 1 for the demographic characteristics of the respondents. Not all students answered every question, so the totals do not all add up to 905.

Table 1: Demographic characteristics of participants (N = 905)

Gender	**n**	**%**
Female	327	36.1%
Male	573	63.3%
Under-Represented Minority	**n**	**%**
Non-URM	767	84.8%
URM*	118	13.0%
Class Standing	**n**	**%**
Sophomore	37	4.1%
Junior	207	22.9%
Senior	513	56.7%
Fifth-year senior or more	148	16.4%

*URM=African American, Hispanic, Native American, & Pacific Islander

2.2 Measures

This study focused on three survey items in EMS 2.0 around question-asking – one on question-asking self-efficacy, and two on outcome expectations. We labeled the two outcome expectation

items as social outcome expectations (whether students think that their peers will react positively to asking questions) and career outcome expectations (whether students think that asking questions will have a positive impact on their career). The specific prompts associated with the three items are:

1. Question-Asking Self-Efficacy (QSE): "How confident are you in your ability to ask a lot of questions?"
2. Social Outcome Expectations around Asking Questions (SOE): "Imagine the work you will be doing in the first year after you graduate. Estimate the likelihood of the following statement: If I ask a lot of questions, I will earn the respect of my colleagues."
3. Career Outcome Expectations around Asking Questions (COE): "Imagine the work you will be doing in the first year after you graduate. Estimate the likelihood of the following statement: If I ask a lot of questions, I will hurt my chances for moving ahead" (reverse coded)

All three items were self-reported on a scale from 1-5. Ratings were labeled as 1 ("Not confident") to 5 ("Extremely confident") for question-asking self-efficacy (QSE) and 1 ("Definitely will not") to 5 ("Definitely will") for social and career outcome expectations (SOE and COE).

In addition to the three question-asking items, our dataset included demographic information (gender, URM-status, and class standing) and participation in extracurricular activities. In addition, school size (large or small) was assigned to each respondent. Students attended a "large" school if they were in the top half (by undergraduate engineering enrollment) of the 27 schools, otherwise the school was labeled a "small" school.

We included four extracurricular experiences from EMS 2.0 in our analysis: (1) working as an intern, (2) conducting research, (3) participating in student groups, and (4) holding a leadership role in a student group. These were selected from a larger set of student-related activities on EMS 2.0. We chose these experiences because they involve working with others, potentially giving the students more opportunities to ask questions. Table 2 shows a summary of the EMS 2.0 items and participation rates used in the analysis. Not all students answered every question, so the totals do not always add up to 905.

These four experiences were also considered in sum in order explore a possible connection between the quantity of experiences in relation to our question-asking variables. To designate a Total Experiences Score (TES), we gave an individual one point for each of the four activities. If a respondent had an internship, conducted research, participated in a student group and held a leadership role, their Total Experiences Score would be 4. If they did not do any of these activities, then their score would be zero. 37 students did not answer all four questions, therefore the total number of responses is 868 for this measure, as summarized in Table 3.

Table 2: Summary of experiences and participation rates (N= 905)

Experience	**Marked "yes" to:**	**Yes**	**No**	**Participation Rate**
Had an internship	"Work in a professional engineering environment as an intern/co-op"	613	292	67.7%
Conducted research	"Conduct research with a faculty member."	371	534	41.0%
Participated in a student group	Participated in at least one of the following activities: a "business or entrepreneurship club," "a community service-based club," "a design club," "a robotics club," "other student clubs or groups in engineering," or "other student clubs or groups outside of engineering."	751	117	86.5%
Held a leadership role	Done at least one of the following: "led a student organization," started or founded "a student club or other student group on campus," or started or founded their "own for-profit or non-profit organization."	381	487	43.9%

Table 3: Distribution of Total Experiences Score *TES (N = 868)*

Total Experiences Score	**Number of students**	**Percentage of students**
0	34	3.9%
1	141	16.2%
2	256	29.5%
3	298	34.3%
4	139	16.0%

2.3 Data Analysis

We conducted data analysis in R. We first calculated descriptive statistics of the three question-asking items. Next, we compared the average QSE, SOE, and COE scores by gender, under-represented minority status, and school size. We conducted t-tests to compare the average scores between different groups.

To compare respondents with high and low question-asking self-efficacy and outcome expectations, we divided the respondents into two groups as described below: students with low and high QSE, SOE, and COE.

For all categories (QSE, SOE, and COE), the "low" group contained those who marked themselves as 3 or below on a scale from 1-5, and the "high" group included those who marked 5 on a scale of 1-5. We chose these markers to try and capture the top and bottom groups (ideally quartiles) as consistently as possible for each measure. See Table 4 for the number of students in each category.

Table 4: Categorizing students with low and high QSE, SOE, and COE

Measure	**Number of students in "low" category**	**Percentage of students in "low" category**	**Indicator of low**	**Number of students in "high" category**	**Percentage of students in "high" category**	**Indicator of high**
QSE	248	27.4%	<=3	317	35%	5
SOE	451	49.8%	<=3	121	13.4%	5
COE	235	26.0%	<=3	251	27.8%	5

We then investigated whether students who are very confident asking questions (High QSE) or have high outcome expectations (High SOE or High COE) are more likely to participate in extracurricular experiences than those who are not confident asking questions (Low QSE) or have low outcome expectations (Low SOE or Low COE). We tested for this by comparing the participation rates in these activities of students in the low groups (QSE, SOE & COE) and those within the high groups (QSE, SOE & COE) using a test for equality of proportions. We analyzed QSE, SOE, and COE separately rather than combining them into one measure because the three items were only moderately correlated with each other (between QSE and SOE, Person's $r = .22$; between QSE and COE, $r = .14$; between SOE and COE, $r = .29$). All these correlations were statistically significant, but these data shows that the items were measuring different qualities.

Finally, we did a correlational analysis between students' Total Experience Score and each of the three question-asking items (QSE, SOE, and COE).

3.0 Results

Table 5 shows the descriptive statistics and a comparison of the three question-asking measures by demographics and school characteristics. We did not see a significant difference in QSE, SOE, or COE by gender, under-represented minority status, or size of engineering school. The only measure that almost reaches significance is size of school in relation to Career Outcome Expectations around Asking Questions, with students at large schools showing slightly less concern about asking questions hurting advancement possibilities (remember this item is reverse coded).

Table 5: Demographic and school characteristic comparisons by Mean QSE, SOE &COE (N = 905). Based on scale of 1-5.

Comparison	**Categories**	**Avg. QSE Mean (SD)**	**Avg. SOE Mean (SD)**	**Avg. COE Mean (SD)**
	All Students	4.02 (0.90)	3.56 (0.83)	3.93 (0.91)
Gender	Female Students	3.99	3.61	3.99
	Male Students	4.03	3.53	3.90
	***p*-value**	0.49	0.18	0.17
URM status	Non-URM Students	4.02	3.56	3.95
	URM Students	4.01	3.55	3.86
	***p*-value**	0.87	0.89	0.30
School Size	Attend Large School	4.02	3.56	3.97
	Attend Small School	4.01	3.56	3.85
	***p*-value**	0.87	0.89	0.09

Next, we compared the participation rates in various activities of people in the low and high QSE, SOE, and COE groups. Table 6 shows the participation rates in each of the four activities for students with low QSE vs. high QSE, as well as low vs. high SOE and low vs. high COE.

Students with high question-asking self-efficacy had higher participation rates in all four extracurricular activities than those with low question-asking self-efficacy (Table 6). The results were statistically significant ($p < .05$) for all values. (For internships, $p = .000$; for research experience, $p = .02$; for student groups, $p = .002$, for leadership, $p = .003$).

Similarly, students with high social outcome expectations for question asking had higher participation rates in all four extracurricular activities than those with low social outcome expectations (See Table 6, below). The results were statistically significant ($p < .05$) for all values (For internships, $p = .005$; for research experience, $p = .04$; for student groups, $p = .009$, for leadership, $p = .000$).

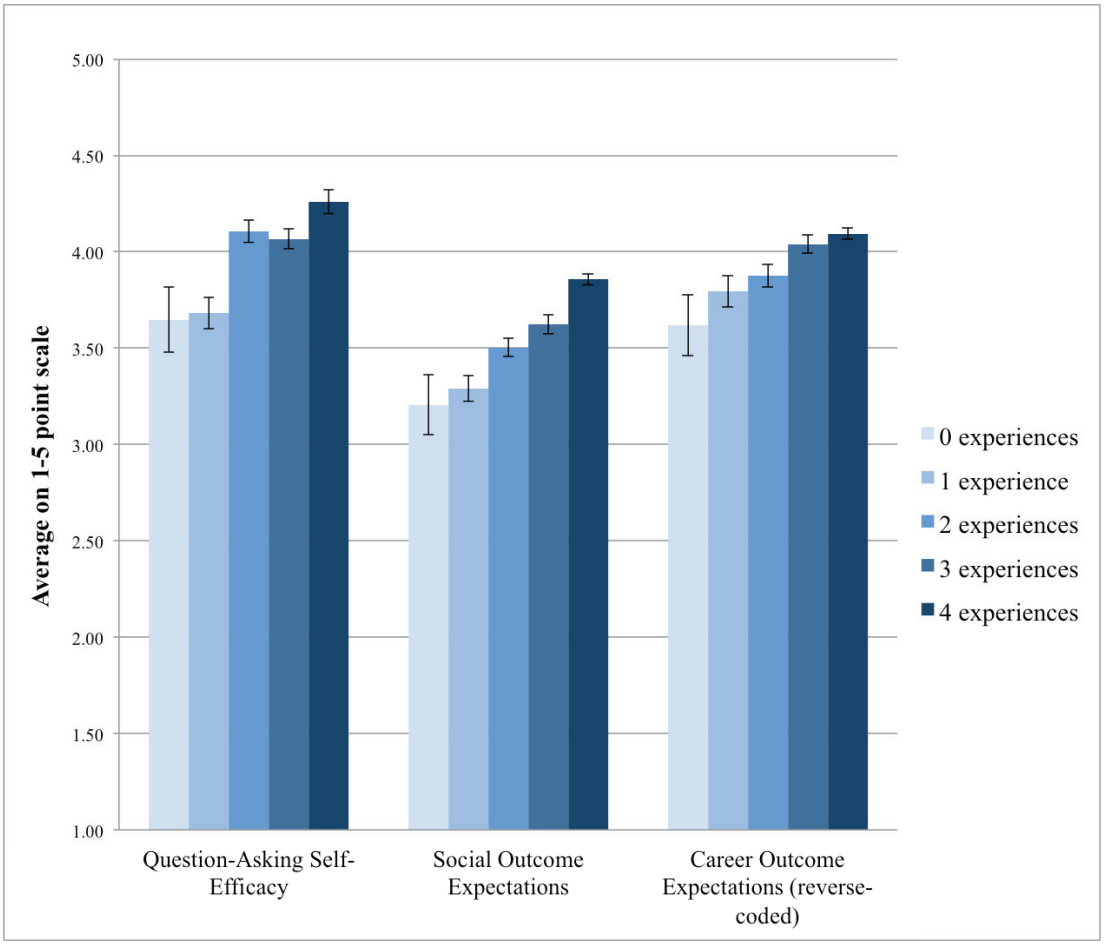
Table 6: Participation rates in undergraduate experiences by high and low QSE, SOE, and COE.

		Had an internship	**Conducted research**	**Participated in a student group**	**Held a leadership or founding role**
Question-Asking Self-Efficacy	Low QSE	56.9%	32.7%	79.2%	36.4%
	High QSE	73.5%	42.9%	89.2%	49.7%
	***p*-value**	.000***	.02*	.002**	.003**
Social Outcome Expectations	Low SOE	63.6%	37.9%	82.6%	36.0%
	High SOE	77.7%	48.8%	93.0%	64.9%
	***p*-value**	.005**	.04*	.009**	.000***
Career Outcome Expectations	Low COE	56.2%	31.9%	83.6%	36.1%
	High COE	70.9%	45.4%	89.6%	45.8%
	***p*-value**	.001**	.07	.08	.04*

(*p < .05; ** p <.01, *** p <.001)

Only differences in internship experience and leadership experience were significantly different between those with high career outcome expectations related to question asking compared to those with low expectations ($p = .001$; $p = .04$). Differences in research experiences or participation in a student group were not significant (Table 6).

Finally, we looked at the average question-asking self-efficacy (QSE), and social and career outcome expectations (SOE and COE) related to question asking for people in each of the Total Experience Score (TES) activity groups (students taking part in 0, 1, 2 ,3 or all 4 extracurricular activities). Figure 2 shows that students who participated in more of the activity categories had higher QSE, SOE, and COE scores. Additionally, there is a positive, significant correlation between the students' TES and the QSE, SOE, and COE scores (QSE, $r = .183$, $p = .000$; for SOE, $r = .217$, $p = .000$; for COE, $r = .138$, $p = .000$).



Note: Error bars represent standard error. n = 868.

Figure 2: Question-asking self-efficacy and outcome expectations by total number of undergraduate experiences (internship, research, student group, leadership)

4.0 Discussion

The current study investigated the relationship between students' experiences and their self-efficacy and outcome expectations related to question asking. Perhaps surprisingly, demographic factors, such as gender and underrepresented minority status, did not relate to students' confidence or expectations around asking questions. Although some past studies found that men tend to speak up in college classes more than women do [16], the results of our study are consistent with other studies showing no difference in confidence asking questions by gender [17]. Many studies have not found self-efficacy differences by gender. For example, one study investigated the science, math, and engineering self-efficacy of 197 undergraduates, and did not find significant differences in self-efficacy by gender [18]. Another study also failed to find any differences in academic self-efficacy by gender among engineering students [19].

Our results also show that students with high question-asking self-efficacy were more likely to participate in the extracurricular experiences of internships, research, student groups, and leadership. Students with high social outcome expectations around asking-questions were also more likely to participate in all of these four activities. Students with high career outcome expectations around asking-questions were more likely to participate in an internship or hold a leadership position. These results are consistent with other studies that show positive results derived from undergraduate extracurricular experiences. Analyzing survey data from over 1,000 college graduates, previous research has found a positive relationship between securing employment post-graduation and participation in internships and student groups [20]. Another study found that more work experiences during undergraduate years correlated with an increased likelihood of getting a job offer before graduating [21]. Although these studies measure different outcomes, they are consistent with the idea that students derive benefits from these extracurricular experiences.

Interestingly, students with more extracurricular experiences had higher question-asking self-efficacy and outcome expectations around question asking. It is important to note that our current understanding is that this relationship is correlational; we do not know if it is causal (and if so, in what direction).

We note that that in other domains, level of involvement correlates with desired outcomes. For example, recent research on grit, which is "perseverance and passion for long term goals" [22] found that young people citing long-term involvement in more hobbies had higher scores in a grit self-assessment [22] and teachers who had engaged deeply with extracurricular activities in college performed better at work post-graduation [23]. In addition, the National Survey of Student Engagement (NSEE) studied "High Impact Practices," which are experiences that take considerable time and effort outside the classroom and involve meaningful interactions with faculty members and fellow students. The 2013 NSEE Report found that High Impact Practices were "moderately related to the three deep approaches to learning and perceived gains in general education and personal and social development" [24]. These studies suggest that there is some benefit that is derived from increased exposure to these activities.

Overall, the results of this study are consistent with Bandura's self-efficacy theory. We found that students who participated in a lot of activities had higher question-asking self-efficacy. Our

hypothesis is that this is due to students practicing asking questions in these activities (increasing performance accomplishment) and seeing others do so as well (gaining vicarious experience), leading to increased self-efficacy. Outcome expectations are also influenced by these activities. One possible example of this mechanism could be that students who have participated in extracurricular activities such as internships see other people learning from asking questions in a workplace setting and therefore have higher career outcome expectations around question-asking. However, again we note that we cannot infer causation from this study. It may be that people who feel more confident asking questions are more likely to choose to participate in the four extracurricular activities and internships – not that these activities build self-efficacy.

Further research calls for a longitudinal study to investigate how engineering students' question-asking self-efficacy and outcome expectations change over time, for example, how students' self-efficacy changes after a summer internship. We could also see experimental studies that probe the relationship between extracurricular experiences and question-asking self-efficacy. Researchers could, for example, investigate how working on a design problem in a group affects question-asking self-efficacy. Another area of investigation is related to the types of questions students ask, since past research has shown that different types of questions may lead to more (or less) creative solutions. [25]

The current study was limited to single-item measures for question-asking self-efficacy and outcome expectations (only three questions total) due to survey design constraints. Further research could involve developing a more robust question-asking self-efficacy instrument to parse out which elements of extracurricular experiences foster question-asking.

Nevertheless, the current study still represents a sample of nearly 1,000 engineering students from 26 out of the 27 engineering schools in the full EMS survey. Although this work is correlational, it suggests a relationship between participation in a wide range of activities and higher question asking self-efficacy. It also acts as a reminder that the college experience is more than just formal academic classes. Students learn from experiences that occur after class or during the summer, and ideally these experiences complement class-derived skills and confidence in asking questions.

Based on our literature review and results, we would like to conclude this article with three practical takeaways for engineering educators to take into consideration when planning their teaching and programs:

1. Asking questions is a valuable skill. Educators should encourage their students to ask questions in class, and possibly train students in how to ask questions. Students sometimes believe that asking questions makes them appear unintelligent, so they may need to re-learn that asking questions is a central part of learning.
2. Students may learn to ask questions outside of the classrooms. Institutions should encourage participation in extracurricular activities – internships, research, students groups, etc. – in order to give all students a robust learning experience.
3. Educators could try to infuse group work and open-ended problems into their classrooms to give students more opportunities to practice question-asking within the curriculum,

especially as students might differ in their opportunities to take part in extracurricular activities.

5.0 Acknowledgments

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