20 Years of Multidisciplinary Capstone Projects: Design Implementation, and Assessment

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Introduction

The Quality Enhancement Systems and Teams (QUEST) Honors Program at the University of Maryland unites undergraduate students with business, engineering, and science backgrounds in order to promote a multidisciplinary, hands-on, learning experience. QUEST's curriculum focuses on quality management, process improvement, and system design. This curriculum is delivered in the form of three required courses and two elective courses. The first program course introduces the concepts of innovation, design, and quality. Multidisciplinary teams work on a series of three projects, challenging them to design products and processes to improve the University of Maryland and the lives of their fellow students. The next required course involves a semester-long systems project where students work in teams to identify and solve problems about which they are passionately invested. Goals of past projects include improving access to healthy foods, providing more opportunities to individuals experiencing homelessness, and improving safety for pilots of light and midsize aircraft. In the final of the three required courses, a consulting project course, QUEST students collaborate on multidisciplinary teams to solve organizational challenges for corporate clients over the span of a semester.

Over the past 20 years, QUEST has linked these multidisciplinary student teams with corporate sponsors in order to provide an opportunity for students to translate the quality tools learned in the classroom to real-world solutions. Teams are guided throughout the semester by course instructors from the colleges of business and engineering, faculty advisors from business, engineering, and science departments, and representatives from sponsoring organizations (referred to as project champions). While the core of the program remains focused on quality management, process improvement, and system design through multidisciplinary teamwork, the program has undergone a number of changes that influence student learning and projects.

QUEST was created in conjunction with a 5-year grant from IBM to bring total quality principles to college campuses. Business and engineering students were recruited and approximately 25 students were admitted to the program after submitting an application and participating in an interview. After the grant expired, the University of Maryland committed to support a majority of program finances. Additional funding is contributed by the organizations sponsoring projects.

In addition to changes in program sponsorship, QUEST has expanded to include students from mathematics, computer science, and physical and natural sciences in addition to those studying business and engineering (aerospace, biomedical, civil, fire protection, materials, and mechanical disciplines). This has enabled more diversity in project topics and the incorporation of more diverse perspectives to the multidisciplinary project teams.

With the expansion of the program to include more academic disciplines, the pool of qualified candidates also grew. From a maximum cohort size of 75 students in the early 2000s, QUEST was recently restructured to admit two cohorts of 45 students per year. In addition to providing more students with the opportunity to take part in this unique learning experience, more faculty with the opportunity to engage with these talented and inquisitive students, and more companies

the chance to sponsor project teams, the program is able to more rapidly innovate and improve by doubling the number of times each course is offered.

Multidisciplinary programs and projects are gaining popularity at universities across the country as they have been found to promote professional and personal development[1, 2]. With twenty years of history, QUEST is able to draw on lessons learned from its own history of failure and success and contribute to a growing body of literature about this important topic. The goal of this paper is to describe the consulting project course, project trends, and its results as reported by students and alumni.

Evolution of Projects

In the spring of 1996, the first cohort of QUEST students worked with seven corporate clients on multidisciplinary projects. Ranging in topic from creating new product concepts for athletic apparel, to creating a cost-estimating tool for a manufacturing firm, to analyzing the feasibility of telecommuting, these projects provided excellent learning opportunities for students and real results for clients.

Ten years later, in the fall of 2006, cohort 12 of QUEST was busy undertaking projects related to inventory management, product design, and mergers and acquisitions. According to one of these students, "We helped an oil and gas company think about how to enable their convenience stores to better cater to 18-24 year olds. We had an immensely supportive project champion, who was very generous with his time to help us better understand the organization, and even invited us to participate in meetings at the company's headquarters where decisions regarding the convenience stores were made. With the right context and the right support from our project champion, we had a much better basis…to arrive at meaningful conclusions [2]."

To date, over 1,000 alumni have participated in the consulting project course. The availability of information related to these and other past projects provides QUEST with a unique opportunity to learn from previous semesters and evaluate trends in projects by industry and by topic area. Some of the lessons learned in terms of successful and unsuccessful topics, importance of client support, and trends in project topics are discussed below.

In evaluating past projects related to student learning and client outcomes, QUEST has been able to discern certain topics that work well and others that are not as successful. Projects that incorporate small wins throughout the semester typically have better outcomes as students are more engaged in the project from the start and build momentum as they progress toward the final project deliverables. An example of a project that works well in this regard is using data to identify relevant metrics and using these metrics to create a tool. A Fall 2014 project involved analyzing the elements of customer payment tendencies that ultimately impact cash-on-hand. This required distinct phases that helped keep the team engaged in the project.

Conversely, projects that require teams to conduct research among industry peers or competitors are typically not successful. QUEST students do not have the requisite research background or professional networks to enable them to uncover meaningful insight to influence their client. While these projects have been appealing to clients and interesting to students on the surface, they have not resulted in significant student learning or client results.

In recent years, most QUEST clients have returned to sponsor a series of projects. While this provides support to our claims of the excellent work our students produce, it also leads to better-developed projects that are an excellent fit for the skills and backgrounds of the students in our program. As clients learn more about our students, the cadence of projects, and our expectations for the semester, it is a better experience for everyone involved in the course.

Looking through twenty years of past project data, it is apparent that project topics have shifted in conjunction with national trends. For example, in the mid-1990s many projects involved making use of the internet and web-based research and communication to enhance quality and improve operations. Starting in the early 2000s and running through the current semester, QUEST has witnessed a number of projects that focused on environmental concerns or reducing environmental impact. In recent years there has also been a surge in demand for projects related to enhancing cyber security, mining data, and utilizing machine reading.

Defining Multidisciplinary Project Scopes

After 17 years of successful projects, QUEST began offering an elective course to involve students in the process of defining project scopes. In this course, students learn about best practices for written and verbal communication and practice having conversations about QUEST and sponsorship opportunities with program faculty and staff, each other, and alumni volunteers. Following this training, students are assigned to companies and manage the process of outreach and defining project scopes. They base ideas for project topics on past QUEST projects and case studies provided through journals and online articles.

Course deliverables include sample emails, scheduling and participating in site visits to clients, and writing and presenting precise and well-defined project scopes. To date, approximately 40 students have taken part in this course on defining consulting projects. Not only have students greatly enhanced their professional network and communication skills, but they have also increased the quality of projects that are handed off to student teams on day one of the practicum course. This, in turn, has led to greater learning among teams and enhanced results for project sponsors. A template of the project scope document is included in the appendix of this paper.

Course Design and Deliverables

The consulting project course is designed to incorporate a number of perspectives. In addition to the course faculty and teaching assistant, students learn from their clients, alumni, guest lecturers, and each other. Each month, teams are responsible for delivering a professional presentation where they receive feedback from alumni, corporate partners, instructors, faculty advisors, and other teams. Teams build upon past work in each phase of project completion. Between presentations, students interact with panels of alumni and clients to obtain guidance and feedback. The course also incorporates guest lectures following the flipped-classroom model where students watch videos and read materials then interact with this material and each other during class time[3.] This results in a truly multidisciplinary experience where students learn from a number of sources and backgrounds and also teach each other through work in teams. A course schedule, detailing this process, is included in the appendix of this paper.

The final course deliverables, a presentation and paper, are the focus of the course. All other deliverables help teams prepare for this final phase of the project. A series of presentations and

papers are due throughout the semester, which contribute to a team's final product. Additionally, teams are required to create a project poster to concisely convey their project results in an easy-to-read and visually appealing manner. These course deliverables, along with other course assignments and evaluations, are detailed in the appendix. As is indicated by this list, there are a number of team deliverables, which is appropriate given the team-based nature of the course. There are, however, a few individual assignments to ensure that all team members are fully engaged in the course and its content.

There are seven learning outcomes that are covered by this course. These learning outcomes relate to student's ability to apply quality management tools, improve processes, design systems, analyze data, work in multidisciplinary teams, provide solutions to clients, understand team roles and mitigate conflict, communicate effectively, manage projects, and use business etiquette skills. A complete list is provided in the appendix of this paper. It should be emphasized that these learning outcomes are strongly related to a number of ABET student learning outcomes, particularly outcome 3d, "an ability to function on multidisciplinary teams [4]".

An example of a past process improvement project involved creating a tool that enabled a large defense contractor to decide whether or not to bid on future work. An example of a past design project involved coming up with a method whereby massive ocean buoys could be safely and effectively deployed.

Project Results

Based on self-reported information, client and faculty advisor evaluations, and a number of direct assessments, it is clear that students learn a great deal from participating in this course. According to data collected from 49 students upon completing this course in Fall 2013, over 80% of students evaluate themselves as "Proficient" or "Advanced" on every course learning outcome, with nearly 100% of students evaluating themselves as "Proficient or Advanced" on most outcomes. These results are detailed in Figure 1 below.

The results of this survey were used to improve the curriculum in areas where students did not feel that they were proficient or advanced. For example, a greater emphasis has been placed on quantitative analysis in future iterations of this class. The survey questions that were asked of students to provide this data are included in Appendix 5. The program has recently made an effort to improve accountability by identifying and measuring student learning outcomes. Therefore, while similar data do not exist for past years, this information will continue to be collected and analyzed moving forward.
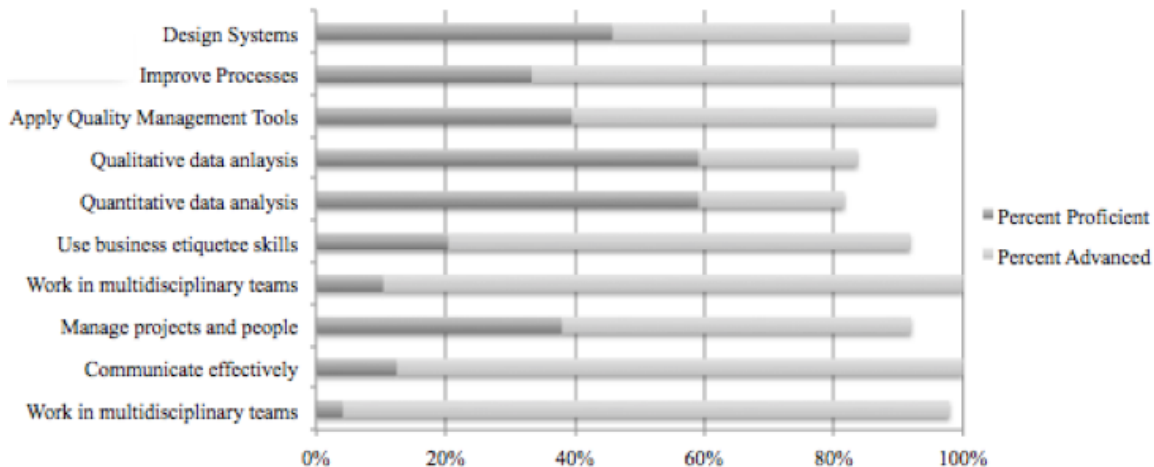
Figure 1: Student self-evaluations

Results from a previous study about QUEST outcomes indicate that alumni value the experiences gained from this course [5]. Alumni were surveyed about how QUEST has made an impact on their professional skills in full-time positions. Results showed that QUEST alumni perceive a high level of skill gained from this course and attribute these skills to professional success. Teamwork, professionalism, communication, and project management self-ratings indicate that QUEST alumni believe themselves to possess higher-than-average skills within these domains than their peers who did not participate in this multidisciplinary program. A table of results from this survey and survey questions are included in Appendix 6.

Recent feedback from clients immediately following projects indicates that all teams meet expectations for a team of senior honors students, 90% of teams exceed expectations, and over half of all teams provide work that is on par with what could be expected from a team of professional consultants. One client stated "The QUEST project is a rewarding experience for both the sponsor and the students. As a sponsor there is an opportunity to have an objective party review internal issues from a fresh, creative angle. For the students, it is an opportunity to work in a professional environment. Internships are valuable but typically very specific to a student's desired field. The QUEST project takes students out of their academic niches, introducing them to working on multidisciplinary teams with exposure to industries that might not be a logical fit for their major fields of study [6]." This exemplifies the multidisciplinary nature of QUEST projects and the value that they bring to all parties involved.

A logical question to follow such positive reviews would be related to the impact of projects months or years after their completion. This information is collected by the program and indicates similarly positive results. Over half of all projects completed in 2012 and 2013 have resulted in a lasting impact for the sponsoring organization. Six months after the completion of a recent project related to supply chain quality enhancement, a client indicated that staffing changes were made based on recommendations from the team and the tool developed by the team was in use across multiple departments. Another past client informed the program that, thanks to the work of the students, the firm was able to win a $250,000 contract to further develop the team's recommendations.

Additionally, both students and clients benefit from this project experience in placing QUEST students in full-time positions after graduation. Of the 73% of students in the QUEST graduating class of 2014 who went on to work full-time after graduation, 59% accepted positions with sponsoring organizations. This shows how, beyond enhancing performance in QUEST learning outcomes, this course provides students with career-building opportunities and provides clients with a talented pool of prospective full-time hires.

Suggestions and Practical Implications

Many elements of this course are not unique to the QUEST program and may be replicated in other courses and at other universities. By identifying and assessing learning outcomes, we are able to better understand what our students are learning and make improvements to the course. This has been critical in enabling comparisons to be made across projects and across years. Additionally, by involving a number of stakeholders in the instruction of the course, students are able to learn from a variety of perspectives, backgrounds, and experiences.

In order to ensure that students are exposed to diversity of perspective beyond course instructors, multidisciplinary teams of students complete all projects. This is perhaps the most important suggestion that we may provide; it gives students the opportunity for a learning experience that is not typical of most undergraduate courses. Students are able to teach each other, and in doing so, gain a deeper understanding of their own discipline. Additionally, students are able to learn from each other. This provides a unique opportunity for students to engage with those coming from different academic backgrounds and approaches and provides critical exposure to the type of work that is encountered in professional settings after graduation. According to a former student's recollections of his Fall 2006 project, "This was a great exercise in people from varied backgrounds coming together as a team. Once we had coalesced as a team, we were more creative and stronger than ever [3]."

While QUEST is unique in that it is structured precisely to enable such multidisciplinary collaboration, other programs or departments may consider collaborating with other disciplines on capstone, senior design, or other semester-long projects. While collaboration across engineering departments is good, it may yield even more benefit if business, science, psychology, architecture, or liberal arts majors are engaged in team projects. This integration of engineering with other disciplines would further enhance the experience of students and better prepare them for teamwork after graduation by enhancing learning and facilitating self-efficacy and innovation.

References

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3. Zohar, Ori. Letter to the author. 25 Jan 2015. TS.

4. Sams, Aaron, and Jonathan Bergmann. "Flip your classroom: Reach every student in every class every day." *International Society for Technology in Education (ISTE)* (2012).
5. ABET, Criteria for Accrediting Engineering Programs, Baltimore, Md.: Engineering Accreditation Commission, 11 Nov 2003. See http://www.abet.org/criteria_eac.html.
6. Ashton, M., Bailey, J., Goodell, K., & Weiland, K. (Peer Reviewed Paper). "The Value of a Multidisciplinary Engineering Education after Graduation." Industrial and Systems Engineering Research Conference. Orlando, FL. 21 May 2012.
7. Penna, Elizabeth. Letter to the author. 19 Dec 2014. TS.

Appendix 1: Project scope document

Project Name:

Sponsor Organization and Department:

Project Champion(s):

Executive Sponsor:

Scoping Contact:

Project Team:

●──●

Client Overview

    Client Summary: Background information (employees, revenue, offices, divisions, etc.)

    Relationship History: How did we connect? Have they worked with (program name) in the past?

Project Summary

    Project Overview: One or two lines → "Scope"

    Business Issue / Opportunity: More in depth discussion

Primary Project Objectives

- Objective 1

- Objective 2, etc.

Project Benefits

    Benefits to Client: List of benefits

Benefits to (program name) Team List of benefits

Primary Project Deliverables

- Gantt chart, process flow diagram, or other visual representation of proposed course of action
- Discussion of the nature and frequency of communication with the client
- Critical issues related to project

Project Conditions

Contributions from Client:

- A gift of $6,000 to the (program name)

- A project champion to provide the team with data, other contacts at the organization, and other items which may be necessary for project success (time commitment is approximately 1-2 hours per week)

- Participation in (program name) 490H Consulting Practicum course (participation on panels, judging presentations, etc.)

Received by Client:

- Thirteen weeks of interaction with a team of (program name) students

- 400-600 hours of consulting services from the student team

- Innovative recommendations to an identified organizational challenge

- Support from (university) faculty and staff included a dedicated process expert for the duration of the project.

Key Project Dates

Project Start: 01/28/2015

Action Plan: 02/18/2015

Status Update: 03/25/2015

Preliminary Results: 04/22/2015

Final Presentations: 05/07/2015

Requests and Notes:

Major Requirements: List requested majors

Other Requests: List any other requests

APPROVALS

Prepared By   _____
                         QUEST Scoping Contact

Approved By   _____
                         Project Champion

                         _____
                         Executive Sponsor

Appendix 2: Course schedule

Course Schedule

Class	Date	Class Discussions, Workshops, Panels, and Presentations	Location	Guests	Attire	Deliverables
1	1/27	**Session 1: Introduction** <u>Discussion</u>: Project Bids, Syllabus and Course Schedule Review, Project Scopes, Alumni Panel	VMH 1415	QUEST Alumni	Casual	Project Bid and Resume – Due January 27 at midnight
2	2/3	**Session 2: Meeting Client Expectations** <u>Panel</u>: Client Expectations <u>Exercise</u>: Identify expectations, hopes, and concerns for projects. <u>Meetings</u>: Teams and clients.	VMH 1415 and meeting rooms	Project Champions	Business Casual	Prepare for Client Meetings (availability, review Statement of Value, prepare questions)
3	*Friday 2/13*	**Session 3: Consulting Retreat**	Reagan Building	QUEST Alumni	Business Casual	Team Charter Meeting Minutes 1
4	2/17	**Session 4: SOW & Action Plan Presentations** 4:30pm Class photo 5:00pm <u>Present</u>: Statement of Work and Action Plan	VMH 1415	QUEST Alumni	Business Professional	Statement of Work and Action Plan (Report and Presentation) Meeting Minutes 2
5	2/24	**Session 5: Project Management and Risk Management**	VMH 1415		Casual	Meeting Minutes 3 Peer Evaluation 1
6	3/3	**Session 6: Quality Tools**	VMH 1415		Casual	Meeting Minutes 4
7	3/10	**Session 7: Data Analysis**	VMH 1415	David Ashley	Casual	Meeting Minutes 5
8	3/24	**Session 8: Status Update Presentations** <u>Present</u>: Status Update	VMH 1415	QUEST Alumni	Business Professional	Status Update Presentation and Report Meeting Minutes 6
9	3/31	**Session 9: Working in Multidisciplinary Teams**	VMH 1415	Dr. Linda Schmidt	Casual	Peer Evaluation 2 Meeting Minutes 7
10	4/7	**Session 10: Ethical Action**	VMH 1415	Corporate sponsor	Business Casual	Meeting Minutes 8
11	4/14	**Session 11: Preliminary Results Presentations** <u>Present</u>: Preliminary Results	VMH 1415	QUEST Alumni	Business Professional	Meeting Minutes 9
12	4/21	**Session 12: Team Time**	No class session			Meeting Minutes 10

13	4/28	**Session 13: Planning for Your Future**	VMH 1415	Dr. Joe Bailey	Casual	Final Project Poster. Portfolio Team Description, Abstract, and Recommendations
14	5/5	**Session 14: Dress Rehearsal** <u>Present</u>: Dress Rehearsal of Final Presentation Vote on "Project of the Year"	VMH 1415	QUEST Alumni, Faculty Advisors	Business Profession al	Draft Final Presentation
	5/6	**Session 15:(program name) Conference 4:00 to 8:00 p.m.**	**Riggs Alumni Center**	**Family & friends;(pr ogram name) students, corporate partners, alumni; University Friends of QUEST**	**Business Professio nal**	**Final Presentation**
	TBD	**Final Examination**	VMH 1415		Casual	Final Report

Appendix 3: Course deliverables

Individual Assignments (30% of Final Grade)

Project Management	2%
Quality Tools	2%
Data Analysis	2%
Multidisciplinary Teams	2%
Ethics	2%
Final Exam	10%
Peer Evaluations (2)	2% and 3%
Advisor Evaluations (2)	2% and 3%

Team Assignments (70% of Final Grade)

TEAM REPORTS (30%)

Statement of Work	5%
Status Update	5%
Preliminary Results	5%
Final Report	15%

TEAM PRESENTATIONS (20%)

Statement of Work	5%
Status Update	5%
Preliminary Results	5%
Final Presentation	5%

OTHER TEAM ASSESSMENTS (20%)

Team Charter	5%
Final Poster and Portfolio Page	5%
Meeting Minutes	5%
Client Evaluations (2)	2% and 3%

Appendix 4: Course learning outcomes

Learning Outcomes

Upon completion of this course, students will be able to:

- Apply quality management tools, improve processes, and design systems;
- Use quantitative and qualitative data analysis techniques;
- Work in multidisciplinary teams to evaluate, analyze and recommend solutions to real-world problems provided by corporate sponsors;
- Work in multi-disciplinary teams with an understanding of different roles and how to negotiate conflict in these situations;
- Communicate ideas effectively in business environments through written, visual and oral methods;
- Manage projects and people using effective project management tools;
- Use business etiquette skills to network and communicate in diverse professional settings and behave in a professional and ethical manner.

Appendix 5: Student Survey

(Program Name) has defined a set of learning outcomes that we would like our students to obtain during their time in the program. For each learning outcome below, please evaluate your knowledge of, or competence in, the given outcome, using a scale from 1 to 4 (as defined below). 4: Advanced (Strong knowledge of, or competence in, this outcome) 3: Proficient (Some knowledge of, or competence in, this outcome) 2: Developing (Minimal knowledge, of or competence in, this outcome) 1: Unacceptable (No knowledge of, or competence in, this outcome

Learning Outcome	1	2	3	4
Manage the new product development process and market a new product or technology working on a multidisciplinary team	○	○	○	○
Work in multi-disciplinary teams with an understanding of different roles and how to negotiate conflict in these situations	○	○	○	○
Communicate ideas effectively in business environments through written, visual and oral methods	○	○	○	○
Manage projects and people using effective project management tools	○	○	○	○
Work in multidisciplinary teams to evaluate, analyze and recommend solutions to real-world problems provided by corporate sponsors	○	○	○	○
Use business etiquette skills to network and communicate in diverse professional settings and behave in a professional and ethical manner	○	○	○	○
Use quantitative data analysis techniques	○	○	○	○
Use qualitative data analysis techniques	○	○	○	○
Apply quality management tools	○	○	○	○
Improve processes	○	○	○	○

Appendix 6: Alumni Survey Questions and Results

Section 1: In this section, you will be asked to rate your skills or abilities in four discrete domains. Please refer to the following scale to rate your responses: 1- Not at all skilled in this domain 2- Some skill in this domain 3- Adequately skilled in this domain 4- Highly skilled in this domain 5- Exceptionally skilled in this domain

1.1. Ability to work on multidisciplinary teams(This could include working in different disciplines, [1-5] working on teams with those of different professional backgrounds, translating technical needs to business needs, etc.)
1.2. Communication(This could include written communication, verbal communication, presentation [1-5] skills in both small and large groups, etc.)
1.3. Management of projects/people in a professional setting(This could include supervisory experience [1-5] or product management experience in the workplace)
1.4. Professionalism/Etiquette(This could include networking abilities, proper etiquette for professional [1-5] events, etc.)

Section 2: In this section, you will be asked to provide subjective information on your career success. Please refer to the following scale to rate your responses: 1- Very unsatisfied 2- Somewhat unsatisfied 3- Neutral 4- Satisfied 5- Very satisfied

2.1. Overall, how would you rate your current level of job satisfaction? [1-5]
2.2. Having been involved in the QUEST program, how satisfied do you feel about your potential for [1-5] career advancement as compared to those of similar backgrounds who were not involved in QUEST?

Section 3: In this section, you will be asked to evaluate how much you attribute the skills you learned in QUEST to your current level of success. Please refer to the following scale to rate your responses: 1- Not at all 2- Slightly 3- Moderately 4- Quite a bit 5- Significantly

3.1. How much do you attribute your ability to work in multidisciplinary teams to your current level of [1-5] success?
3.2. How much to you attribute your communication skills to your current level of success? [1-5]
3.3. How much to you attribute your ability to manage projects/people in professional settings to your [1-5] current level of success?
3.4. How much to you attribute your professionalism/etiquette to your current level of success? [1-5]

Section 4: Demographic information

4.1. To which QUEST cohort do you belong? Or year of graduation. [1-16]
4.2. What is your gender [male/female]
4.3. From which UMD college did you graduate? [business/engineering/science]
4.4. What is your current salary (including bonuses)? [<50k; 50k-75k; 75k-100k; 100k-125k; 125k-150k; >150k]

Section 5. (Optional) Please answer the following open-ended questions.

5.1. Please tell us how the skills you learned in QUEST have contributed to [open-ended] your job satisfaction or current level of success
5.2. Please tell us how you would define "job satisfaction." [open-ended]
5.3. Please tell us why you think your participation in QUEST has helped [open-ended] you secure greater opportunities for career advancement/promotion as compared to those who did not participate in QUEST.

Variable	Description	Mean	Min	Max	St. Dev.
S_COMM	Communication skills (1-5)	4.41	3	5	0.55
S_TEAM	Teamwork skills (1-5)	4.51	3	5	0.55
S_PROJECT	Project management skills (1-5)	4.00	3	5	0.74
S_PROF	Professionalism skills (1-5)	4.49	3	5	0.64
A_COMM	Communication skills attribution to success (1-5)	4.49	3	5	0.64
A_TEAM	Teamwork skills attribution to success (1-5)	4.32	2	5	0.76
A_PROJECT	Project management skills attribution to success (1-5)	4.17	1	5	0.89
A_PROF	Professionalism skills attribution to success (1-5)	4.32	2	5	0.88
YEARS	Number of years since graduating (1-16)	3.41	1	16	3.68
FEMALE	Binary; 1 if female and 0 if male	0.44	0	1	0.50
TECH	Binary; 1 if science or engineering grad and 0 if business	0.41	0	1	0.50
SALARY	Ordinal 0-5 increasing salary level	1.83	0	5	1.48
SATISFACTION	Job satisfaction (1-5)	3.85	1	5	0.91
ADVANCE	Opportunity for advancement (1-5)	4.44	3	5	0.67