

Industry Sponsored Capstone Projects: Factors Influencing Success

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Abstract

Experiential, or action-learning, projects are becoming increasingly popular in engineering programs. Often provided in conjunction with support from sponsoring organizations, these projects provide benefit to students and industry sponsors. With the recognition that experiential projects help students develop skills in creativity, problem solving, professionalism, and other important domains, there is a need to evaluate which projects provide students with the best learning opportunities and sponsoring organizations with the most meaningful results. In this study, ten criteria are used to evaluate experiential learning projects from a capstone undergraduate course. Regression analysis validates the utility of these criteria as collective predictors of project success and identifies the perception of the project's strategic value as an independently significant predictor. Principal components analysis identifies the critical role of a program, course, or university in facilitating the relationship between industry sponsors and students.

Keywords: Engineering education, experiential projects, action-learning, capstone course, multidisciplinary

1. 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, reality-centered, team learning experience revolving around quality management, process improvement, and system design. QUEST instills these educational outcomes by offering a foundation of three core courses concentrated on idealized design, innovation, and systems thinking along with two elective courses. This action-learning curriculum culminates in the form of a capstone course in which QUEST seniors collaborate on teams to solve real-time organizational challenges for corporate clients over the span of a semester.

Over the past 20 years, QUEST has linked student teams with corporate sponsors in order to provide an opportunity for students to translate the quality tools learned in the classroom into real-world solutions. Multidisciplinary honors programs are gaining popularity universities across the country as they have been found to promote professional and personal development [1, 2]. Additionally, capstone courses, especially those with industrially sponsored projects, have gained recognition as an important test of graduating students' ability to synthesize the curriculum while also fast-tracking their career development through fostering decision-making and other important skills [1-5].

Not only are corporate project sponsors able to benefit from implementing recommendations but QUEST typically retains sponsors for future projects that have a tendency increase in technical caliber, learning opportunity, and business impact with each successive project sponsorship[4]. This mutually beneficial cycle supports QUEST's recent decision to formalize the project scoping development process by involving QUEST students in addition to program leadership and corporate clients. In a program elective, students focus on scoping capstone projects and developing business relationships in order to maximize potential success among all stakeholders.

Directly linking student interests with corporate goals through the scoping course has coincided with an increase in the number of sponsors and projects involved with QUEST. This expanded network of corporate clients across various industries seeking involvement with QUEST has exposed an exciting challenge to overcome. The project scoping process has shifted from accepting and strategically editing a majority of project proposals from clients toward evaluating project proposals for acceptance due to the proposals outnumbering the number of student teams available, despite recent program growth. Project proposals are submitted in the form of a Statement of Project Value that establishes the client background, project champion, scope, business issue, perceived challenges, unique elements, objectives, expected benefits, and client requests.

In the spirit of continuous improvement, QUEST recognized a potential for opportunity in that a quantifiable method of evaluating project proposals would benefit future project teams, corporate sponsors, and the program as a whole. While “finding a successful project remains an art” rather than a science [6], decreasing the subjectivity with which decisions are made about which projects to pursue and which scopes need refinement benefits students and industry partners [6, 7]. A goal of this process is to objectively accept projects with the greatest likelihood of success over the course of a semester that also sufficiently challenge and engage student teams. We have found that the creation and application of a Project Evaluation Tool (PET) helps minimize the risk of delivering unrefined scopes to project teams through actively monitoring which areas of the scope need improvement during the project scoping process. Additionally, the use of a PET for project scope evaluation proves useful in identifying key factors that drive project success and weighting these factors to facilitate comparison of project scopes and results.

This study explores the effectiveness of the PET criteria (Appendix 1) in predicting QUEST’s successful projects, as perceived by corporate sponsors and program leadership (Appendix 2). Through regression analysis and principal components analysis, the statistical significance of ten preconceived factors (criteria) that may contribute to project success are determined based on the evaluation of 39 projects among six QUEST students. The criteria and their respective weights, determined by current students, program directors, previous project champions, and a review of related literature [4-8], include general fit with the program, learning opportunity, probability of success, client relationship, fit among the student cohort, fit among other projects, scope variability, strategic value, cool factor, and “Project of the Year” prospect.

2. Background

Determination of project success is highly dynamic and extends beyond achieving initial project goals. This is due to the variety of factors that contribute to the overarching project experience and the wide array of interests across student teams, corporate clients, and program leaders [4-7]. Through reviewing historical corporate sponsor feedback and past evaluations of final project results, the factors that most frequently shaped the perception of overall project performance are grouped into ten criteria within the PET.

Depending on the stakeholder, each criterion’s level of importance varies but still maintains a meaningful role in the collective judgment of any project. Figure 1 breaks down the relationships of criterion importance across the three primary stakeholders of capstone projects: clients, students, and programs (or courses). In order to compensate for the extent that each dimension plays a role in determining success among multiple stakeholders, a weighting system ensures that higher priority criteria drive the evaluation score, which can be observed in the PET template found in Appendix 1. These weights were determined by running PET criteria by past projects and evaluating the contribution that each criterion made to overall success. This exercise was conducted in conjunction with the three primary stakeholders and a review of related literature [4-8]. Using the PET, the ten criteria summarized in the subsections below are each scored on a scale of one to ten with one being the lowest and ten being the highest possible score. Each dimension’s highest possible weighted score sums to one hundred percent. Consequently, the PET tool evaluates projects using a scale from 1 to 100. These scores were used as independent variables in our analysis.

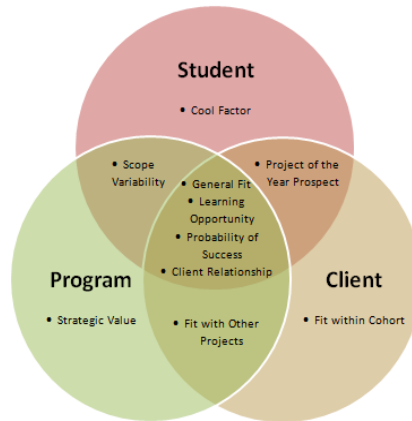


Figure 1: Background: Criterion Relationships

2.1.1 General Fit (GenFit)

General Fit takes into account how well the project scope embodies the QUEST curriculum. QUEST is rooted in quality management, process improvement, and system design. Through applying quality tools and systems thinking, the nature of these capstone projects should center on uniting various disciplines toward a common goal. This is an important criterion of capstone projects beyond the QUEST program [5]. A minimum score of one may represent a project completely based in a single discipline. A maximum score of ten represents a project requiring advanced business, engineering, and science expertise while also incorporating all three elements of quality management, process improvement, and systems design.

A project scope that successfully embodies the program's principles benefits students by offering an opportunity to test their understanding of learning outcomes identified by the program as integral to personal and professional development [9]. Additionally, QUEST benefits from projects that achieve general fit with the program through having the capacity to reflect on and assess learning outcomes based on student performance in applying the curriculum [9].

2.1.2 Learning Opportunity (Opportunity)

Learning Opportunity measures the student's exposure to unfamiliar concepts, situations, and/or technologies during the course of the project. The minimum score of one could be associated with projects that already map out a path for students to arrive at desired outcomes. A maximum score of ten could be awarded to a project scope that challenges students to not only forge their own path toward a clearly defined solution, but also conduct independent research to support certain methodological approaches. Clients, especially corporations rooted in highly specialized fields, can gain from offering a robust learning opportunity by increasing familiarity of their business activities among the program's students [10]. Students benefit from the (unfortunately) rare opportunity to creatively approach open-ended research for the purpose of solving a real business issue [6, 10].

2.1.3 Probability of Success (ProbSuc)

Probability of Success captures a student team's capacity to achieve project goals and fulfill expected deliverables based on student knowledge and the project period. A collection of clearly defined, interrelated, and quantifiable deliverables should complement the high standards of project goals [5, 6]. A minimum score of one could involve a scope that vaguely captures a single general goal which is expected to take two semesters to complete. A maximum score of ten would represent a scope that resolutely identifies a variety of key performance indicator (KPI) improvement goals in addition to offering access to relevant historical data or previous internal approaches to similar areas of opportunity.

The program has a strong interest in developing projects with a high probability of success in order to boost overall perception of the value in sponsoring a QUEST capstone project. Projects that achieve client goals reflect positively on the program, which attracts new corporate clients and sustains relationships with previous clients [4, 10]. Clients promote scopes with a high probability of success because they directly benefit and maintain ownership of the results of achieved deliverables [10].

2.1.4 Client Relationship (Client)

Client Relationship evaluates the project sponsor's projected involvement with QUEST. This evaluation is determined by past support and alignment of core company and/or project principles. The strength of the project champion and executive support are also key factors to be taken into account [5, 6]. Extended duration of existing partnership with the program, demonstrated interest in recruitment from the program, and presence on campus all favorably impact the strength of a client relationship [4].

Corporate partners benefit on an organizational and individual level when a strong connection with the program exists. Through understanding the core principles of QUEST and the traditional format of the capstone project, corporate partners have a higher likelihood of experiencing sustained benefits following implementation of recommendations [4]. As companies adopt continuous process improvement philosophies, the employees that champion projects gain a fresh perspective on business issues through student interaction as well as significant leadership experience on a results-driven project [9]. Moreover, 45% of graduating students of the program accept jobs with corporate partners. Successful projects linked to consistent and highly involved corporate partners positively impact student opinions of a company's cultural alignment with QUEST [9].

Students also gain from well-developed client relationships through acquiring an advantage in corporate recruiting after having the opportunity to demonstrate proficiency in creative problem-solving and professionalism during the course of the project [9]. The program succeeds due to these student and corporate benefits tied to strong client relationships because of the resulting revolving door effect [4]. Students who accept offers with corporate partners tend to bolster executive support for future project sponsorship, champion the projects as alumni of the program, and continue to recruit from the program.

2.1.5 Fit within Cohort (StudFit)

Fit within Cohort assesses the make-up of skills across the pool of students in the capstone course (or the "cohort") in relation to the requirements of the project scope. For instance, a highly technical project that calls for an experienced computer programming background would receive a minimum score of one if the cohort does not have any computer science majors. Conversely, if a project calls for experience in supply chain management and materials engineering and these are common majors among a group of students, the project may receive a score of ten for this criterion.

A project's fit within the cohort is a primary concern of corporate sponsors in order to ensure that goals can be reached based on the variety of skills present in the program. Projects requiring specialized technical skills or distinctive conceptual understanding must be evaluated against student capacity to grasp difficult concepts in order to ensure higher likelihood of success [5].

2.1.6 Fit with Other Projects (Unique)

Fit with Other Projects judges the unique aspects of a project scope that set it apart from other projects planned for the same period. Project scopes are also judged by their overall fit in QUEST's historic project portfolio. The highest scoring projects in this category fill voids in the program's portfolio by incorporating unique deliverables and calling for untraditional multidisciplinary collaborations. The program benefits from a diverse portfolio through documentation of students' consistent and collective proficiency in a wide range of industries. Unique projects that test students' adaptability are more favorably reviewed than projects that share elements with other current or previous projects [9].

2.1.7 Scope Variability (ScopeCreep)

Scope Variability considers a potential project's definitive goals and expected deliverables. A minimum score of one would suggest that a project has high potential for scope creep due to vague expectations. Scopes that are developed to generate small wins, or multiple deliverables at designated points throughout the semester, receive higher scores for having a tightly bound scope and low potential for scope creep.

While it is acceptable for projects to deviate in some ways from the initial scope, the most successful projects have consistent primary goals with secondary goals that are altered early in the project span if at all

[4, 5, 9]. On a student, program, and client level, reduced scope variability is beneficial for its direct impact on adhering to the project timeline and increasing likelihood of achieving project goals [4, 5].

2.1.8 Strategic Value (Value)

Strategic Value measures the value of working with a particular client or on a specific project. Factors such as current events and industry trends can boost a project's impact potential due to immediacy of these types of opportunities. Through targeting potential clients and projects that align with QUEST's core values, students and program leadership can gain key insight into the curriculum-related activities of corporations [9]. Also, corporations that are identified for their strategic value to the program can utilize this knowledge to gauge and leverage recruitment initiatives [10].

2.1.9 Cool Factor (Cool)

Cool Factor evaluates the extent that the company and/or project appeals to students. As project scopes continue to increase in level of challenge and organizational impact, it is important to prioritize project and company appeal to students in order to sustain strong motivation to achieve project goals [6]. Projects that successfully incorporate high appeal not only benefit students but also can positively shape the program's culture and reflect well on the client's dedication to involvement.

2.1.10 Project of the Year Prospect (POY)

Project of the Year Prospect takes into consideration the likelihood that a project's final results will be deemed successful by a panel of alumni from the program. While it is important to consider the open-ended nature of the path that teams can take toward arriving at a solution, this dimension is included to judge a project's relative standing among others if all goals and deliverables are achieved. In a competitive honors program, students are motivated to excel and tend to be results-driven [5]. The prospect of contributing to the winning project team can motivate students to go above and beyond initial deliverables in order to exceed expectations of the team and the program, which maximizes output for the client.

2.2 Evaluation of Project Success

In order to evaluate the ability of the PET criteria to predict project success, PET scores for project scopes must be compared with project outcomes. After the conclusion of the project period and once deliverables are finalized, QUEST evaluates project success by obtaining scores from two key stakeholders: project champions and faculty advisors. These evaluations are based on the 1-5 Likert scale that can be found in Appendix 2. Using this scale, the most successful projects are assigned a score of 5. These scores serve as the dependent variable in our analysis.

3. Methodology

Current QUEST students were trained on how to use the PET criteria. This training consisted of evaluating sample project scopes against the PET criteria and discussing scores. The PET tool was then utilized by 6 of these students to evaluate 39 project scopes with the 10 criteria previously discussed. These scores serve as the independent or predictor variables in our analyses. Industry sponsors and faculty advisors evaluated the outcomes of these same 39 projects. The previously defined scale of project success was used for this evaluation. These scores serve as the dependent or outcome variable in our analyses. Cronbach's alpha was calculated to evaluate the reliability of both independent and dependent variables. Independent variable scores demonstrate strong reliability with all values of Cronbach's alpha above 0.80. Cronbach's alpha for dependent scores was found to be acceptable with a value of 0.66.

3.1 Hypothesis Development

This study tests the following hypotheses: (1) PET criteria may collectively predict project success; (2) PET criteria may individually predict project success; (3) Composites of PET criteria may predict project success. The models in Figures 2-4 below represent these hypotheses.

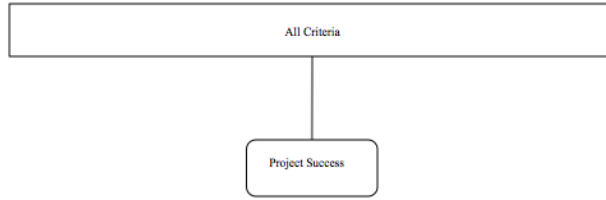


Figure 2: Collective Influence (Hypothesis 1)

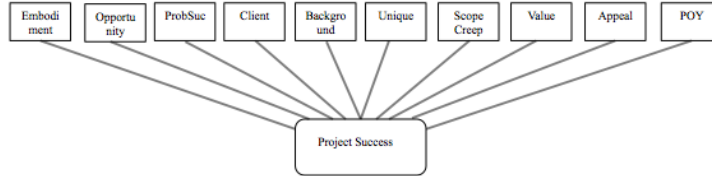


Figure 3: Individual Influence (Hypothesis 2)

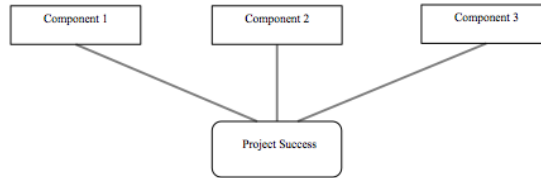


Figure 4: Composite Influence (Hypothesis 3)

3.2 Data Analysis

The statistical analysis program R was used to conduct a series of regression analyses and a principal components analysis of our data.

4. Results

4.1 Regression Analyses

A regression was run to determine the influence of all PET criteria on project success (testing hypothesis 1, Collective Influence). The overall bivariate regression was statistically significant ($R^2 = 0.273, F(1,37) = 13.87, p < 0.01$). Together, all 10 criteria accounted for 27.3% of the variance in project success.

A second regression was run to determine the influence of each criterion on project success, holding all other criteria constant (testing hypothesis 2, Individual Influence). The overall multiple regression was statistically significant. ($R^2 = 0.489, F(10,28) = 2.684, p = 0.019$). This means that, when modeled as individual predictors, the PET criteria account for 48.9% of the variance in project success. The only criterion to individually have a statistically significant effect on project success in this model was Value (the value of working with a particular client or on a specific project). The unstandardized regression coefficient for Value was 1.198 ($t(28) = 2.624, p = 0.014$), meaning that for each unit increase in Value, project success can be predicted to increase by approximately 1.2 units, holding all other criteria constant.

Based on the results of this model and using Gelman and Hill’s guidelines of eliminating predictors that are not statistically significant and do not have expected signs [11], we removed 5 of the 10 criteria from our model. The removed predictors, ProbSuc, Client, StudFit, Unique, and Cool, all correlated negatively with the outcome variable and were not significant. Our modified model for hypothesis 2 is provided below.

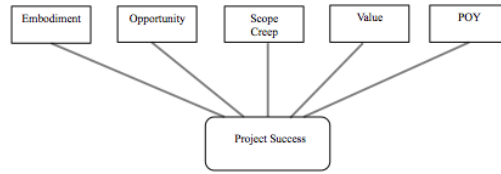


Figure 5: Modified Individual Influence (modified hypothesis 2)

In this model, the overall multiple regression was statistically significant ($R^2 = 0.458, F(5,33) = 5.575, p < 0.01$). The 5 remaining criteria (GenFit, Opportunity, ScopeCreep, Value, and POY) accounted for 45.8% of the variance in project success. Again, the only criterion with a statistically significant effect on project success was Value. The unstandardized regression coefficient (β) was 1.098 ($t(33) = 2.823, p < 0.01$), indicating that for each unit increase in Value, project success can be predicted to increase by approximately 1.1 units, holding all other criteria constant. Re-running this model but allowing for the criteria to interact indicated that there were no significant interactions, therefore interactions were not included in this model.

Regression diagnostics were then evaluated for this model. There were no projects with problematic leverage, discrepancy, or influence. Assumptions for linearity, normality, homoscedasticity, and independence were met. The assumption of independent predictors was, however, not met. This is not a problem if we are simply concerned with predicting project success based on all of our criteria. If we are interested, however, in understanding how each of the various criteria impact project success, this multicollinearity of variables is problematic. Variance Inflation Factors (VIFs) illustrate the problems that multicollinearity brings to our model. This result was somewhat expected as many of our criteria were based on similar concepts. In order to account for correlation among predictor variables, we ran principal components analysis to identify the number and composition of the most salient components of our criteria.

4.2 Principal Components Analysis

R was again used for our principal components analysis. All 10 criteria were evaluated in this analysis. Based on the scree plot for this model, it was determined that 3 components should be extracted. Each of these components had eigenvalues greater than 1. Running a varimax rotation, and evaluating component composition, it was determined that each component represented one of the three relationships displayed in Figure 1: Component 1 – Program-Student (GenFit, Opportunity, Unique, Value, Cool, POY); Component 2 – Client-Student (Probability, StudFit); Component 3 – Client-Program (Client, ScopeCreep, Value). Figure 6 outlines these relationships. Factor loadings and communalities for each of these three components are provided in Table 1.

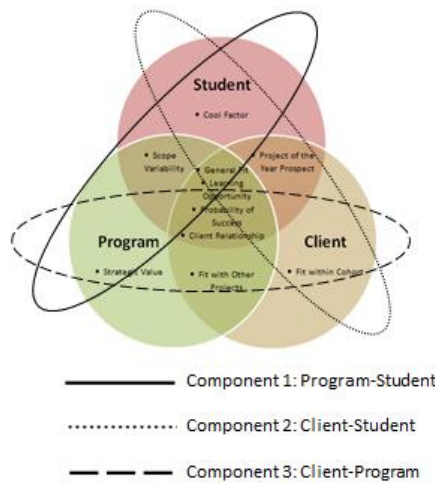


Figure 6: Composition of Principal Components

Table 1: Loadings and communalities from varimax rotation

	PC1	PC2	PC3	h^2
GenFit	0.84	0.28	0.22	0.84
Opportunity	0.84	0.07	0.20	0.75
ProbSuc	-0.15	0.79	0.18	0.69
Client	0.02	-0.03	0.90	0.82
StudFit	0.30	0.78	0.12	0.71
Unique	0.75	-0.15	0.07	0.58
ScopeCreep	0.23	0.22	0.80	0.74
Value	0.55	-0.29	0.54	0.67
Cool	0.89	-0.11	-0.10	0.81
POY	0.89	0.14	0.23	0.86

Scores were weighted based on these loadings and a regression was run to evaluate the effect of these three components on project success (hypothesis 3, Composite Influence). In this model, the second component (Client-Student) was not statistically significant ($p = 0.743$) and the direction of the unstandardized regression coefficient was unexpected. This interesting finding will be discussed later in the Discussion section of this paper. Based on Gelman and Hill’s general principles [11], this component was removed and the regression was re-run (hypothesis 3 was updated to include 2 principal components).

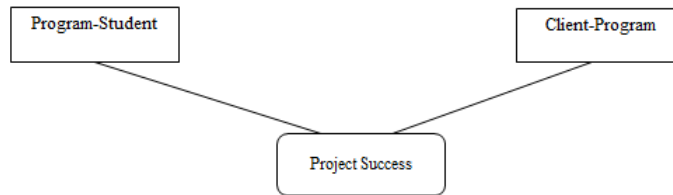


Figure 7: Modified Composite Influence (modified hypothesis 3)

In this model, the overall multiple regression was statistically significant ($R^2 = 0.333, F(2,36) = 8.99, p < 0.01$). Program-Student was statistically significant at a level of $\alpha=0.05(p = 0.006)$ and Client-Program was significant at level of $\alpha = 0.1 (p = 0.051)$. The unstandardized regression coefficient (β) for Program-Student was 0.115 ($t(36) = 2.899, p < 0.01$), indicating that for each unit increase in this component, project success increases by approximately 0.115 units, holding all other criteria constant. The unstandardized regression coefficient (β) for Client-Program was 0.138 ($t(36) = 2.016, p = 0.051$), indicating that for each unit increase in this component, project success increases by approximately 0.138 units, holding all other criteria constant.

4.3 Model Comparison

Akaike information criterion (AIC) is a measure of the relative quality of fit of statistical models for a given data set. Lower values indicate better model fit. Based on the below values comparing a null model to the Collective Influence model, the Modified Individual Influence model, and the Modified Composite Influence model, it is clear that each the hypothesized models does a better job than a null model for the prediction of project success. Accounting for the trade-off between goodness of fit and model complexity, the Modified Individual Influence model provides the best-fitting model to predict project success.

Table 2: AIC values

Null	106.253
Collective Influence <i>(Predict project success using composite of all criteria)</i>	95.834
Modified Individual Influence <i>(Predict project success using GenFit, Opportunity, ScopeCreep, Value, and POY)</i>	92.373
Modified Composite Influence <i>(Predict project success using Program-Student and Client-Program relationships)</i>	94.453

5. Analysis and Conclusions

Based on the results of our data analysis, we have confirmed all three of our hypothesis. PET criteria do collectively predict project success. The criterion Strategic Value individually predicts project success, though no other criterion is individually significant. And composites of PET criteria (Program-Student and Client-Program relationships) both collectively and individually predict project success.

5.1 Discussion

The results of these analyses provide QUEST with a vast amount of information regarding the impact of the PET criteria on project success. Perhaps most importantly, the critical role of the program in facilitating client-student interactions was identified and quantified. Additionally, overall significance of the criteria in predicting project success indicates that these criteria provide a means to predict project success from comprehensive project scopes. While not all criteria were individually significant, and some took on surprising values, it should be noted that these outcomes could be due to correlation among criteria rather than a truly negative or insignificant relationship with project success. For example, the correlation between GenFit and both Opportunity and POY is greater than 0.80. This likely skewed the individual impact of these criteria. In other instances, correlation between some criteria is large and negative. Probability of Success received low scores where the project scored well above average on GenFit and Opportunity criteria. Our assumption had been that students naturally viewed projects as more challenging when they clearly required greatest collaboration of educational backgrounds outside of their own major. Meanwhile the magnitude and range of project goals or deliverables that ultimately determine success could receive less consideration while evaluating scopes.

The components that were significant in model 5, Program-Student and Client-Program relationships, indicate that unique projects that embody the principles of the program and require diverse student skills while also providing client support and value, are most successful. Perhaps more interesting, however, is that component 2, Client-Student relationship did not have a statistically significant relationship with project success. This point emphasizes the critical role that the program plays in realizing the full potential of the mutually beneficial Client-Student relationship. This is a takeaway not only for QUEST, but for all capstone project courses that serve as a mediator between students seeking action-learning experience and clients striving toward continuous improvement. Future research should investigate this finding to determine whether this relationship holds in other contexts.

The single criterion that was significant in both models 1 and 4, Strategic Value, indicates that the quality of being perceived as valuable to the program has the greatest influence on whether or not a project is successful. This could be indicative of “important” projects receiving more resources from program faculty and staff. It could warrant an evaluation of the way that resources are divided amongst projects over the course of the semester and increase considerations of long-term corporate partnership opportunities.

One limitation of this study is that it relies on subjective evaluations of both criteria and project success Measures were taken to ensure granularity of scale and trainings were conducted to ensure appropriate use of the PET, however, it is impossible to entirely remove subjectivity from evaluation process.

5.2 Conclusions

QUEST has already begun to notice the effects of utilizing the PET in evaluating project scopes. When evaluating project ideas internally and with prospective clients, it is helpful to have a set of criteria upon which to base decisions about which projects to pursue. As was discussed previously, the overall effect of the PET criteria on project success indicates that, collectively, these criteria are able to predict whether or not a project will be successful. An illustration of project success based on total PET score is provided below.

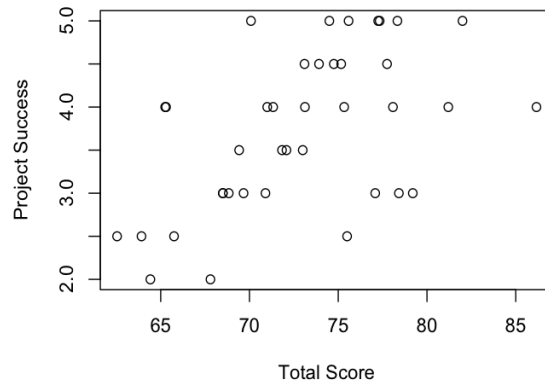


Figure 8: Effect of total score on project success

The overall trend of the above graphic indicates a weak positive relationship between total score and perceived success. One can imagine program leaders or course faculty setting cut points at various scores in the above figure based on the level of certainty with which they would like to predict project success. Similar graphics may be produced for both other models outlined in this study; however, it is largely an internal decision about how comfortable program leaders or course instructors are moving forward with a project. So while this tool could be used in an absolute sense of proceeding with or rejecting projects, this tool is likely more helpful in evaluating projects that may need to be further refined by targeting low-scoring criteria in order to increase their likelihood for success.

It should be noted that the overall R^2 is not overwhelmingly high in any of the models considered. The inclusion of additional variables, including existing data or a defined current state, may improve the overall model fit. Future analyses should consider whether these additional variables are able to account for more variance in project success while still maintaining model parsimony. Additionally, future studies could further evaluate the role that interaction among variables or components may play and could consider incorporating mediating or moderating variables.

Perhaps the most important takeaways from this study are the significance of Strategic Value in predicting project success and the importance of QUEST in facilitating the relationship between clients and students. Strategic Value should be emphasized when deciding on which projects to pursue as this criterion was consistently highlighted as a deciding factor in overall project success. This will be done immediately by QUEST and should also be considered by capstone course leadership in other programs or institutions.

Students, industry sponsors, and universities are offering more and more opportunities for students to work on industrially sponsored projects for credit [1-5]. While some may question the need for a university to be involved in this relationship, arguing instead for co-ops or internships, this paper quantifies the importance of a course or program as a mediator of this relationship.

Acknowledgements

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References

1. Holley, K.A., 2009, "Best Practices Related to Interdisciplinary Education," ASHE Higher Education Report, 35(2), 89-99.
2. Hotaling, N., Hermann, C. D., Fasse, B. B., Bost, L. F., and Foresta, C. R., 2012, "A Quantitative Analysis of the Effects of a Multidisciplinary Engineering Capstone Design Course," Journal of Engineering Education, 101(4), 630-656.
3. Herremans, I.M., and Murch, R., 2003, "Multidisciplinary Decision Making Through Experiential Learning: Perspectives from Practical Trials," Innovative Higher Education, 28(1), 63-83.

4. Kauffmann, P., and Dixon, G., 201, "Vetting Industry Based Capstone Projects Considering Outcome Assessment Goals," *International Journal of Engineering Education*, 27(6), 1231-1237.
5. Farr, J. V., Lee, M. A., Metro, R. A., and Sutton, J. P., 2001, "Using a Systematic Engineering Design Process to Conduct Undergraduate Engineering Management Capstone Projects," *Journal of Engineering Education*, 90(2), 193-197.
6. Brackin, P., Knudson, D., Nassersharif, B., and O'bannon, D., 2011, "Pedagogical Implications of Project Selection in Capstone Design Courses," *International Journal of Engineering Education*, 27(6), 1164-1173
7. Cheville, A., 2010, "Designing Successful Design Projects", *Proceedings of the 2010 ASEE Annual Conference and Exposition*, Louisville, Kentucky, 2010.
8. Gnanapragasam, N., 2008, "Industrially Sponsored Senior Capstone Experience: Program Implementation and Assessment," *Journal of Professional Issues in Engineering Education and Practice*, 134(3), 257-262.
9. Lamancusa, J.S., Zayas, J.L., Soyster, A.L., Morell, L., and Jorgensen, J., 2008, "The Learning Factory: Industry-Partnered Active Learning," *Journal of Engineering Education*, 97(1), 5-11.
10. Lynch, D.R., and Russell, J.S., 2009, "Experiential Learning in Engineering Practice," *Journal of Professional Issues in Engineering Education and Practice*, 135(1), 31-39.
11. Gelman, A. and Hill, J., 2007, *Data Analysis Using Regression and Multilevel/Hierarchical Models*, Cambridge University Press, New York.

Appendices

Appendix 1, Project Evaluation Tool (PET) Template

Project Sponsor: _____ Area of Opportunity: _____ Project Topic: _____					
Dimension	Description	Rating (1: Low, 10: High)	Comments	Weight	Score
General Fit	GenFit of QUEST principles			20%	
Learning Opportunity	Opportunity for students to learn from project			15%	
Probability of Success	Probability of successful project given student knowledge and time frame			20%	
Client Relationship	Projected satisfaction with QUEST; strong project champion & executive support			15%	
Fit within Cohort	Cohort possesses background / skills required of project (e.g. computer science)			5%	
Fit with Other Projects	Unique aspects set this project apart from others (if already decided upon)			5%	
Scope Variability	Potential for scope creep			5%	
Strategic Value	Value of working with particular client or on specific project			5%	
Cool Factor	Company and project appealing to students			5%	
Project of the Year Prospect	Likely to be deemed successful by peers in cohort			5%	
Raw Score				Total	

Appendix 2, Project Success Evaluation Scale

Score	Description
5	The team provided to the client well-documented, justifiable, and meaningful results. Their work was polished, thorough, and on par with what could be expected from a team of 5 consulting professionals.
4	The team provided the client with results that were generally well-documented, justifiable, and meaningful. Their work was polished, thorough, and mostly comparable to what could be from a team of 5 consulting professionals.
3	The team provided the client with results that may be somewhat meaningful. Their work was mostly acceptable, though lacked some important information or clarity. The team did not meet professional standards, but met expectations for a team of senior honors students.
2	The team provided to the client results that may have some merit but are mostly meaningless. Their recommendations were understandable, but unlikely to be used based on a lack of clarity or detail. The team fell somewhat below expectations for a team of senior honors students.
1	The team did not provide any meaningful results to their client. Their recommendations were completely unintelligible and/or useless. The team did not come close to meeting expectations.