AC 2009-62: EXPLORING THE IMPACT OF FIRST-YEAR ENGINEERING STUDENT PERCEPTIONS ON STUDENT EFFICACY

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Exploring the Impact of First-Year Engineering Student Perceptions on Student Efficacy

Abstract

Students in higher education enter the system with varying expectations. By examining their expectations, and subsequent perceptions, it is possible to prepare them for a rewarding and successful college classroom experience. This paper examines the use of a service quality model to predict and enhance student efficacy and performance. Results indicate that the difference between students' expectations and perceptions (gap score) was significantly related to their academic, team, and career efficacy. Additionally, the change in efficacy over the semester was significantly related to student satisfaction. This paper examines the causes for these results in detail, and discusses the implications of the results on course design and first year students.

Introduction

The importance of student motivation, mechanisms for teaching and learning, and self-efficacy has been widely studied in higher education.[1-6] The degree to which students believe they can succeed, with an accompanying commitment to achieving that success in their chosen field of study, however defined, is influenced by a variety of factors. Personal values and goals, early academic preparation, gender/race/socio-economic[7] factors and even group dynamics within a given student cohort can affect a student's determination and persistence in his/her major. This is clearly seen among students pursuing degrees in engineering where rates of retention are alarmingly low and continuing to decline.

Mindful of these issues, the Swalm School of Chemical Engineering at Mississippi State University, in the fall 2006 semester, began modifying ChE 2213 Chemical Engineering Analysis (hereafter referred to as "Analysis"). Originally offered to mid-/upper-level chemical engineering students subsequent to the traditional Mass and Energy Balances course, the course was re-examined as a vehicle for engaging students in a variety of topics and activities in addition to the original scope of the course—namely numerical and statistical techniques using Microsoft Excel and Visual Basic. Topics including team-building, engineering problem solving, and project design and development have been added. An interesting feature of the course was the addition of LEGO NXT robotics systems with a growing cache of chemical engineering applications. Such an addition has energized student enthusiasm and a sense of inquiry/discover heretofore absent (to put it mildly!) from the course.

Logistically, the course was moved from a mid-level course to the spring semester for the freshmen year; thereby, bridging a gap between the fall-semester orientation course and the sophomore fall semester Mass and Energy Balances course. This move allows us to maintain contact with students in an otherwise "ChE-free" semester and, equally important, to build a foundation for the all-important Mass and Energy Balances course.

Goals of the course include building students' sense of control over their academic pursuits—giving forethought and self-regulation to the academic enterprise (i.e. Bandura's "agency")[8] and

perception of increased self- and team-efficacy. Such qualities are foundational to sustained motivation necessary for successful completion of an engineering degree.

To assess these qualities, the authors are conducting an ongoing study using a Service Quality model. Quality in service settings is highly dependent on a customer's perception. Higher education is no exception. Students serve as customers to the university and their perceptions regarding the university's service performance are critical to the success of the university. By examining education quality using a service quality model, we are able to compare students' perceptions to what they expect when they enter the service system. Assessing this gap will allow for a true understanding of university performance, rather than assessing only performance metrics. The service quality gap may also be a significant factor in determining a student's efficacy, which has already been linked to student success.

Literature Review

To put this study into context, the underlying theoretical frameworks which have informed and shaped the course evolution to date are first presented with the definition of some necessary terms. This is followed by background information on the Service Quality model used for this study.

Agency

Human agency[8] comprises the centrality of the academic endeavor. Cognitive ability, the ability to comprehend, assimilate and process ideas with a resultant reasoning and problem-solving capability, describes the processes traditionally assessed in academe. However, this must be accompanied by a meta-cognitive ability to reflect, assess and regulate one's engagement in learning. For a learner human agency constitutes a foundation upon which new knowledge is assembled and integrated into a framework for choosing and adequately performing vocational pursuits. Our students bring these traits to bear upon their decisions when choosing a vocation and the requisite educational training/certification necessary to enter this vocation.

Unquestionably, causal factors (e.g. prior knowledge, socio-economic factors, psychological "tenor") influence "agency"—thus our current study of these factors. The centrality of one's beliefs about individual capabilities to control events affecting his/her life has been addressed[9] and is crucial to motivation and persistence in the academic arena. Such belief is captured by the concept of self efficacy.

Self Efficacy

First described by Albert Bandura[10], self-efficacy is defined as one's belief about his/her ability to achieve success, either generally or with regard to specific tasks. Considerable study has been reported relating self-efficacy with a variety of factors influencing students' persistence and achievement including self-efficacy beliefs of women in STEM (i.e. Science, Technology Engineering and Mathematics) careers[11]; interests, expectations and choices of engineering students[12-13]; and, the role of self-efficacy in team performance[14]. Recognizing the importance self efficacy plays in student learning and performance, the Analysis course has been designed

(and continues to be re-designed) to foster improvements in students' abilities to adapt to new technologies (e.g. LEGO robotics adapted to chemical engineering applications) and experience personal growth (i.e. improvements in self-efficacy) with regard to their capabilities to pursue their chosen major.

Team Efficacy

One of the outcomes chosen for evaluation in our study is "team success" or team efficacy. Following on Bandura's self-efficacy work, and building on his recognition of the effects of team or group efficacy on individual's perceptions[15], research has shown the importance of the interplay between group- and self-efficacy in group and individual success[16-19]. The link between self- and group-efficacy is not necessarily direct, however, in that individual characteristics or factors such as cognitive ability, preparation or motivation may not correlate directly with group performance[16]. For example, consider the analogy of sports or academic teams where the "underdog" (i.e. that group comprising individuals evaluated as having subordinate performance characteristics) surprises everyone with an "upset" victory. Longevity of the team further affects performance. As in the case of students assembled in teams for a single project or semester, factors such as motivation and preparation may play a less significant role for such teams than for teams linked for a longer period with a broad array of goals to accomplish (e.g. vocational-related teams)[19].

Service Quality

It may appear intuitive, but to the staid and sometimes glacial forces at work among institutions of higher education, service quality can appear as a recently discovered phenomenon[20]. What McDonald's recognized in the 1940s, we now hail as the new way to conduct our "business" of educating. Namely, that services must be aimed at meeting customer needs in order to be successful. This is distinctly different from simply customer satisfaction, in that quality measurement superimposes more than one specific service interaction. That is, service quality is a customer's regard towards a service system as a whole, even if they have never used the system[21].

The composition of a customer's service quality measurement is made up of many factors. The most common factors reported in literature include reliability, tangibles, responsiveness, assurance, and empathy[22]. The measurement of service quality is often done by relating these dimensions to outcome dimensions, such as perceived service quality, satisfaction, and behavioral intention[23-25]. However, the key to assessing service quality lies in the measurement of a gap score. The gap score is the difference between what a customer expects from a service system and what he or she actually perceives[21]. When a negative quality gap exists, the system is not meeting the expectations of the customer. When a positive gap exists, the system is exceeding the customer's expectations. A weighted gap score can also be calculated by asking subjects' the relative importance of each service quality dimension. The weighted gap is then calculated as a weighted average value, with more important dimensions being weighted heavier, rather than a simple average. A graphical depiction of the application of service quality to higher education is shown in Figure 1. The desired values of service quality dimensions are used to establish student expectations. T he actual realized dimension values form their perceptions. The

comparison of expectations to perceptions results in the student's gap score, which is a single metric of service quality in an organization.

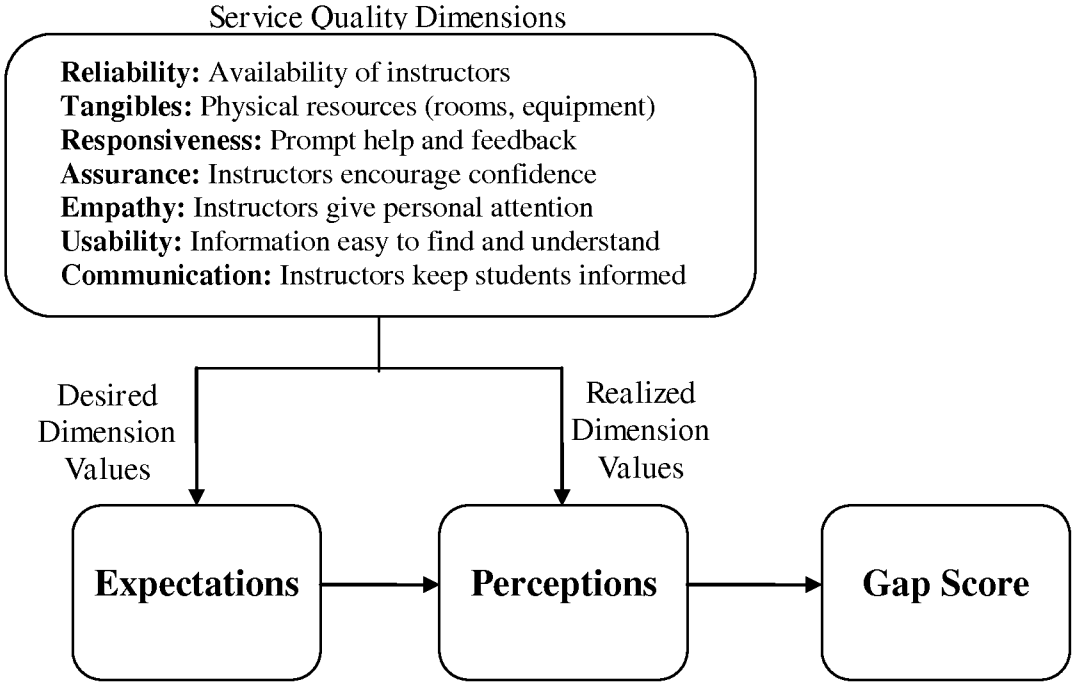

Figure 1. Service Quality Gap Model for Students in Higher Education

Of course, students may enter the higher education system with an unrealistic set of expectations, particularly with regard to studying engineering. For example, a number of students enthusiastically embark on a whirlwind trip to the "bazaar" of campus activities (i.e. catching all the opening social events of the academic year, joining any number of good organizations, and developing a wide-ranging social network) only to discover that, after several weeks of frenetic activity they are woefully behind in their studies (hopefully the primary reason they came to the university campus!) By deploying a service quality model to assessing student satisfaction in a foundational engineering class, we hope to discover factors that significantly contribute to either students' satisfaction or dissatisfaction with their perceived capability to continue on in their chosen field of study.

Research Objectives

The purpose of this project is to identify factors that improve student efficacy using a service quality paradigm. The study examines whether realistic expectations, perceptions of the course, preparation, and team experiences impact a student's efficacy. Specific hypotheses for the project are as follows:

- Students whose perceptions closely match or exceed their expectations will have higher efficacy.
- Students who are better prepared will have higher efficacy.
- Students who have high efficacy will also be highly satisfied.
- Students who have high efficacy will have high success.

Methodology

Data Collection Protocol

Data collection for the project was conducted at four points throughout the semester. Four surveys were given throughout data collection, as shown in Table 1. The surveys included a demographics survey, efficacy questionnaire, and three service quality questionnaires. Each of the surveys is explained in more detail below.

Table 1. Data Collection Schedule

Data Session	Approximate Date	Material Distributed
1	Week 1	Consent Forms Demographic Survey
2	Week 3	Efficacy Questionnaire Service Quality 1 Questionnaire – Expectations Service Quality 2 Questionnaire – Factor Weights Service Quality 3 Questionnaire – Perceptions & Outcomes
3	Week 8	Efficacy Questionnaire Service Quality 3 Questionnaire – Perceptions & Outcomes
4	Week 15	Efficacy Questionnaire Service Quality 3 Questionnaire – Perceptions & Outcomes

Surveys

The efficacy survey consisted of 10 questions, which were divided into three subsections: academic, team, and career efficacy. The questions are shown in Table 2. Each question was followed by a 7-point Likert scale for the students to rate their agreement with each statement. Academic efficacy questions related to a student's confidence regarding learning, solving course problems, and completing coursework. Team efficacy questions related to a student's confidence in their team achieving set goals. Career efficacy focused on a student's confidence in mastering necessary skills in their chosen field of study. The Likert responses were averaged for each sub-category. The average score for all ten questions was referred to as overall efficacy in this study.

The service quality surveys attempted to quantify the expectations, importance, and perception of the various service quality dimensions as they related to the course. Dimensions addressed in the survey were tangibility, reliability, responsiveness, assurance, empathy, usability, and communication. The survey was a modified form of SERVUSE[26,27], a previously validated measurement tool. Subjects responded to each question on the survey using a 7-point Likert scale.

The first part of SERVUSE contains 20 questions regarding subjects' expectations for the service system, or the ChE 2213 analysis course for this project. As an example, one expectation questions states "In excellent courses, instructors listen carefully to their students." The second part of SERVUSE asks subjects to rate the importance of each of the seven factors using seven questions. The third part of SERVUSE is a duplication of part one, with the expectation that it addresses subjects' perceptions for that specific course. For example, one perception question states "In ChE 2213, instructors listen carefully to their students." Finally, the fourth section of

SERVUSE presents four questions, each addressing a dependent variable: perceived quality, satisfaction, and behavioral intent (recommending the course to friends, and taking similar courses).

Table 2. Efficacy Survey Questions

Academic Self-Efficacy
1. I'm certain I can master the skills taught in class this semester.
2. I'm certain I can figure out how to do the most difficult class work.
3. I can do almost all the work in class if I don't give up.
4. Even if the work is hard, I can learn it.
5. I can do even the hardest work in this class if I try.
Team Efficacy
6. Achieving my team's goals is well within our reach.
7. My team can achieve its task without requiring us to put in unreasonable time or effort.
8. With focus and effort, my team can do anything we set out to accomplish.
Career Efficacy
9. I'm certain I can be successful in my undergraduate program (e.g. chemical engineering).
10. I'm confident that can master the skills needed for my chosen field (e.g. chemical engineering).

Subjects

The study was performed during spring 2008 semester at Mississippi State University. Among the students in the class, 33 of them provided enough information during the study and thus their information were considered for analysis. Approximately 76% of the respondents were male. Among respondents, 82% were freshmen while the rest were sophomores. Most of the students (82%) classified their ethnic background as Caucasian, 15% as African-American and 3% as Asian. Regarding distance from home, 9% of the students were less than 50 miles away while at university, 51% of them were between 51-150 miles away, 30% between 151-250 miles away, and 24% were more than 250 miles away. The subjects had an average ACT score of 28.9, an average high school GPA of 3.70, and an average college GPA of 3.39.

Results

Descriptive analysis of the survey data was the first step of the analysis. The mean and standard variation values for the subdivisions of the survey as well as gap scores are shown in Table 3. Total mean value for academic efficacy is 5.99, team efficacy is 6.18, and career efficacy is 5.62. The overall mean efficacy of the survey after 3 stages is 5.98 with a standard deviation of 0.93. The overall mean value of expectation of the students which was gathered in the beginning of the semester is 6.10. The mean value for perception of the students decreased over time from 6.06 in stage two, to 5.94 in stage three, and 5.85 in stage three of the analysis. The weighted gap scores were positive only at the beginning of the semester. Overall, the weighted gap score considering all time periods was -0.12. The overall mean value for perceived quality of the survey was 5.92, while the overall mean value of satisfaction was 5.78. The overall mean value for behavioral intention 1 (recommendation to other students) of the survey was 5.86 and behavioral intention 2 (taking similar courses) had the overall mean value of 5.82.

Table 3. Descriptive Statistics

Variable	Data Collection Period						Total	
	2		3		4			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Efficacy								
Academic efficacy	5.98	0.60	6.15	0.62	5.85	0.78	5.99	0.86
Team Efficacy	6.18	0.79	6.07	0.57	6.29	0.67	6.18	0.87
Career Efficacy	5.74	0.91	5.74	1.06	5.39	1.22	5.62	1.10
Overall Efficacy	6.00	0.92	6.05	0.89	5.89	0.99	5.98	0.93
Service Quality								
Expectation	6.10	0.99	n/a	n/a	n/a	n/a	6.10	0.99
Perception	6.06	1.10	5.94	0.96	5.85	1.05	5.95	1.04
Gap Score	-0.04	1.28	-0.16	1.27	-0.25	1.36	-0.15	1.31
Weighted Gap Score	0.01	0.47	-0.10	0.58	-0.25	0.68	-0.12	0.58
Outcome Variables								
Perceived Quality	6.12	1.02	5.94	1.18	5.70	0.95	5.92	1.06
Satisfaction	5.88	1.29	5.84	1.19	5.64	1.08	5.78	1.18
Behavioral Intent 1	5.94	1.46	5.94	1.03	5.72	1.40	5.86	1.30
Behavioral Intent 2	5.91	1.49	6.10	1.47	5.48	1.82	5.82	1.61

With respect to the first hypothesis, no significant relationship was found between realistic expectations and efficacy at the first two measurement stages (beginning and mid semester). However, the final efficacy measurement (end of semester) did show a slight significant relationship with student gap scores (difference between expectations and perceptions). An ANOVA revealed that gap score sign (positive or negative) had a near significant relationship with career efficacy (p = 0.058), academic efficacy (p=0.078), and team efficacy (p = 0.092). Students with positive gap scores had significantly higher mean values in these three variables. Results of the ANOVA are displayed in Table 4.

Table 4. ANOVA for SERVUSE: Third Data Collection

Independent Variable	Dependent Variable	Source	df	SS	MS	F	Sig.	R-Sqr.
Efficacy Gap Score (third perception - expectations)	Third Academic Efficacy	**Corrected Model**	1	1.91	1.91	3.31	0.078	9.7%
		Intercept	31	17.85	0.58			
		Total	32	19.76				
Efficacy Gap Score (third perception - expectations)	Third Team Efficacy	**Corrected Model**	1	1.30	1.30	3.03	0.092	8.9%
		Intercept	31	13.29	0.43			
		Total	32	14.59				
Efficacy Gap Score (third perception - expectations)	Third Career Efficacy	**Corrected Model**	1	5.31	5.31	3.88	0.058	5.8%
		Intercept	31	41.05	1.37			
		Total	32	46.37				

When considering student preparation, high school GPA did not present any significant correlations with efficacy. However, the number of high school preparatory courses (e.g. calculus, physics) was significantly correlated with the third measurement of academic self-efficacy (0.476, p = 0.006). The positive correlation signifies that students who took more preparatory courses achieved higher levels of academic self-efficacy by the end of the semester. Additional significant correlations are found in Table 6.

Students who experienced an increase in academic self-efficacy throughout the semester reported significantly higher results for two outcome variables: perceived quality (p = 0.017) and satisfaction (p = 0.034). Additionally, students who reported an increase in academic self-efficacy throughout the semester had significantly higher quiz grades (p = 0.028). The ANOVA analysis for significant results of increases in academic self-efficacy is shown in Table 5. Also, change in efficacy over the semester was significantly correlated with perceived quality (0.448, p = 0.011), satisfaction (0.470, p = 0.008), and behavioral intention (0.500, p = 0.004). Finally, There was also a significant correlation between academic self-efficacy and quiz grades (0.556, p = 0.001), as well as college GPA and quiz grades (0.737, p < 0.001). The correlation scores are shown in Table 6.

Table 5. ANOVA for Changes in Academic Efficacy

Independent Variable	Dependent Variable	Source	df	SS	MS	F	Sig.	R-Sqr.
Increase in Academic Self-efficacy (third survey - first survey)	Perceived Quality	**Corrected Model**	1	5.135	5.135	6.40	0.017	18%
		Intercept	29	23.252	0.802			
		Total	30	28.387				
Increase in Academic Self-efficacy (third survey - first survey)	Satisfaction	**Corrected Model**	1	5.40	5.40	4.95	0.034	14.5%
		Intercept	29	31.69	1.09			
		Total	30	37.10				
Increase in Academic Self-efficacy (third survey - first survey)	Average Quiz Grades	**Corrected Model**	1	43.79	43.79	5.32	0.028	15.5%
		Intercept	29	238.62	8.23			
		Total	30	282.41				

Table 6 - Significant Correlation Scores

Variable 1	Variable 2	Correlation	p-value
Number of high school preparatory courses	Third academic efficacy	0.476	0.006
Average quiz grades	Overall academic efficacy	0.556	0.001
Average quiz grades	College GPA	0.737	<0.001
Overall change in efficacy	Perceived quality	0.448	0.011
Overall change in efficacy	Satisfaction	0.47	0.008
Overall change in efficacy	Behavioral intention 2	0.5	0.004

Discussion

The measurement of efficacy throughout the semester presented some surprising findings that are not noticeable unless the measure is taken at multiple points through the semester. Overall efficacy went down (along with academic and career efficacy) while team efficacy increased. While the cause for a decline in efficacy was not found throughout the study, a couple of possible explanations can be presented. First, the final efficacy measure was taken in week 15 of a 16 week semester. This is a time when many first year students are experiencing a bit of burnout and feel overwhelmed with term papers and upcoming final exams. This could have led to lower ratings of confidence on the efficacy scales. For team efficacy, the increase was expected as teams learn throughout the semester to function effectively as a unit.

The decrease in academic efficacy has serious implications for student success. Higher efficacy scores were realized by students who were successful in the course (e.g. quiz grades), which means the opposite is true for those with low grades in the course. Interventions throughout the semester could be useful in preventing the decrease in academic efficacy measures. Reducing the emphasis on course grades as a measure of success, clearly detailing learning objectives and course expectations, and emphasizing positive performance from all students may be helpful in reversing the observed efficacy trend.

The average gap score between all three data collections was -0.15. This value increased slightly to -0.12 when the factor weights were included in the calculations. This shows that students' perceptions did not match their expectations. In fact, their perceptions regarding the course were slightly lower than expected. The trend over the three data collection periods shows the gap score getting more and more negative over time, bottoming out at -0.25 at semester's end. Because the expectation values were only calculated once, the decrease in perception is what drove the decrease in gap scores. That is, students had lower perceptions of the course as the semester progressed. This could be caused by an increased awareness of workload, frustration with the course, or a misunderstanding of objectives at the beginning of the semester. The near zero gap scores at the beginning of the semester could speak positively to students' preparations at the beginning of the course. The near zero gap scores could also be due to well formed and accurate expectations they attained from speaking with peers and having positive hopes for the course.

Through statistical analysis, the efficacy scores and gap scores in the final round of data collection were shown to be significantly related to one another. That is, students with higher efficacy scores had higher gap scores. Those whose perceptions exceeded expectations had higher efficacy. This could be due to the effect of the course during the semester on students. Students whose efficacy was improved during the semester were actually able to increase their team, academic and career efficacy by the end of the semester. Also, those students whose expectations were not met by the end of semester experienced a decrease in their academic, team, and career efficacy. This would show the importance of calculating students` gap between their expectation and perception. If students have higher expectations and these expectations are not met, students would experience lower academic, team, and career efficacy.

A significant correlation between overall changes in efficacy and satisfaction, perceived quality, and behavioral intention is a very interesting finding. Similar findings have not been discussed in literature before. The implication is that if students have changes in their efficacies, their satisfaction, perceived quality and behavioral intention would change accordingly. It could also be said that when students have more self confidence in themselves, they are actually enjoying more about the course. Therefore, it is recommended that behaviors which would increase student efficacy be more supported in the education system specifically for first year students.

The primary hypothesis of this study, that students whose perceptions closely matched their expectations would have higher efficacy, was supported in the results. The support of this hypothesis lends additional support to the strength of using service quality paradigms to assess higher education, and more importantly, student efficacy. The link between efficacy and student (i.e. "customer") satisfaction in this particular course may find interesting analogies to self-efficacy observed among customers using self-service technologies[28]. In this situation, a study was conducted investigating the role post-training self efficacy played in influencing customer perceptions when using self-service technologies (e.g. Automatic Teller Machines or self-service checkout at a university library). The analogy here relates to the nature of our Analysis course being highly "self-directed" or "self-trained" as student teams engage in projects that require them to learn to build and operate robotics systems to accomplish tasks and achieve goals heretofore not experienced or even seen.

The results of this study can be extended to course design, although specific design variables (e.g. structure, group size, number of assignments, etc.) were not included in the analysis. For example, the results point to the provision of more feedback, especially on non-grade related matters. In the current semester of the course, the instructor is providing frequent, informal feedback by regularly providing sustained conversation and interaction at multiple stages of project development thereby increasing the level of "coaching and cheerleading" for each team. Additionally, frequent brief information sessions are provided enabling students to ask broad, far-ranging questions about the curriculum, co-operative education opportunities, general academic issues, etc. While indirectly related to the course content, this "sounding board" role of the instructor may enable students to maintain a higher sense of academic efficacy in conjunction with the observed increase in team efficacy.

Another impact on course design is clearly defining course objectives and workload. Increasing the clarity of information initially communicated about the course to allow students to align their perceptions and expectations. During the spring 2009 semester, during week four, the instructor noticed that students were beginning to appear somewhat distracted and unfocused given the general freedom of the class environment. By increasing the team-to-instructor interaction, individual focus seemed to improve, anecdotally. Whether or not this will be observed by improvements in self-efficacy awaits final analysis of that semester's data.

Finally, the project results present implications specifically for first year students and freshmen courses. The development of such a course at the freshmen level offers tremendous potential for all engineering majors. The relatively inexpensive cost of the robotics kits enables an entire class to focus on active learning. The great flexibility of projects that can be developed offer a multitude of discipline-specific opportunities. For engineering disciplines focused on structures

(e.g. civil or mechanical), the integration of sensors like strain gauges could enable students to learn about stresses, forces and strains on functional systems. Accessible programming code makes available the potential for electrical and computer engineering freshmen to design unique sensors for controlling systems. The availability of biological or chemical-based sensors allows a wide array of projects directed at fields such as biomedical or environmental engineering. Another unique feature of this type of system is the ability to engage students in a life-like process orientation. Rather than have students only acquire data passively, the robotics system necessitates the design of a responsive system, completing some desired task as a result of the data acquired thereby providing a more complete picture of how engineering really works to improve the world around us. The systems view of the robot, including task design, process flow, and integration would allow for projects aimed at industrial and systems engineers. A particularly exciting potential exists for building interdisciplinary teams across the freshman engineering classes, thereby addressing an often challenging program objective for many engineering assessment programs.

Conclusions and Future Work

This study demonstrated how the use of service quality techniques, specifically gap scores and perceptions, could be used to predict student efficacy. This significant relationship between how students view courses before they even enter (expectations) as well as while they take them (perceptions) and their resulting efficacy is a new way to examine student efficacy. This is supporting evidence that helping students form realistic ideas of courses will improve their efficacy, and ultimately their success in higher education. Narrowing the gap, the difference between expectations and perceptions, is a critical step in helping first year students acclimate and succeed.

The work presented in this paper is ongoing. ChE 2213 is offered every semester, allowing data collection to continue. The increase in sample size for the data will increase the strength of significance in the current findings as well as the validity of the conclusions. Further work is needed to reach definitive explanations for the trends described in the paper. Further work is also needed to establish a connection between project results, course design guidelines, and first year experience interventions. Finally, detailed guidelines on how these results can be used to monitor student progress and design mid-semester course adjustments need to be detailed.

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