

A Student Centered Approach to Improving Course Quality Using Quality Function Deployment (QFD)

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Abstract

The aim of this study was to develop an approach based on the QFD method to use appropriate pedagogies found in the literature, that will lead to an increase in student satisfaction with their education experience in a redesigned course. The key elements of the approach are to obtain and categorize in the students' own words, attributes that would constitute a good course, and a good instructor. Mapping these attributes to established pedagogies, coupled with continuous assessment and refinement ensures that there is not a mismatch between the student and faculty expectations. The approach was successfully implemented in a first-year engineering design course that had previously undergone a major revision in course content and delivery, resulting in very poor student evaluations at semester's end and general student dissatisfaction. Maintaining the new content, the QFD-based approach was able to significantly increase student satisfaction.

1.0 Objectives

The quality of a course should be judged by the extent to which the learning objectives are realized and the value the students attribute to it. A component of course quality is the delivery or presentation of the course content. This study focused on developing strategies to improve this aspect of course quality. Often in engineering, instructors focus more on what *they* believe is good for the students (and they are often correct), but do not adequately take into account the students' point of view on the instructional delivery methods and the entire educational experience. This often results in gaps or mismatches between student expectations and learning preferences, and faculty expectations and teaching preferences.

Stedinger [1] illustrates how these gaps can be overcome if faculty members help students to better articulate what is working and not working for them in a course. Similarly, Felder and Stice [2] state that students are better prepared to improve their learning environment when they understand and can articulate what is effective for them. Further, Anson et al. [3] observe that “[with a] diversity of approaches [to engineering education], the potential for mismatches between students' learning styles, preferences and practices on the one hand, and teaches pedagogies on the other, is considerable”. They go onto state, “... to understand and solve such mismatches requires seeing education as a ... symbiosis involving complex relationships between students' and teachers' beliefs and practices.”

While we acknowledge that students are not adequately equipped to address broader learning objectives, appropriate course content and teaching methodology [1.4], we hypothesize

that soliciting their opinions on what constitutes a good educational experience, and what instructional delivery methods they prefer (in their own words), then mapping these attributes to appropriate teaching methodologies rooted in published best practices, should result in a better educational experience for the students and increased learning. The objectives of this study, therefore, was to

1. Develop an approach that views the students as ‘the customer’ who has paid for a ‘service’ that is delivered by the instructor. The approach is based on the Quality Function Deployment (QFD) method that has been modified to make it suitable for this application.
2. Ground the method on established best practices for improving course quality that are widely documented in the literature.

The QFD method is widely used in industry and is focused on delivering products and services that satisfy the customer, by listening to the ‘voice of the customer’ throughout the product or service development process. QFD provides a set of tools and techniques that can be used to assure quality and customer satisfaction in new products and services [5,6].

2.0 Background and Motivation

The approach was applied to one section (32 students) of a first-year introductory required engineering design course, *ED&G 100 Introduction to Engineering Design*. The course underwent a major revision both in terms of delivery methods and content, and was piloted in a single section (out of 13 sections) in the 2004 Spring semester. ED&G 100 employs a design-driven curriculum with emphasis placed on skills such as teamwork, communication skills (graphical, oral and written), and computer-aided design and analysis tools. The course introduces first-years to the engineering approach to problem solving with strong references to basic science and math skills, as well as testing and evaluation of design ideas by building models or working prototypes.

The major content change in the 2004 Spring semester pilot was an increased emphasis on design and the design process, embodied in two open-ended design projects. For the first project, the instructor provided content information as needed while guiding the students step by step through the design process. Emphasis was placed on the acquisition of skills (for example, technical and graphical communication, teamwork, project management) and an understanding of the steps and the tools used in the initial stages of the design process (for example, customer needs analysis, decision making, product dissection, patent analysis, concept generation methods). The second project (and the second half of the semester) focused on the transference of what was learnt in project 1 to a more difficult design problem. Less guidance was provided and students were expected to be able to apply the skills acquired and use the design tools taught during project 1. In addition, students were exposed to additional design concepts such as the theory of inventive problem solving (TRIZ), materials and material selection, green design, and engineering ethics.

The end of semester student course evaluations scores for the section, however, turned out to be significantly lower than the mean of all 13 sections, and significantly lower than the values the authors typically receive for this course. The very low scores and general student dissatisfaction with the course provided motivation for this work. This aim of the study, therefore, was to develop a QFD-based approach using student input to improve the instructional

delivery and the entire course experience, yet still retain the new course content. Success would be determined by significant improvement in both the numeric measures and the qualitative responses from the end of semester course evaluations.

3.0 Previous work

QFD has previously been applied in university settings, but primarily for the development of course content. In these studies, the relevant stakeholders, for example industry, students, and graduate schools were identified as the customer and their needs translated into QFD “product features” (*read* course content) such as communication skills, teaming skills, and technical knowledge [7-9]. Mazur [10] used QFD for both course design and improvement of delivery, for the latter using the students as the customers. He however charged a student group as part of their final project, to perform the QFD study and to suggest improvements to the instructor for implementation the following semester.

Other studies have discussed different methods for using student input to improve instructional delivery and the educational experience. Stedinger [1] employed a Total Quality Management (TQM) approach based on ideas of customer focus, data-based decision making, and continuous improvement, to a 100-student junior level probability and statistics course. Biweekly short open and closed-ended surveys were employed to solicit student recommendations for effective teaching techniques they had seen in other classes and to comment on the extent to which current mechanical and motivational instructional approaches were working, or not. This approach is inline with other methods that employ the “One-minute paper” to achieve the same. These methods, though very beneficial, focus more on the micro-level of instructional delivery (example comments include, “cannot see bottom of screen”, “computer type is uniform and boring”, “give us time to complete notes”) and rely upon the students for suggested improvements. In addition the open-ended nature of the surveys does not allow for a statistical assessment of improvement in course satisfaction. Further they do not systematically incorporate pedagogies from the published literature, instead relying heavily on the instructor’s own teaching philosophy.

The proposed approach focuses on the macro-level of instructional delivery, with recommendations gleaned from best practices published in the literature. The use of both open-ended and closed-form surveys allows the elicitation of students diverse views, as well as the statistical assessment.

4.0 Student centered approach to improving course quality using QFD

The basic approach uses a modified house of quality (a central tool in QFD) and consists of the following sequential steps:

1. Perform a customer needs analysis (using surveys) to determine from the students *in their own words* what attributes they expect from a good instructor and what features/attributes they expect in a good course. In addition, have the students weigh the importance of the attributes.

2. Determine a comprehensive list of interventions from the published literature that can be used to improve various attributes of course quality or good instruction.
3. Determine correlations between the attributes put forth by the students and interventions to achieve them from the literature.
4. Set targets in order to quantify intervention outcomes.
5. Conduct assessment on a regular basis (we performed the survey three times a semester, once a month), to track how the instructor and the course are doing with respect to the attributes identified by the students in step 1. This step is crucial as it provides regular feedback from the students and allows mid-course corrections to be made (if necessary) that affect the current cohort of students, as opposed to end of semester course evaluations which do not.
6. Use the interventions compiled in step 2 with the help of the correlations from step 3, to improve any identified weaknesses. Provided feedback to the students on the assessment results, as well as the interventions to be used. This step helps the students feel empowered that they have input into the quality of their education, and that the instructor values and cares about their opinion.

5.0 Results

The results are presented corresponding to each of the steps outlined in the previous section.

5.1 Customer needs analysis

An important aspect of customer needs analysis is to capture the voice of the customer with regards to the desired attributes that one wants to improve. In our context, therefore, it was important to learn from the students what attributes they thought a good instructor and a good course should have. On the first day of the semester, the students were asked to complete the open-ended survey in Table 1. Open-ended surveys allow elicitation of in-depth information, especially when the subject is complex, and there are several avenues to explore [11], as is the case here. Despite the large number of attributes compiled from the customer needs, they were readily grouped into a manageable level of twelve general attributes each, for course and instructor quality (Table 2). More detailed lists, including sub-attributes, are displayed in Appendix Figures A.1 and A.2, respectively. The students' actual statements were included as the sub-attributes to give them and the instructor a complete understanding of each attribute. Duplicate statements were omitted.

5.2 Compilation of instructional best-practices from the literature

Prior to the commencement of the course, the authors had searched the engineering education literature for instructional best practices that may later be applied to improve both course delivery and student learning. Brief summaries of the best practices that were actually used and their expected outcomes are presented in Table 3.

Table 1. Open-ended survey presented to students in ED&G 100.13 at the start of the semester

<ol style="list-style-type: none"> 1. What are your expectations of this course? 2. In general, what items/attributes do you expect from a good course 3. In general, what attributes do you expect from a good instructor 4. Do you prefer to work in teams or to work alone? 5. Do you prefer lectures or in-class hands-on activities? 6. As lectures must be given to some degree, what would be your ideal length (in minutes), past which you stop paying attention?

Table 2. Compiled student attributes for a good course and a good instructor

Good Course	Good Instructor
<ol style="list-style-type: none"> 1. Informative 2. Fair learning environment 3. Challenging 4. Student Input 5. I expect hands-on knowledge as well as knowledge in the fundamentals 6. Involve students so that they are not just ears listening to the instructor go on and on 7. Variety of activities 8. Structured teaching style 9. Ability to enjoy the material 10. Interesting 11. Obtain a better understanding of the material 12. Useful 	<ol style="list-style-type: none"> 1. Organized 2. Well versed in subject matter 3. Interested in subject matter 4. Interested in the success and work 5. Available 6. Makes the material easier to understand 7. Is just and fair 8. Outgoing and creative 9. Can communicate the subject matter well 10. Let us know what is expected of us 11. Accepts student input 12. Leads by example, not just by words

Table 3 Brief summary of representative ‘best practices’ used to improve course delivery

Best Practice	Description	Expected Outcome
Teaching around the cycle [12-15]	Use of teaching methods that traverse all four learning styles of the Kolb model: divergers, assimilators, convergers, and accommodators.	Higher level of thinking and understanding.
Cooperative learning [16-18]	Students work in small groups throughout the semester. Consists of five basic elements: positive interdependence, face-to-face promotive interaction, individual accountability and personal responsibility, collaborative skills, and group processing.	Most engineering students are visually-biased learners, as well as inductive and active. Typical lectures are passive and provide no opportunities for reflection on the presentation.
Active learning [19-21]	Introducing activities into the traditional lecture (breaks up the lecture) and promoting student engagement (activities designed around important learning outcomes and promote thoughtful student engagement).	Improved retention and student performance.
Inductive learning [1,12]	Integrating the course material with past learning experiences, previous courses or situations from everyday life. Starting with examples and experiences and working up to a general understanding.	A better understanding of course material. Connections of course material to the broader context of engineering in society.
Timely feedback [23-24]	Repeat exercise of a skill or application of a concept, followed by timely constructive feedback on the initial attempts.	Increase in level of mastery and understanding
Teams-Games-Tournaments [22]	Employs team-based competitions to increase the cooperative nature of group projects and provide additional motivation to team members to perform.	Increase in academic achievement, understanding of subject matter, and peer tutoring.

5.3 Finding qualitative correlations between best practices and student-identified attributes

A key tool of QFD is the House of Quality (HOQ), that contains qualitative correlations (strong, moderate, weak, none) between customer desires and technical requirements of the product or service. A modified HOQ was used to obtain subjective correlations between the identified student attributes for a good course, and instructional best practices obtained from the literature (Table 3) is shown in Figure 1. Note that the attributes for a good instructor for the most part were pretty self-explanatory and therefore were not placed into an HOQ.

Once the relevant pedagogies had been identified and the corresponding correlations established, the authors decided upon actual activities that would be immediately implemented to meet the student needs. A summary of these activities tabulated with the corresponding pedagogy is listed in Table 4. Only those activities that are different or modified versions of the previous semester are included. Needless to say, development of relevant activities using these guidelines continued throughout the semester.

5.4 Formative Assessments

Two formative assessments were conducted during the semester, the first at the end of September (~ 4 weeks into the semester) and the second at the end of October. Students were presented with closed-form surveys (shown in Figures A.1 and A.2), where they were asked to rank on a Lickert scale (1-strongly disagree 2- disagree 3-neutral 4-agree 5-strongly agree) the extent to which the course and the instructor met each of the listed attributes. Closed-form surveys provides a practical method for obtaining statistically reliable conclusions. Limiting the response choices allows for repeated data collection of attitudes over time [11]. For all attributes, both for the instructor and the course, target values were set at 4.

Results from the September course and instructor assessments are shown in Figures 2(a) and 3(a), respectively, with the numeric scores summarized in Figure 1 and Table 5. The course attribute assessments all exceeded the target score of 4 along all dimensions, except for “Challenging” and “Student Input”. As these were the initial stages of the course, the material was still relatively easy and we expected this attribute to increase as the semester wore on. For “Student Input”, we decided that more emphasis needed to be placed on listening to the students’ points of view and trying to encourage more dialog in class. The instructor attributes all exceeded the target score, except for “available” that had a low score of 3.77. This was quite puzzling given that the instructor had three hours of office hours each week (that no student had come to), and generally waited around after class until the last student left. However, it was decided to constantly remind students about the office hours, consistently ask them in class how they were doing, both one-on-one, and as a class, and if they needed help with any aspects of the course.

Results from the October course and instructor assessments are shown in Figures 2(b) and 3(b), respectively, with the numeric scores summarized in Figure 1 and Table 5. For the course scores, the averages were slightly lower for most attributes, but the number of “strongly disagree”, “disagree”, and “neutral ratings” drastically diminished. The lower averages are due to a sizeable number of ratings dropping from “strongly agree” to “agree”. This was not surprising as the course had become significantly more challenging at this point and more

	Teaching around the cycle	Cooperative Learning	Active learning	Inductive learning	Timely feedback	Teams-games-tournaments	Target	1st Assessment	2nd Assessment	% change
Informative				●			4	4.15	4.42	6.51
Fair learning environment					●		4	4.15	4.54	9.40
Challenging		●	○				4	3.81	4.00	4.99
Student Input		○					4	3.92	3.88	-1.02
Hands on and fundamentals		●	●				4	4.35	4.04	-7.13
Involve students		●	●		●	●	4	4.12	4.13	0.24
Variety of activities	●	●	●			●	4	4.23	3.96	-6.38
Structured teaching styles	○		○	○			4	4.19	4.08	-2.63
Able to enjoy material		●	●	●		●	4	4.35	4.08	-6.21
Interesting			●	●		●	4	4.38	4.17	-4.79
Obtain better understanding	●	●	●	●	●	●	4	4.31	4.17	-3.25
Useful				●			4	4.50	4.50	0.00

Figure 1. Modified HOQ showing qualitative correlations between desired student attributes for a good course and established pedagogies from the literature that might achieve them.

Table 4 Brief summary of activities corresponding to best practices that were introduced to the course

Best Practice	Activity
Teaching around the cycle	All major concepts were taught through teaching around the cycle, by illustrating what and why in lecture, having the students practice the how in an in class exercise, and then having them apply the what-if to an open ended problem, typically embodied in their design projects.
Cooperative learning	Students formed groups that they sat next to in class and also worked with for group projects. Numerous in class activities were used including problem-solving, research online, laboratory exercises, etc., where the students worked in their groups. Teaming skills and exercises were also taught and practiced including project management, group personality assessments, etc.
Active learning	Previously all classes were preceded by a 30-50 min. lecture followed by group activity. All lectures broken down to 10-15 min. segments, with activities that bring out the learning objectives interspersed in between.
Inductive learning	Most lectures were preceded with a real world example or situation, and constant references were added to illustrate how the material learnt would be applicable in the future.
Timely feedback	Immediate feedback was provided for all in class activities, summarizing student results and correcting any misunderstood concepts. All assignments were promptly returned within a week. More detailed written feedback was provided on the assignments.
Teams-Games-Tournaments	An element of competition was added to both projects that were now peer-evaluated. Winning teams were treated to lunch by the course instructor.

demanding of the students' time. However, nearly all measures remained above the target 4 score. As expected, the "challenging" attribute went up, but despite the interventions there was a drop in the "student input" score. In addition, the "variety of activities" score drop to 3.96, but still very close to the target. Nearly all the instructor scores rose in the second assessment, most notably, the "available" score low in the September assessment (3.77), rose by 10.55% to 4.17.

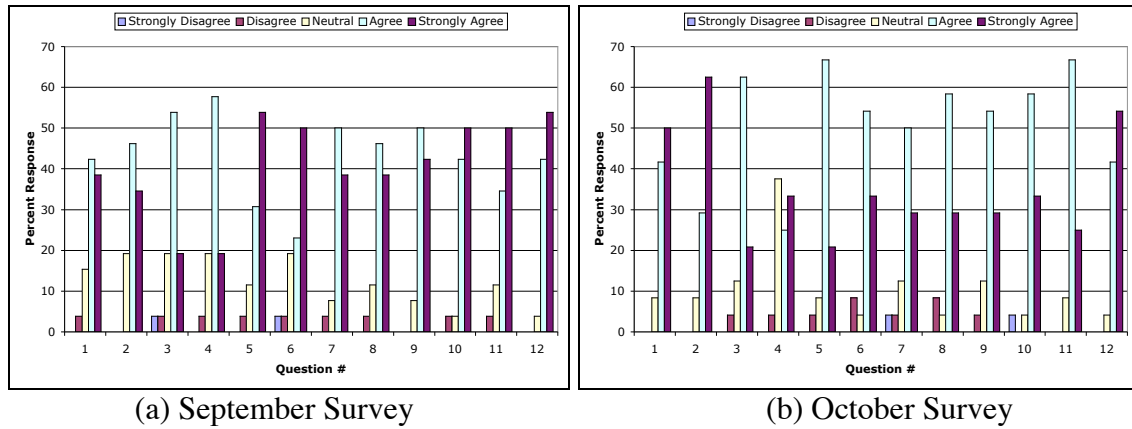


Figure 2. Responses from survey to assess student opinions of attributes of a good course along twelve dimensions.

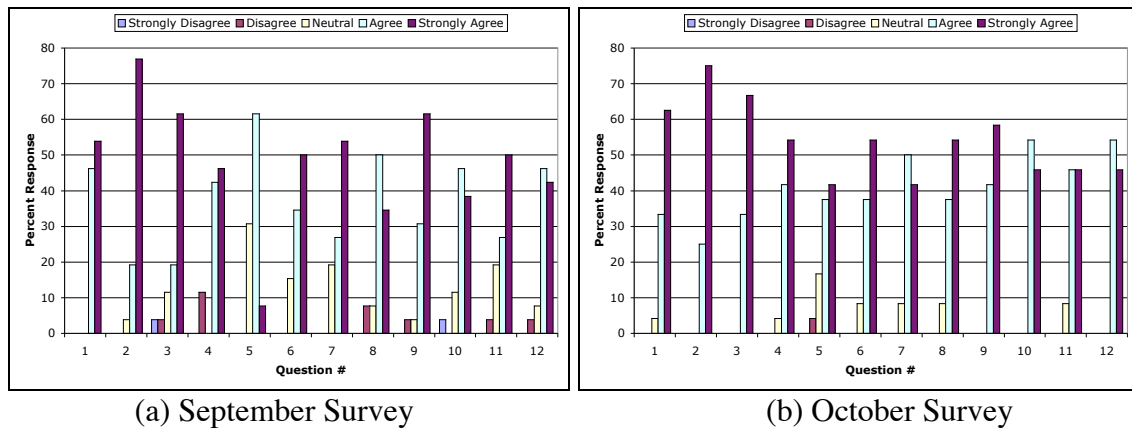


Figure 3. Responses from survey to assess student opinions of attributes of a good instructor along twelve dimensions.

Table 5. Mean scores from both the September and October surveys of student opinions on the extent to which their instructor met the 12 attributes of a good instructor

Question	1	2	3	4	5	6	7	8	9	10	11	12	Average
Sept. Score	4.54	4.73	4.31	4.23	3.77	4.35	4.35	4.12	4.50	4.15	4.23	4.27	4.29
Oct. Score	4.58	4.75	4.67	4.50	4.17	4.46	4.33	4.46	4.58	4.46	4.38	4.46	4.48
% Change	1.0	0.4	8.3	6.4	10.5	2.6	-0.3	8.3	1.9	7.3	3.4	4.4	4.37

5.5 Overall student satisfaction with the course

Using the university administered end of semester course evaluations, students' overall satisfaction with the course was compared along 11 dimensions. A description of the dimensions and corresponding scores for students over a three semester period, Fall 2003 - Fall 2004, are given in Figure 6. With the inclusion of Fall 2003 scores we would like to show the student satisfaction with the course before the content revamp. Likewise, Spring 2004 scores show the scores when the content revamp was implemented, and Fall 2004 scores show the result of the QFD based delivery quality improvement as reflected to overall student satisfaction with the course. The scores were based on a Likert scale from 1 (strongly disagree) to 7 (strongly agree). The figure shows a dramatic increase in the scores between Spring 04 and Fall 04 along all dimensions, with overall course quality and overall instructor quality increasing by 47% and 64%, respectively. A comparison of students in the Fall 03 and Fall 04 classes also show an increase in student satisfaction across all dimensions, with a 6% and 3% increase in course quality and instructor quality, respectively.

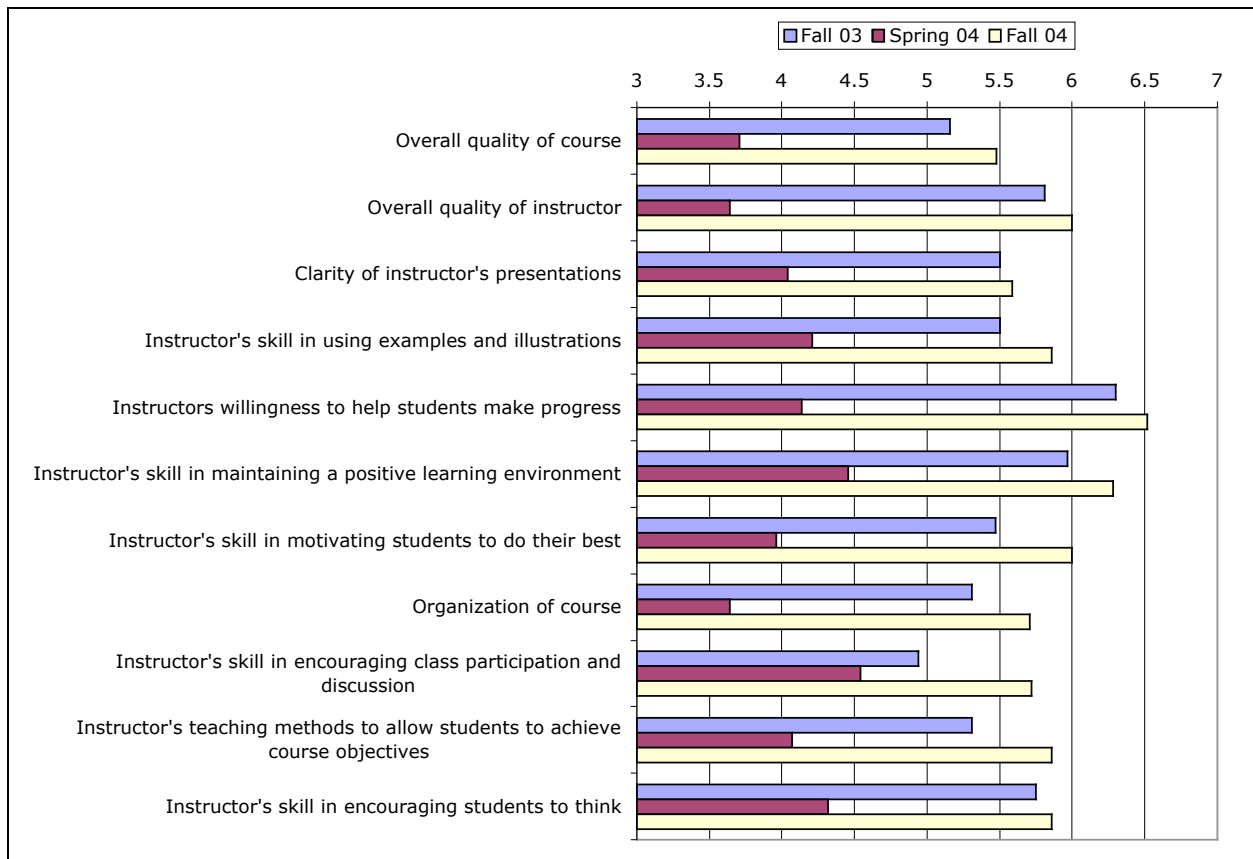


Figure 4. Comparison of average scores of student attitudes measured along eleven dimensions for 2003 Fall semester and 2004 Spring and Fall semesters. Ratings range from 1 – 7.

6.0 Discussion and Key Conclusions

The aim of this study was to develop an approach based on the QFD method to use appropriate pedagogies found in the literature, that will lead to an increase in student satisfaction with their education experience in a redesigned course. The key elements of the approach are to obtain and categorize in the students' own words, attributes that would constitute a good course, and a good instructor. Mapping these attributes to established pedagogies, coupled with continuous assessment and refinement ensures that there is not a mismatch between the student and faculty expectations. We believe that the approach detailed here has been successful at showing that our previously stated hypothesis, “*soliciting student opinions on what constitutes a good educational experience, and what instructional delivery methods they prefer (in their own words), then mapping these attributes to appropriate teaching methodologies rooted in published best practices, should result in a better educational experience for the students and increased learning*”, is indeed true.

When implemented the first time, an inordinate amount of time is required to go through the literature, to find and understand how to use and adopt appropriate pedagogies. The student assessments themselves, however, required a minimal amount of time, ~10-15 minutes of class time three times in the semester. Compiling the first list of attributes from the open-ended survey took about an hour, and another hour to agree on the relevant pedagogies and qualitative correlations. Compiling the second and third assessment data required ~30 minutes each time. Implementing the approach a second time should be much easier as all the assessment templates have already been established, and most classroom activities already designed.

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Appendix

Figure A. 1. Compilation of student views on the attributes of a good course

	Score
1 Informative	
Learn something that will stay with me for many years Provides current information To use the knowledge gained in the good course and be able to apply it to real life situations and other courses Good content Knowledge obtained from course be accurate and upto date Course that teaches through real life experiences Relates contemporary problem solving to fundamental skill sets Ability to meet or exceed all objectives of course	
2 Fair learning environment	
3 Challenging	
Homework is useful and requires effort but is not overwhelming To be challenging but not ridiculous. Challenge my mind and take my thinking skills and work habits to the next level Challenging but not insanely hard Comprehensive but not excessive classwork	
4 Student Input	
A two side affair and not always controlled by the instructor There should be flow of thought from both sides Curriculum that is reponsive to student ideas Involvement of students	
5 I expect hands-on knowledge as well as knowledge in the fundamentals	
Good balance of lecture time and hands on work Information should be presented through lectures so that they can try it in the lab portion	
6 Involve students so that they are not just ears listening to the instructor go on and on	
A curriculum that is Interactive	
7 Variety of activities	
A change in the norm, not always doing the same old thing	
8 Structured teaching style	
Time in class is used effectively Moves at a steady pace Well taught lectures Clear instruction	
9 Ability to enjoy the material brought forth in the course	
Ability to remember almost everything taught Fun, not always serious, but structured Fun, good atmosphere Enjoyable	
10 Interesting	
I like when the material learnt is interesting To stay on the central topic but have enough diversions to keep the subject interesting Just thorough information, but not too much to bore me	
11 Obtain a better understanding of the material	
Forces you to learn, but helps you learn it	
12 Useful	
Use it later in my career Take away more than just the skills from the course Course that can change the way you look at people Course that can change the way you work with people You are learning stuff that will help you be more successful in the future	

Figure A.2. Compilation of student views on the attributes of a good instructor

	Score
1 Organized	
Informed, prepared instructor Gives targetted lectures on point	
2 Well versed in the subject matter	
Understanding of subject material Expert in the field Knowledgeable She/He must know what he is talking about	
3 Interested in subject matter	
Excited about the topic Enthusiasm Energetic	
4 Interested in my success and work	
Someone who is approachable Patience Someone who can teach me about my self as well as the subject Willing to help students learn Someone who is understanding Someone who cares about the well-being of their students Wanting the student to learn Does not hand feed us the information Someone who wants to see their students suceed and will do all they can to see this happen Show students how to [achieve] and eventually lead the students past their goals and objectives Someone who will push me but not drive me into the ground	
5 Available	
Take time to help students who want to be helped She/He should be available for assistance when necessary Has a lot of help sessions for students	
6 Makes the material easier to understand	
She/He should explain the problem and solution thoroughly	
7 Is just and fair	
Tough but fair Clear and fair Understanding Reasonable Realizes that this is not the only class I am taking and assigns work accordingly	
8 Outgoing and creative	
Down to earh Someone who is personable A good sense of humour and entertaining personality always works too.	
9 Can communicate the subject matter well to students	
Ability to be heard Communicate subject matter in an interesting way Presents the material well Attention holder - sometimes grabbers are too over the top Present information in an interesting manner New and unique way to present the information necessary A way to maintain interest in the subject Someone who can keep my attention Should apeal to the classes learning style Good communicator Intelligent coherant professor Interesting/Not to dull Clear instruction	
10 Let us know what is expected of us	
Provide timely feedback on work turned in	
11 Accepts student input	
Give ideas and listen to yours Is open to different opinions about a topic that does not have concrete meaning	
12 Leads by example, not just by words	

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