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Critical Thinking, Design Practices, and Assessment in a Fundamentals of Engineering Course

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Abstract

This Complete Evidence-based Practice paper will describe a longitudinal study of 6 years of enhanced attainment of course and programmatic outcomes in a Fundamentals of Engineering course. A process of continuous improvement of active learning techniques to achieve each course goal and demonstrate each outcome has resulted in more effective development of first-year engineering students.

One of the signature assignments in the course, the short midterm research paper and presentation, demonstrates effective incorporation of elements from The Critical Thinking Initiative. It is a framework to teach a mentality of critical thinking, guide development of a researched writing piece, and as a rubric instrument to assess student critical thinking through writing. Student oral communication is another key outcome. A subjective rubric has been replaced with a transparent, straightforward, binary check sheet rubric.

Another signature assignment in the course is a team-based design challenge. Evaluation of student performance was difficult and subjective. Through continuous improvement built on student feedback we developed a transparent method of evaluating the design challenge. We demonstrate the effectiveness of a simple check-sheet style rubric for evaluation of demonstrated design thinking and project management skills in the team-based design challenge.

Results of this 6-year study show steady achievement of the course outcomes, with progress toward achieving all course goals.

Introduction

This complete evidence-based practice paper describes a longitudinal study of 6 years (from 2012 – 2017) of attainment of course and programmatic outcomes in a first-year Fundamentals of Engineering course that was entirely redesigned using the backward course design methodology to incorporate numerous active learning and project based learning techniques(in 2012) [1].

First-year engineering courses are subject to a variety of forces in defining their direction and purpose. In this case, each course goal has been carefully chosen *a priori* and linked to ABET accreditation aligned course outcomes. The course goals are: (I) create a passion for engineering; (II) develop an engineering mindset, problem solving skills, and critical thinking; (III) develop engineering professionalism. Each course outcome links to one of those goals. Those outcomes, which are also explicitly linked to various ABET defined student outcomes [2], are used to define and measure the success of each activity and learning module in the course. A process of continuous improvement of active learning techniques to achieve each course goal and demonstrate each outcome has resulted in effective development of first-year engineering students.

Since redesigning the course, two signature assignments have remained as primary performance indicators in course outcome attainment throughout the six years. Those are the short research paper (approximately two pages long) with its oral presentation (approximately five minutes long), and the team-based design challenge with its team presentation. These assignments are significant as they also replace traditional exams in the course. They weigh heavily in determining student grading, as well as outcome attainment.

Continuous Improvement Process

Year to year we have sought to improve the effectiveness of the research paper and design challenge by evaluating not only the student's grades and course outcomes, but also the level of cognitive development and student feedback regarding the assignments themselves. We have incorporated a continuous improvement process for the assignments. Through this process, we have developed and implemented a set of effective evaluation rubrics used to assess each of these assignments. This has led to improved student outcomes, as well as high student satisfaction with the assessment rubrics used.

Each year the feedback process itself has improved. For perspective on the development, a bit of history is helpful. In the first years of the course, the feedback came through standardized course evaluation surveys, and free-response surveys. Those results regularly included comments from students regarding the assignments and associated grading techniques, occasionally expressing dissatisfaction with the purpose of the writing assignments and the transparency of the project grading. Beginning with the second year, we hired a second-year student as a teaching assistant, to aid students in making the desired connections within the assignments. End of course surveys provided student feedback. Similar complaints were still noticeable from multiple students in both the second and third years.

In the fourth year, a student group-feedback session was conducted during class time, after the team design project was complete. During those sessions, student teams met with faculty to discuss the grades they had received on the project. Specifically, multiple student groups expressed a desire for a clear rubric-based grading scheme, so that they could more clearly understand in advance, in the requirements of each assignment. This provided excellent insight for faculty to consider, and resulted in significant changes to the assessment methods in years five and six. Explicit rubrics were developed that led to greater student success in course outcome attainment, and increased some expectations of the level of cognitive development.

In year six, not only were rubrics included to assess student learning, but also students were specifically surveyed regarding their satisfaction with those rubrics, and the effect of those rubrics on their learning. Results of that meta-assessment follow.

The Role of Critical Thinking in writing

One course goal is to develop an engineering mindset, including critical thinking. Critical thinking is notoriously difficult to define, teach, and demonstrate in a clear way. As an engineering course, the initial assumption was that problem solving and design would best assess critical thinking skills. This course goal was separate from the engineering professionalism course goal. Initially, the individual technical writing assignment (ITW) and the individual oral presentation (IOP) were chosen as the tools to assess the course outcomes tied to effective communication, and the engineering professionalism goals. Critical thinking was seen more as the domain of problem solving. However, this meant that the focus of the individual technical writing was very narrow in its purpose. The initial focus of that assessment was to demonstrate competence in writing using a technical style, citing peer-reviewed work, and including correct information. These were all skills seen as necessary to proper engineering communication. Students were graded holistically, more on the correctness of their stylistic choices in writing, than on the content of their writing, as the writing was only expected to impart knowledge of an engineering topic of the student's choice.

However, this consistently received negative comments from students. To them, the writing seemed irrelevant to their future engineering careers. This despite instruction in technical styles, and faculty comments about the importance of clear communication in lab reports, white papers, and potentially authored articles. It became clear that the writing assignment was not having the intended effect. This resulting in analyzing how to improve the writing assignment, if it was to stay in the course, as it was still an effective method of demonstrating communication skills, one of the desired ABET-oriented course outcomes.

It became clear that the writing assignment itself was a good tool to demonstrate the desired outcome, but that its effectiveness needed to improvement by making it more meaningful to students. Research on writing in the disciplines [3] and meaningful writing [4] led to a change in focus of the content and scope of the individual technical writing assignment. For example, we introduced the National Academy of Engineering Grand Challenges of Engineering [5] and encouraged students to select one of those Grand Challenges that they felt most drawn to, as the central focus of their paper. In an effort to increase the meaningful nature of the writing task, while still demonstrating effective technical communication, the paper focus also shifted toward higher-level cognitive skills. Rather than just demonstrating knowledge and understanding, the students identified a problem, and evaluated possible solutions. They were asked to demonstrate critical thinking. By increasing the cognitive level of the paper, it became difficult to describe clearly to the students what the expectation was, and how they could be accurately assessed.

Assessing Critical Thinking through writing

We decided to incorporate elements from *The Critical Thinking Initiative* [6] (*TCTI*) to attain a more purposeful evaluation of critical thinking using a generalized writing assessment instrument adapted to an engineering framework. It is used as both a constructive framework to teach a mentality of critical thinking to guide the development of a researched writing piece, and as a rubric instrument to assess students' critical thinking through their writing. This is a markedly different approach to writing and thinking in engineering, which enhances student ability to tackle a complex problem, even early in their engineering career. Student attainment of written communication outcomes are measured with this rubric.

The Critical Thinking Initiative utilizes the Target™ rubric as guide and instrument. The rubric is a visual representation of the process of critical thinking, which also defines what attainment levels are (the grade), as in Figure 1.

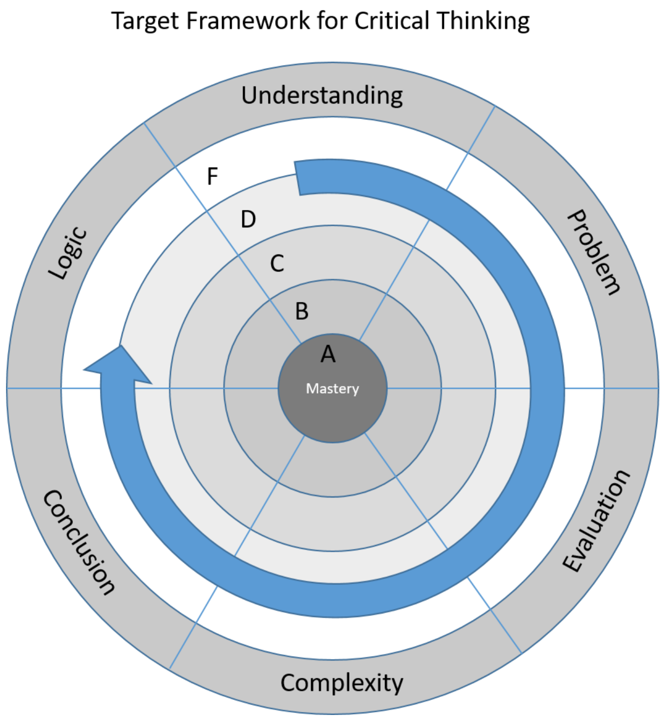

Figure 1 – The Target™ rubric (adapted from The Critical Thinking Initiative [6]) showing the progression from Understanding to Logic, as each aspect relies on those before

Before receiving the assignment, students learn the framework. We describe each of the six indicators of critical thinking: Understanding, Problem, Evaluation, Complexity, Conclusion, and Logic. The utility of this framework is that the precise definition or use of each of the six traits can be refined to meet the needs of the particular discipline. In our case, engineering. The writing is evaluated trait by trait, with attainment measuring the level to which the writing pushes toward mastery of a trait at the center. Students look for continual incorporation of the trait, as they move from an "F" which is a complete lack of the trait, toward an "A" or mastery, where they are incorporating that trait throughout the whole paper. They evaluate one trait before moving to the next. As mentioned in *TCTI*, it is difficult to have mastery of a later trait, if the earlier trait is weak; those first traits serve as a foundation. This provides a way of troubleshooting the paper, as students can often trace poor critical thinking to a weak understanding, or flawed problem statement, which leads to weak conclusions or poor logic developing throughout the paper.

In our course, we ask the students to demonstrate **Understanding** by demonstrating how the foundational ideas or background information of paper topic build to the problem that is addressed. This leads to a clear problem statement.

The **Problem** is not just assessed by being present as a single statement, thought that is a good beginning, but is assessed for whether the bulk of the paper is directly tied back to that problem statement. In other words, does the paper remain on topic throughout? For our purposes, we coach the students to choose a problem of proper scope for the assigned 2-page length limit.

Evaluation of sources is often the most challenging area for students to achieve mastery. Evaluation is defined as recognizing the assumptions, limitations, validity, and implications of a source as it relates to the Problem. This is challenging because it asks students to go beyond simply summarizing a relevant source. In fact, summary of the sources will only earn a grade of D or C on that portion.

Complexity in our engineering papers is demonstrated through an analysis of multiple possible solutions to the problem, weighing likely advantages of each. Attainment is also tied to the number of perspectives explored. A one-sided or either/or perspective is worth an F or D respectively. Grades of C or higher require exploration of multiple perspectives. They can also examine the role of non-technological factors on a proposed solution, which ties directly in to the need for students to demonstrate an ability to propose solutions within realistic economic, social, and environmental constraints. Mastery requires students to move beyond listing multiple solutions as isolated possibilities, and toward consistently weighing them against each other, or against a common set of constraints, much as would be done in a decision matrix process.

The paper should draw **Conclusions**. A student must evaluate all of the evidence they have presented, and reach a conclusion that is relevant to the problem statement. In addition, to show consistency rising to the level of mastery, they need to show how their evaluation of the sources and evidence lead them to that conclusion throughout the paper.

Logic is demonstrated when students avoid logical fallacies [4], [7]. It is quite common at this early stage to see student writing incorporate generalities or biases not explicitly supported by evidence in their sources. The other common logic error is drawing an unsupported conclusion. This follows the foundation built in the previous traits, since it is very difficult to have logical conclusions without exploring multiple options, or making clear which sources most influence the paper.

These six traits, once assessed, generate the holistic grade (base letter grade on a 4-point scale) by averaging them with equal weight. Once the traits of the rubric are discussed for the holistic grade, students are introduced to the brief prose rubric regarding organization, correctness, style, and citation format. This rubric is similar to that shown in Figure 2. Those points, which were the entire focus of the initial years, become a secondary consideration relative to the holistic critical thinking traits. In summary, those characteristics together have the weight to shift the holistic grade by a plus or minus on a 4-point scale. Each is evaluated for whether it hinders or enhances the reader's understanding of the author's intent.

As the Target™ framework is a teaching tool; students are not just introduced to it for their own grade. In class, we walk through an example paper, and students work in small groups to assess and evaluate that paper on the rubric. Afterwards we discuss as a class, so that there is a norming process helping everyone to reach a better understanding of what each level of attainment requires.

Prose Rubric

	Organization	Correctness	Style	Formatting/ Citations
Exceptional **(+)**	-----Enhances the reader's understanding-----			
Satisfactory **(0)**	-----Reader understands writer's thinking-----			
Unsatisfactory **(-)**	-----Hinders the reader's understanding-----			

Figure 2 – Back page of TARGET rubric, showing the 4 prose categories used to adjust the holistic Target grade

Once students draft their own papers, there is a formative feedback process. They share their papers in small peer-groups, where they evaluate each other on the Target rubric. They then revise, and submit a second draft for instructor review. The instructor reviews, and grades on the Target rubric. They point to specific evidence in the paper as to why a particular attainment level was chosen for each trait, with suggestions for improvement. Students then make a final revision.

The final version is graded for summative feedback on the same Target rubric, with comments provided to support any changes in attainment level.

In Fall of 2017, 63 of 65 students (95%) achieved the desired threshold score of at least a 70, considered as meeting the course outcome. The average score on the final paper was 87%, with a standard deviation of 6.5%.

Additionally a student poll of rubric effectiveness (see appendix A) indicates that while 56% of respondents Agreed or Strongly Agreed that they could articulate how to demonstrate critical thinking through writing *prior* to being introduced to the Target rubric, 80% of respondents Agreed or Strongly Agreed that they found the Target rubric helpful in improving their critical thinking. Additionally, 75% of respondents Agreed or Strongly Agreed that they found the Target rubric helpful to their writing process. Similarly, 73% of respondents also Agreed or Strongly Agreed that the Target rubric was effective at teaching and evaluating critical thinking. In terms of the holistic scoring, 81% of respondents Agreed or Strongly Agreed with the point breakdown between the holistic traits and technical elements, indicating a general agreement with the idea that content mattered more than style.

Assessing Critical Thinking in Oral Presentation

Student oral communication is another key course outcome linked to ABET student outcomes and course goals. Oral communication is assessed using a 5-minute individual oral presentation (IOP) on the same topic, and immediately following, the individual technical writing already discussed. In previous years, the presentations were graded using a subjective 5-point scale, with five categories: Organization, Technical Content, Visuals, Speaking, and Timing,

Students are also asked to rate the presentation of each other student using the same rubric. Again, feedback from students made apparent that they needed more guidance on expectations, as well as how they should be evaluating their peers. Peer evaluation contributes a portion of the grade. Because of that student feedback, the subjective rubric was replaced in this sixth year with a more transparent, and explicit binary check sheet rubric.

To develop the rubric, the team of instructors met to agree on new criteria. We began by listing the initial categories, and then deciding what factors we would be looking for to demonstrate effective achievement within those categories. Categories given more weight were assigned more factors. All factors were worded in a positive way, so that assessment could be done by simply marking which factors were present during the majority of the presentation. Each factor was to be marked either demonstrated or not.

The categories reflected, and grew out of the previous presentation rubric, but with specific points now guiding student preparation, peer assessment, and instructor assessment, equally. The Content area was reworded to address the points from the Target rubric, so that the students were given the expectation that their critical thinking process needed to be demonstrated during their oral presentation as well as during the writing. The other points addressed technical aspects of the presentation including: organization, visuals/slides, timing, speaking, and nonverbal communication. The full IOP Rubric is given in Appendix B.

The student poll of rubric effectiveness (see appendix A) indicates that 83% of respondents Agreed or Strongly Agreed that they found the IOP rubric helpful in teaching them how to prepare their presentation. Additionally, 75% of respondents Agreed or Strongly Agreed that they found the IOP rubric a helpful method in evaluating their peers' presentations. Nearly 65% of respondents Agreed or Strongly Agreed that they found the binary system of the IOP rubric provided the right amount of detail in evaluating their peers' presentations. Only 13% Disagreed with that same statement. Meanwhile 75% Agreed or Strongly Agreed that the IOP rubric was an accurate method of grading their own IOP presentation.

Assessing Design Practices

Another key element of the course, since the redesign, is a team-based design project (TDP). This challenge embodies engineering for these first year students. Evaluation of student performance in that challenge, however, is difficult, and somewhat subjective. Student feedback in the first years indicated a need for a more transparent evaluation method. Early iterations involved instructors meeting to holistically evaluate all teams at once, and assign grades based on reaching common consent.

Through continuous improvement, we built on student feedback to develop a transparent method of evaluating the design challenge. We decided, for consistency, to implement a simple check-sheet style rubric for evaluation of demonstrated design thinking and project management skills in the team-based design challenge (see Appendix C). Either skills are demonstrated, or they are not.

The same design challenge and criteria are given to each team in the course, and all are asked to design a solution that will be competitive against the other teams. Our chosen challenge is [name removed for blind review]. This challenge presents the team with a specific scope, design criteria defining success, a budget, and a rigorous deadline that must be met, all key components of a project.

We again met as a team of instructors to decide which categories were most important in both the design and the team presentation. Within each of those categories, more factors were identified for those categories deemed most important, to increase the respective weight. The categories were chosen to define the aspects of the design process that we were looking to assess: creativity, performance in competition, engineering design cycle, project management, and presentation (with the same categories as the IOP rubric, but with less factors, to reduce the weight). This rubric resulted in 25 factors, plus up to 5 points for actual objective performance in the competition event, for a total of 30 points.

This TDP rubric was slightly different, in that some elements were assessed on the day of competition, such as novelty of the design, and following competition rules (design criteria). However, other aspects were assessed during the team presentation. For example, the project management had to be shown in the presentation, by documenting the design, build, and test phases with photos, as well as identifying the project management roles that each team member had to fulfill, such as the budget manager, and communications manager. The TDP rubric was provided to students as part of the TDP assignment, so they were well aware of all grading criteria in advance, so that they could plan accordingly. This rubric allowed us to define clearly, why a particular grade was earned, rather than the previously used subjective, holistic approach.

Again, we found this new TDP rubric to be effective in helping students meet the desired outcome. Out of 15 teams, 100% exceeded the minimum threshold of 70% for satisfactory performance. In fact, the lowest grade was an 83%. While this did not provide for a large spread in grades (average was 92% with a standard deviation of only 4.2%) the teaching faculty were quite satisfied with the achievement of all teams, seeing no major weaknesses in any of the desired skills.

The student poll of rubric effectiveness (see appendix A) indicates that 79% of respondents Agreed or Strongly Agreed that they found the TDP rubric helpful in teaching them how to prepare their TDP presentation. Additionally, 83% of respondents Agreed or Strongly Agreed that they found the TDP rubric effective at evaluating their team's engineering design process. In addition, 90% of respondents Agreed or Strongly Agreed that they found the TDP rubric to be an accurate method of grading their project and presentation.

Course Outcomes

Achievement of course outcomes has been tracked through quantitative assessment for continuous improvement and accreditation purposes. Students consistently met the performance threshold of 70% for these assessments in previous years. In the Fall 2016 semester, student averages were 85% on ITW, 87% on the IOP, and 87% on the TDP. Well above the desired threshold, with 95% or more of students meeting the desired threshold on all three assessments.

With implementation of the new rubrics, student outcome attainment increased. Students averaged 87% on the ITW, 84% on the IOP, and 92% on the TDP. These scores were well above the 70% minimum performance indicator for our ABET assessment, with 97% of students meeting or exceeding the threshold. So outcome attainment can be said to have continued better than satisfactory, while also addressing many student concerns to improve student satisfaction with the course.

These attainments can be compared back to the first year assessment of these items, when the average score on the ITW was 88%, IOP was 90%, and TDP was 80%, with 5% of students not meeting the threshold for the ITW and IOP, but with nearly 20% of students not meeting the threshold for the TDP. Acceptable levels of attainment, but markedly improved since the first year, especially considering that the expected cognitive level of the ITW and IOP have increased from simple knowledge and understanding toward evaluation, by demonstrating critical thinking, while still achieving high levels of outcome attainment.

Student Feedback

In addition to the quantitative feedback from the student survey, we also collated anecdotal comments from the team feedback sessions. These sessions served as miniature focus groups with the students to garner input for future course improvements. Students were explicitly asked to discuss the ITW, IOP, and TDP with the instructor in the feedback session, to provide any suggestions they liked. The instructors will consider these feedback items for the next iteration of the course. A few comments stood out as themes or particularly impactful.

Student feedback regarding the ITW primarily in summary was that the Target rubric was helpful, but some more clarity on certain attainment levels is needed. We will work to provide an additional example, as well as more explicit description of those expectations. As this is students' first exposure, it is not surprising that there was some confusion.

The IOP rubric also received a few comments to improve the specificity of certain factors. Those comments will be considered to revise the IOP rubric in the future, or provide greater instruction. As this was the first implementation, some refinement is to be expected.

In regards to the TDP rubric, specifically, several mentioned that the rubric was very helpful, but that they would prefer items that are more specific for the presentation. It was also frequently mentioned that a rubric to assess team dynamics, which could be taught to all students ahead of time, and then reported on by teammates would be helpful to improve coordination and motivation of all members. This is something that we have already begun to research for next year's class.

All of this feedback, in addition to faculty observations will be considered for improvement of next year's course.

Scalability

As the course has developed, it requires more resources to adapt to a growing number of incoming first-year engineering students while maintaining and improving quality of delivery. To retain a consistent format, style, and outcomes the course is team taught to allow for continuous training of new faculty to teach the course, as well as to incorporate regular faculty feedback into the continuous improvement process. We can measure effectiveness of the course improvements due to consistency in delivery achieved through close peer collaboration as team teachers. The course has scaled up through team teaching. The course also builds in year-over-year consistency by incorporating undergraduate student mentors and teaching assistants, who are trained in the assessment methods, after having taken the course, so that they can serve as effective mentors in the class to the new first-year students. This has allowed us to offer four identical sections with four different instructors.

Conclusion

Results of this 6-year study show continued success in achieving course and programmatic outcomes through these assessment instruments. Concurrently, we increased the relevant cognitive level to incorporate critical thinking. Our research shows student opinions greatly support these new rubrics for assessment of critical thinking and engineering design practice. We believe that providing these simple rubrics help students meet the expectations of the course, so that they experience greater success in their engineering education during the first-year. These rubrics provide enhanced learning of material, and greater transparency for student assessment.

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Appendix A - Student Survey of Rubric Effectiveness

ID	Question Text	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	No answer	Sum Agree and Strongly Agree
	Student Evaluation of Rubrics Survey 2017							
	Thinking about the TARGET rubric used to grade the ITW:							
1	Could you articulate how to demonstrate critical thinking through your writing prior to being introduced to the TARGET	16.2	40.54	37.83	5.41	0	0	56.74
2	Did you find the TARGET rubric helpful in improving your critical thinking?	35.14	45.95	10.81	5.41	0	2.7	81.09
3	Overall did you find the rubric helpful to your writing process?	37.84	37.84	13.54	10.81	0	0	75.68
4	Were the definitions of each segment of the TARGET (Understanding, Problem statement, Evaluation, etc.) clear?	37.84	43.24	10.81	8.11	0	0	81.08
5	Which of the definitions of the TARGET segments (Understanding, Problem Statement, Evaluation, Complexity, Conclusions, Logic) was the least clear?	Complexity Identified by 35%						
6	Were the definitions of each level of the TARGET (A through	27.03	45.95	18.92	8.11	0	0	72.98
7	Was the TARGET helpful in assessing your peers' writing during trio read-alouds and presentations ?	21.62	35.13	29.73	10.81	0	2.7	56.75
8	Was the TARGET an accurate way to assess your writing and critical thinking?	21.62	56.76	16.22	5.41	0	0	78.38
9	Did the TARGET rubric reduce your perceived difficulty in writing the ITW essay?	21.62	32.43	27.03	16.22	2.7	0	54.05
10	Did the TARGET rubric reduce your perceived stress in writing the ITW essay?	18.92	24.32	21.62	27.03	8.11	0	43.24
11	Did the TARGET rubric increase your perceived difficulty in writing the ITW essay?	16.22	27.03	21.62	32.43	2.7	0	43.25
12	Did the TARGET rubric increase your perceived stress in writing the ITW essay?	18.92	27.03	24.32	27.03	2.7	0	45.95
13	Overall did you find the TARGET rubric effective at teaching and evaluating critical thinking?	24.32	48.65	16.22	8.11	0	2.7	72.97
14	Did you agree with the point breakdown for grading, regarding the weight of the TARGET elements vs. the "technical"	18.92	62.16	16.22	2.7	0	0	81.08
	Thinking about the IOP rubric:							
15	Did you find the IOP rubric effective at teaching you how to prepare your presentation?	27.03	56.76	5.41	5.41	0	0	83.79
16	Did you find the IOP rubric effective at teaching you how to prepare your presentation?	27.03	43.24	18.92	8.11	2.7	0	70.27
17	Was the IOP rubric a helpful method of evaluating your peers' presentations?	16.22	59.46	18.92	5.41	0	0	75.68
18	Was the binary system of the IOP rubric helpful in evaluating your peers' presentations?	18.92	45.95	21.62	13.51	0	0	64.87
19	Did the binary system of the IOP rubric provide the right amount of detail in evaluating your peers' presentations?	16.22	48.65	21.62	13.51	0	0	64.87
20	Was the IOP rubric an accurate method of grading your IOP presentation?	16.22	59.46	16.22	0	8.11	0	75.68
21	Which elements of the IOP rubric were least clear (select up to	text response						
22	How would you reword one of those elements?	text response						
23	If a scale score were used instead, how many levels would be best (1 – 10)?	10 levels or 5 levels preferred by roughly 40% each						
	Thinking about the TDP rubric:							
24	Did you find the TDP rubric effective at teaching you how to prepare your presentation?	27.03	51.35	16.22	2.7	2.7	0	78.38
25	Did you find the TDP rubric effective at teaching you how to prepare your presentation?	29.73	45.95	18.92	2.7	2.7	0	75.68
26	Was the TDP rubric effective at assessing the engineering design process that your team followed?	40.54	43.24	10.81	5.41	0	0	83.78
27	Was the TDP rubric an accurate method of grading your TDP project and presentation?	29.73	59.46	10.81	0	0	0	89.19
28	Which elements the TDP rubric were least clear (select up to	text response						
29	How would you reword one of those elements?	text response						
30	If a scale score were used instead, how many levels would be best (1 – 10)?	10 levels majority by 48%, 5 levels 27%						
31	Would a peer-evaluation of teamwork have been helpful for	Yes 65.	No 35.14%					
32	Suggest one improvement to the TDP rubric?	text response						

Appendix B - Rubric for Individual Oral Presentation

Binary Check sheet Rubric for IOP

From Target™

1. Demonstrates understanding by discussing how the source material builds ideas
2. The Problem is clearly stated
3. There is consistent Evaluation of source material that supports the problem
4. There is ongoing discussion of multiple perspectives
5. Conclusions are drawn from clear logic supported by the evidence

Presentation skills

Organization

6. There is a logical sequence to the topics
7. The takeaways are clear
8. The talk progress from general to detailed information

Visuals/Slides

9. Text size is appropriate
10. Slides clearly convey the message
11. Each slide serves a purpose
12. There were no technical errors in the slides
13. Images/Figures were clear
14. Graphics consistently support the presentation

Timing

15. Stayed within total allotted time
16. Topics are uniformly paced

Speaking

17. Student did not read from notes excessively while speaking
18. Spoke fluently, without hesitation, excessive interruption, or fillers

Nonverbal Communication

19. Maintained eye contact with the audience
20. Used gestures or laser appropriately

Appendix C - Rubric for Team Design Project

TDP Grading Rubric

Creativity

1. Novelty of design
2. Used materials in a new way

Performance

3. Followed all competition rules
4. High Quality Craftsmanship
5. Performance in Competition (0 – Did not meet design goal, 1-5 based on best time)
    a. 5pts – less than 1 min [0,1)
    b. 4pts – 1 - 2.5 min [1,2.5)
    c. 3pts – 2.5 – 4.5 min [2.5, 4.5)
    d. 2pts – 4.5 – 6 min [4.5, 7.5)
    e. 1pts – 6+ min [7.5, 15]

Engineering Design Cycle

6. Demonstrated Problem Solving approach
7. Showed consideration of multiple concepts or ideas
8. Described the Engineering Design Cycle by showing iterations, drawings, calculations, etc.
9. Showed evidence of material testing, component testing, and final design testing prior to competition day

Project Management –

10. Stated project goal
11. Articulated series of steps or processes to achieve goals
12. Determined, procured, and optimized all resources needed
13. Created and maintained budget
14. Demonstrated that the project goal was met
15. Each Team member held a project management role

Presentation

Organization

16. There is a logical sequence to the topics
17. Lessons-learned are clear

Visuals/Slides

18. Slides clearly convey the message
19. There were no technical errors in the slides

20. Images/Figures/Text were clear

Timing

21. Stayed within total allotted time
22. Each presenter contributes equally to the presentation

Speaking

23. The students did not read from notes excessively while speaking
24. Spoke fluently, without hesitation, excessive interruption, or fillers

Nonverbal Communication

25. Maintained eye contact with the audience
26. Used gestures or laser appropriately