REDESIGNING ASSESSMENT: THE DESIGN AND IMPLEMENTATION OF A RUBRIC-BASED ASSESSMENT SYSTEM TO IMPROVE ENGINEERING DESIGN EDUCATION

by

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Abstract

Engineering education serves to provide society with competent engineering graduates, capable of making a difference to their profession and the world around them. Since the Grinter Report of the 1950s in the United States, engineering education has focused its approach upon improving the technical and analytical competencies of engineering students. Many practicing engineers find that recent graduates are adequately developing their technical skills but are lacking in a deep-knowledge of engineering's core creative process: design.

Although there has been an increase in design instruction in some engineering programs, there is typically a lack of focus on related assessment, which forms a key part of the educational process. Students focus their efforts upon that which is being graded, resulting in students focusing on achieving deliverable requirements rather then on deeply learning the process and techniques of engineering design.

The research question asked was: will students be more likely to achieve core course objectives and learning goals in an intensive, multidisciplinary course by using a well tailored rubric-based assessment process, in comparison to a more "traditional" course assessment scheme? Traditional course assessments often focus upon

the success of a final deliverable for students to achieve a good mark, and in design courses can focus on the success of the final product.

Student opinion towards its implementation and value in helping them reach learning goals was surveyed to determine the usefulness of the rubric in helping to reach course objectives and learning goals. These surveys indicated: strong student support for the use of a rubric system; a positive student response to the feedback being provided to them through weekly rubric-based advice; the rubric provided a suitable level of detail to be helpful to students in achieving course objectives; students were capable of internalizing the learning goals and using the assessment system to evaluate their peers; and finally that the assessment system was a viable alternative to traditional course assessments.

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Chapter 1. Introduction

The goal of undergraduate engineering instruction is to "ensure that graduates of accredited engineering programs have the skills they need to become productive members of the profession" (Canadian Council of Professional Engineers, 2008). In striving to do so, engineering educators take an active role in developing curriculum, instruction material, assessment methods, and delivery systems to help students become productive members of the profession, and of society in general. Students enrol and participate in a variety of courses during their tenure at Canadian universities, covering a broad range of subjects. Of these fields of study one of the most critical is engineering design. Tom Brzustowski, former President of the Natural Sciences and Engineering Research Council of Canada (Presented at Canadian Design Engineering Network conference, Montreal, 2004), defines design as the "central creative process" of engineering. As it is plainly apparent how important engineering design is to a student's development, improving upon design education can reap benefits for the student, the profession, and society. While design is one of, it not the most, important elements of engineering, it has not taken its rightful place within the curriculum. For over 40 years, engineering education has become more theoretical and analytically focused, losing some of the emphasis on the creative process, including design (May,

2006). Recent work has been done, including the development of the NSERC Design Chairs program, to help tackle this shortcoming. Acknowledging that design is critical and lacking has led to a push to improve the amount and quality of design instruction that students receive.

The research that follows strives to reach these goals of increasing the quality and quantity of design education by beginning with an understanding that students learn best from that upon which they expend effort. Furthering this is an appreciation for student behaviour, where they expend energy based on what is being evaluated and graded. Starting with these two postulations, this research strives to design an improved assessment method to focus student efforts, and therefore learning, upon core education objectives. The study then gauges student opinions towards the use of a markedly different assessment method. Finally conclusions and recommendations are drawn about how students experienced the alternative assessment method. Additional conclusions for future improvements in implementation and iterations of the assessment system's design are also included, with further proposals for future research.

1.1. Assessment of Design

In an attempt to improve student learning, educational research findings were combined with practical experience. Clear links have

been drawn highlighting how students focus their efforts on that work for which they are being evaluated (Oehlers & Walker, 2006), (Brinkman & Geest, 2003). While improvements to assessment methods and implementation can yield benefits for the instructor, the most important factor tackled in this research problem is the emphasis on student comprehension and awareness of learning objectives and course goals. By tailoring a student's course assessment, and therefore directing their efforts, the aim was to determine if students would respond positively to an assessment system designed with achieving learning goals as the express objective.

With this in mind, an experimental assessment system was designed in an attempt to utilize and articulate the learning goals of a multidisciplinary design course at Queen's University at Kingston, *APSC 381: Fundamentals of Design Engineering*. This design involved utilizing a process similar to what students were learning in APSC 381, involving problem definition, idea generation, and working from conceptual design to a testable prototype. APSC 381 was selected as a test course due to its intensive and multidisciplinary nature, in addition to a willingness on behalf of the course instructor (Prof. D.S. Strong, P.Eng.) to strive to improve his courses. Using previous research into assessing non-analytical skills in a discipline-free environment (Strong & Fostaty Young, 2007), it was decided to focus

on the impact that a rubric-based system could have on helping students to accomplish the learning goals set for them. The system was designed to highlight learning goals found in design literature (particularly *Tools and Tactics of Design*, (Dominick, et al., 2001)), incorporating the pre-existing course objectives as set out by Prof. Strong, based on his extensive professional design engineering experience. The focus of the course, driven by the learning objectives, was to help students gain the ability to use design process to create innovative solutions to satisfy a stated need. In addition, students were taught and expected to learn and apply a variety of design tools and techniques. These "tools and techniques" fall into a broad category used to describe a host of approaches that an engineer can use when tackling a design problem. These range from procedures for decision making (such as weighted evaluation matrices and Quality Function Deployment), project management (Gantt charts and group management approaches), and business choices (cost-benefit analysis) to brainstorming techniques (TRIZ) and project risk and reliability analysis mechanisms (such as Failure Modes and Effects Analysis). Tools generally describes discrete and widely practiced procedures an engineer or engineering student can use to help solve a particular problem encountered while designing. Techniques are defined as more general approaches used to deal with issues within a

phase of a design process, potentially involving the use of one or more specific tools. While the composition of the skills applied to each project is different, the goal is for students to be able to use the appropriate techniques to the benefit of their project within the context of the design process, the scope and constraints of the user need.

Academic literature and practical experience suggest that traditional 'checklist' assessment schemes do not necessarily encourage students to meet the desired design learning objectives. Therefore, using a design methodology similar to that which was being taught to students, the Alternative Assessment Method (AAM) was developed by the author to help articulate the complex and numerous learning goals as efficiently as possible. This efficiency is achieved through optimization of providing students with a level of detail and description of the learning goals that they can use effectively, while avoiding making the AAM any more complicated, long, or overly detailed then necessary.

1.2. Methodology

In order to gauge the level of student acceptance for a different assessment method, as well as their appreciation for the articulation of learning goals within the system, a qualitative analysis procedure was followed. Using the expertise and experience of prominent qualitative

researchers such as Patton (1980) and Creswell (1998), a case study approach was used to develop a package of information for interpretation. These interpretations, and their subsequent verification, emanated from the rigorous adherence to this methodology. Student acceptance of a rubric-based system is essential to ensure that it will be used by students in the intended manner. Other assessment schemes run the risk of students “check-marking”, or just completing deliverables so they can receive a grade for them, not because they used them to advance their understanding of the course material. With this rubric system one of the goals was to avoid this, and to help students use deliverables to advance their understanding. If students can appreciate, and express this appreciation, for using the rubric-based system then their support is indicative of an effort to use the scheme to improve their understanding of course material.

1.3. Recommendations

The research study has culminated in conclusions relating to students’ willingness to adopt alternative methods of course assessment, their feelings towards the specific mechanics and implementation of an ICE-based [an acronym for *Ideas, Connections, Extensions* developed by Fostaty-Young & Wilson, (2000)] rubric assessment system, and recommendations for improvements in design and implementation of the ICE-based system.

Chapter 2. Literature Review

2.1. What is Engineering Design?

Design is often employed when discussing any number of occupations or hobbies, but within the context of the engineering profession, it is important to understand it as the "central creative process" which drives engineering and innovation (Brzutowski, 2004). Despite differing definitions of design, it is critical to realize that one cannot have engineering without design. In an attempt to improve understanding of design as an area of research and instruction, most engineering design textbooks tend to define design in terms that allow for a thoughtful critique of previous work, and permit improvement on techniques, tools, or processes. According to Dym and Little:

> "*Engineering Design* is the organized, thoughtful development and testing of characteristics of new objects that have a particular configuration or perform some desired function(s) that meets our aims without violating any specified limitations" (C. L. Dym & Little, 2000).

The nuances of engineering design cannot necessarily be captured in a summary definition and are worthy of discussion on their own. As Dym and Little state the "organized, thoughtful development and testing" implies a well defined procedure for moving from an idea or need, through to an artefact (be it a product, procedure or system) that can be tested and validated. The procedure, usually known as the

(engineering) design process, is important for ensuring that the results of the endeavour are the best available solution to the stated need. That need is seen above as having “a particular configuration” or “performing some desired function(s)”. What makes the exercise challenging, and worthy of an engineer’s efforts, is the recognition of limitations. Constraints and limitations, be they economic, physical, cultural, environmental, or temporal, challenge the engineer to design something for more than purely aesthetic concerns. In fact, engineering work at its core should serve the public interest, something the Canadian Academy of Engineering clearly states:

> “Engineering is a profession concerned with the creation of new and improved systems, processes, and products to serve human needs. The central focus of engineering is design, an art entailing the exercise of ingenuity, imagination, knowledge, skill, discipline, and judgment based on experience. The practice of professional engineering requires sensitivity to the physical potential of materials, to the logic of mathematics, to the constraints of human resources, physical resources and economics, to the minimization of risk, to the protection of the public and the environment” (Canadian Academy of Engineering, 1999)

If engineering is at its heart designing within constraints for the benefit of society, and engineering institutions strive to teach students to become the best engineers they can, then it stands to reason that

instruction in design methodology and design tools should take a critical place in those students' tutelage.

2.2. Engineering Education & Engineering Practice

In as much as practicing engineers must constantly improve their methodologies, knowledge of codes and standards, and awareness of the changing needs of society, engineering educational institutions must adapt their instruction techniques, curriculum, and attitudes to fit the teaching in which they are engaged. However, the demands of engineering practice has far exceeded, in pace and scope, the evolution of engineering education (Eggert, 2002). This divide between industry practice and education, including the resultant expectations of practitioners for recent engineering graduates, is clearly illustrated in a recent Master's thesis, *Engineering Design Education: Education Meets Industry* (May, 2006). As accredited Canadian institutions have an obligation to the society that entrusts them (through their licensing bodies), there is onus on these institutions to ensure that engineering students of the highest quality, ethical standard, and professional training are being awarded diplomas, with all their rights, responsibilities, and privileges.

The first step to understanding the divide is to examine instructional methods, particularly how they relate to teaching engineering students design techniques. Although there have been

improvements to instruction, much of engineering teaching relies on the lecture/tutorial format. The use of interdisciplinary and industry-sponsored design projects has become more widespread and is frequently perceived as an improvement on traditional instruction methods (Ivins, 1997), (Keefe, Glancey, & Cloud, 2007). Other design courses introduce elements on competition (Paulik & Krishnan, 2001) or place an emphasis on problem-based learning (Benjamin & Keenan, 2006). The traditional methods of the lecture/tutorial format usually involve several classes per week accompanied by a tutorial or laboratory session to support the material in the lecture and allow for more hands on practice. Resource constraints, a lack of will to change, or a level of comfort with the practice might all play a role in keeping this as the norm within the standard Canadian four-year engineering program. As May points out, many programs teach design tools and techniques as part of a “capstone” course (May, 2006). These projects act as a summary activity of an engineering students’ education; involving usually, but not necessarily, some instruction on design process, tools, and best practices. However students are often judged, and subsequently graded, on the quality of their final product, rather than the learning of the design process and tools which a student can then demonstrate. Dym suggests that engineering education should be the study of systems, and the system of systems

(C. Dym, 2004). Teaching engineers the process of design is critical, more so than the success or failure of a final product. He even quotably suggests that design should be “the cornerstone of [the] engineering curriculum, not the capstone” (C. Dym, 2004).

May’s work brings to light a gap in expectations that practitioners have of engineering graduates, as well as graduates false perceptions of their own abilities in several key areas. May recommends that the content of the engineering curriculum be adjusted as well as the method of instruction improved upon. If instruction is to be part of the focus, it is important to understand what constitutes “instruction”. Instruction includes not only tangible pieces of information transferred from teacher to student (such as processes, tools, and techniques) but also the assessment processes used by the teacher to evaluate the students’ performance (McMillan, 2007). As such, efforts to improve all aspects of instruction are important to “providing a comprehensive engineering design experience”, which is “an important part of any undergraduate engineering program” (Paulik & Krishnan, 2001).

2.3. Improving Instruction

Understanding that improvements to instruction are necessary to enhance the quality of design education, it is important that we recognize the educational outcomes students should achieve.

Unfortunately, most engineering programs spend the first few years of the curriculum focussing on an “engineering science” model (C. Dym, 2004), being courses taught by mathematicians and physicists. This is regrettable, as “…content related to material and technical processes is characterized by rapid obsolescence while technological mental processes remain relatively stable and continue to be useful for many years…the primary emphasis should be placed on mental processes” (Hill, 1997). This lack of permanence suggests that great improvements can be brought about not only by improving the amount of design education within a curriculum, but improving the quality of the design instruction. Clarification of the learning objectives that design instruction attempts to achieve is important for both the student and the instructor. Instructors are better able to assess the learning being demonstrated by students, and students, through increased clarification, and are able to focus their energies on absorbing and applying the lessons being learned.

In order to recognize the value of clarifying design education objectives, it is first important to understand the different approaches to design instruction present in the literature available to instructors and students.

2.4. Engineering Design Literature

Design textbooks can be divided into two principle categories; those that choose to tackle the tangible quantification of the design process, which often include explanation or elaboration on some design tools and techniques, and those books that choose to confront the philosophies of design, and how they can affect an engineer's holistic perspective of the work in which they engage. Moving from the latter to the former allows for a "big-picture" to "detailed approach" appreciation of existing literature.

Henry Petroski, in his book *Invention by Design*, uses an interesting approach to communicate the challenges, expectations, and lessons of engineering design to readers, while fully conveying critical points of the design process. Using simple, illustrative examples of 'classical' engineering products, problems and systems, Petroski focuses on many of the key lessons that an engineering student would hope to learn from engaging actively in the design process (Petroski, 1996). This book is important from both an historical and illustrative perspective, as it strives to underline the permanence of the *process* involved in design engineering.

Realizing the goal of and inspiration for designing, Petroski goes on to elaborate on the nuances of the design process. Creating a relationship between cantilever beam research during the early history

of science and the persistent problem of broken pencil leads, Petroski explains that analysis is a critical part of an engineer's work. He uses the example of broken pencil lead to explain how analogies can be used to increase the understanding of an engineering problem. If one compares the behaviour of the pencil tips to that of a cantilevered beam, much information can be shared between the two. This understanding of behaviours, failure modes, and analysis techniques for one can be easily applied to the other. The ability to draw comparisons and relationships can be critical to a designer's success (Petroski, 1996).

One of the finer points of design, the long, iterative process of going from conceptual design to popular product, is explained using the journey that several consumer goods underwent before achieving commercial success. Velcro, zippers, and Ziploc bags are used to illustrate how a product can undergo much iteration, create many spin-off products, and undergo many improvements before reaching common acceptance (Petroski, 1996).

Many other aspects of design education are discussed and considered by Petroski, including constraints and influencing factors in design, societal benefit, and safety. While *Invention by Design* is helpful in appreciating the overall goals of engineering design, its use as an instructional guide is limited within the current teaching context.

In contrast to Petroski's mostly holistic approach, there are a number of books that attempt to quantify the design process, and its accompanying tools and techniques, into a more technical practice. Two principal texts were reviewed in order to highlight differences in the way that the design process can be explained. Gerald Voland, in his book *Engineering by Design*, uses a 5-step cycle to describe the design process, and strongly emphasises the theme of 'iteration' (Voland, 2004). Beginning in the *Needs Assessment* phase, Voland has the process moving into *Problem Formulation*, *Abstraction & Synthesis*, *Analysis*, and finally *Implementation*. Voland highlights the need for iteration, and describes how it can begin at any point within the design process. Throughout the book Voland reflects on many highly technical points, such as creating classifications for problems and defining design specification categories. Voland's book strives for technical definitions of the design process, but in many instances fails to relate the goals of the design process and its key milestones to objectives that can be relayed to students.

In contrast to Voland's 5-phase process, Dominick et al in *Tools and Tactics of Design* utilize a four-phase model for the design process; beginning with *Defining the Problem*, then *Formulating Solutions*, *Developing Models & Prototypes*, and finally finishing with *Presenting & Implementing the Design*. Within each phase there exist

four major steps to outline what is involved as a designer moves through the design process. Dominick, et al. stresses the importance of iteration throughout the process, as well as the importance of involving others in the design, beyond just the designers themselves. Bringing in people of different disciplines and in different positions along the development chain is essential and Dominick, et al. makes a strong case for this early in the book (Dominick, et al., 2001). In parallel to the discussion about how to move through the different phases of the design process, Dominick, et al. discusses four critical skills that engineers need to succeed (in designing as well as in other endeavours). He extracts these skills from professional experience as well as ABET (Accreditation Board for Engineering and Technology) requirements. *Decision Making, Project Management, Communication*, and *Collaboration* can be well demonstrated by students through active and experiential work with design projects. Most importantly, Dominick, et al. demonstrates how these four skills can be learned in each of the different phases (2001). This translation of skills in terms of milestones is important for students as it allows them to see a direct impact on their professional skills and provides progress markers in what can be a confusing process.

In addition to those discussed above, a broad body of design literature was reviewed, not only to increase familiarity with the

material and research being performed, but also to find resources to supplement the design of the rubric-based assessment method. While books such as Dym & Little's *Engineering Design: A project-based introduction* (2000), *Engineering Design Methods* (Cross, 2000), and *The Mechanical Design Process* (Ullman, 2003), were among books reviewed, and no doubt helped to shape the design literacy landscape, they failed to assist in the design of the alternative assessment method (AAM). Dominick, et al.'s *Key Concepts* and *Key Steps* division, which will be discussed later, was highly influential in being able to create a rubric-based assessment system that students and instructors could easily use. The usage of this core division, created within Dominick, et al.'s book led, to the adoption of some of their definitions and terms related to the design process, in preference to those outlined in other books.

Lacking in these books, as well as other design texts and literature, is a discussion about assessment or feedback that could be provided to students. While the detailed design process explanation is useful, without proper feedback to ensure students' achievement of the outlined goals, both the entire exercise and the students fail to reach full potential. One might assume that the authors have chosen to leave this up to instructors, but another interpretation may simply be that assessment is not typically seen to be sufficiently important to

justify inclusion. However, despite the lack of attention that assessment receives in design textbooks, there is a body of literature, in engineering journals, as well as educational books and journals, that does consider assessment.

2.5. Assessment's Importance to Learning

If improvements are to be implemented within undergraduate engineering curriculum, it is important that these advancements are coupled with appropriate and relevant assessment methods. Olds points out that advancement of engineering education depends on assessment (Olds, Moskal, & Miller, 2005). This is corroborated by Rompelman who believes that assessment is highly related to the goals of engineering education (Rompelman, 2000). To advance one without the other would fail to achieve their common objectives, and as such assessment is important to the design education of undergraduate engineering students. Recent literature has stated it plainly:

> "A renewed emphasis on instruction in engineering design … [has] exposed a crucial need for formal methods for evaluating design courses. A well-grounded assessment plan has three components: a statement of educational goals, a valid set of instruments to measure achievement of these goals, and a plan for utilizing the results from the assessment to inform policies to improve the educational process" (Safoutin, 2000)

In order to ensure that the assessment methods employed in an improved engineering design program are meeting their objectives, it is important to first understand if it will have an impact on students. This needs to be contrasted against existing issues to make the case that improvement is necessary. It is then crucial to ensure that the methods are sound, linked to appropriate performance and mastery indicators, and address the objectives of the course and/or program. To aid in the evaluation of these factors, it is also important to review other work done in the field and address challenges that have occurred, or might arise, as a result of the implementation of an improved assessment system.

2.6. Students Respond to Quality Assessment

The importance of assessment to the learning process cannot be overstated; Oehlers plainly points out that the assessment portion of the teaching process has been overlooked as a method of driving the students' approach to the material, regardless of the instruction method used (Oehlers & Walker, 2006). This is furthered by Brinkman who straightforwardly states "Students are only human, and their grades are a prime motivator for working hard" (Brinkman & Geest, 2003). Thus improvement and iteration of the assessment techniques used to gauge students' mastery of the design process can be considered a venture worth tackling. If "the assessment process drives

the student's learning method" as Oehlers (Oehlers, 2006) says, then it is worth refining assessment to help create a long-term and deep appreciation of the material. Not only can student assessment form the basis for aiding the students' learning method, it helps to craft the environment and relationships that the student forges with the instructor, the material and their peers (Brookhart, 2003). The environment in which a student learns material is important to ensure a deep-understanding and appreciation for the information, which should be the goal for the instruction of a significant mental process, such as the design process. Bailey & Szabo agree:

> "Rigorously assessing students' design process knowledge is essential for understanding how to best create learning environments to facilitate the development of such knowledge" (Bailey R, 2006)

Once a learning environment has been created that encourages and fosters a deep appreciation of the material, students are free to form positive relationships with the instructors, classmates, and the material itself. These positive relationships lead to a deeper understanding of the material as opposed to a surface approach which requires memorization or reproduction of knowledge (Ditcher, 2001). Ditcher cautions, however, that the over-use of assessment tasks creates an environment were students focus on meeting the assessment targets, and as such succumb to a 'surface' level of

learning, as opposed to learning the material in depth and developing an appreciation for it (Ditcher, 2001). This indicates that instructors must take care to ensure that assessment tasks (often known as deliverables) should be meaningful and relevant to the learning being performed, as well as being aware of the perceived value to the students. Assessment needs to be an important part of the teaching process, not just an “add-on” (Ditcher, 2001). Once the stage has been set for the implementation of quality assessment, it is important to define its parameters. First, specific elements of assessment tools will be discussed, and then these can be linked back to the previously discussed constituents that make assessment an important part of the learning process.

2.7. Creating Quality Assessment

The case has been made for the implementation of high quality assessment methods, but it is important to define what makes a quality assessment. Tackling the task of evaluating the learning achieved when students engage in an open-ended design project is no easy venture, as they do not lend themselves cleanly to ‘finely-tuned’ assessment (Gibson, 1998). To address this, what is being assessed first needs to be clear and well defined. Students learn best and understand more when they are aware of the criterion that is being applied to them. (Pellegrino, Chudowsky, & Glaser, 2001). Harkening

back to Brinkman's previous comments, students will focus their energies on what is being assessed. If the criterion by which they are being graded is unclear or ill-defined, then students will focus their energies on trying to decipher the goals of their deliverables rather than focusing on improving and meeting evaluation measures.

Assessment, on a broad scale, can be broken into summative and formative elements. Summative assessment can be defined as "assessment that occurs at the end of an instructional unit to document student learning" while formative assessment is described as "assessment that occurs during instruction to provide feedback to teachers and students" (McMillan, 2007). While it is important to use both methods, formative assessment has been shown to be one of the "most effective instructional methods" for improving student learning (Commission on Engineering and Technological Systems, 1991). By providing feedback to students, formative assessment methods help to show areas of deficiency as well as areas of mastery. This has a dual purpose in helping to motivate students and focus their efforts, as well as reward previously accomplished work. By providing feedback to instructors they are able to adapt teaching methods, topics, and timelines to ensure that the material is being absorbed and internalized by the learner. Further to this, the Commission on Engineering and Technological Systems points out:

> "Summative assessments provide information about students' understanding of domain knowledge, but are usually not systematically used as a learning opportunity for students" (Commission on Engineering and Technological Systems, 1991)

This indicates that although summative assessment methods are often easier for instructors to manage, their failing as a learning tool prevents them from truly helping to advance a courses' learning objectives. Summative assessment, as described by Brookhart, requires that assessors become members of a community of practice, whereas when formative assessment is used assessors and learners become members of the same community of practice (Brookhart, 2003). This relationship is important as both the instructor and the learner should be striving towards the same goals and objectives. A case can still be made for summative assessment to be used to document learning accomplishments of students over a period of time (that is, from one learning period/course to the next), while formative assessment should be the primary focus of evaluators during course instruction.

Formative assessment can be closely linked to the principles of "Assessment *as* Learning". Table 1 - Characteristics of Assessment of Learning, for Learning, and as Learning below highlights a few of the key differences between various approaches to assessment as described by McMillan. The motivations to shift assessment to a blend

of ‘for learning’ and ‘as learning’ can be plainly seen as offering advantages over the alternative ‘of learning’ approach. With students more engaged in the learning process, there are multiple benefits including improved understanding, increased confidence, and heightened engagement with the material (McMillan, 2007).

Table 1 - Characteristics of Assessment of Learning, for Learning, and as Learning

Assessment *of* Learning	Assessment *for* Learning	Assessment *as* Learning
Summative	Formative	Nature of assessment engages students in learning
Certify learning	Describes need for future learning	Fosters student self-monitoring of learning
Conducted at the end of the unit; sporadic	Conducted during a unit; ongoing	Conducted during a unit of instruction
Often uses normative scoring guidelines; ranks students	Tasks allow teachers to modify instruction	Emphasizes student knowledge of criteria used to evaluate learning
Questions drawn from material studied	Suggests corrective instruction	Student selects corrective instruction
Used to report to parents	Used to give feedback to students	Fosters student self-monitoring
Can decrease student motivation	Enhances student motivation	Enhances student motivation
Delayed feedback	Immediate feedback	Immediate feedback

(McMillan, 2007)

In order to take full advantage of a ‘*for* learning’ approach, which is formative and instructive to the student and teacher, an appropriate assessment method must be employed. It is thus proposed that rubric assessment methods serve the dual goals of grading students and providing feedback to instructors and students.

Rubrics are scoring guidelines that "differentiate between levels of student proficiency" (McMillan, 2007). While there are several methods of employing rubrics, using various scales and measurements, Young & Wilson make a persuasive case for the implementation of the *ICE* rubric system (2000). The ICE (Ideas, Connections, Extensions) approach of assessment is a technique for measuring the degree to which students are moving through different stages of learning, from novice through expert. ICE is similar in many ways to Biggs' and Collis' SOLO taxonomy, but is designed for increased portability and utility by students and instructors (Strong & Fostaty Young, 2007). Lessons learned from the application of the SOLO and ICE systems when applying them to *APSC 190: Professional Engineering Skills*, as discussed in Strong & Fostaty-Young, led to the use of the economical ICE scheme. These lessons included improved reliability between raters (teaching assistants in APSC 190), the development of an appreciation for the interconnection of information in meaningful ways, and the promotion of a common language with which to communicate learning objectives during the course (Strong & Fostaty Young, 2007). The ICE approach uses three different stages of learning. "*Ideas"* represents the basic building blocks of learning. Within this stage, students should be assessed on their understanding of the basic steps involved in a process, the necessary vocabulary, and

an introductory skill set. Secondly, students progress to the "*Connections"* stage. Connections occur when students are able to demonstrate they understand relationships between different elements learned in the *Ideas* phase. Ideally, students progress to mastery of the topic in the "*Extensions"* stage. At this stage, learners internalize the material and are able to develop new learning on their own (Fostaty Young & Wilson, 2000). The ICE approach allows for instructors to fully articulate the level of a student's understanding of the material. It also allows for instructors to provide feedback on what students must do in order to advance to the next stage of comprehension. It is important to understand that ICE rubrics are different than 'Good, Better, Best' methods of scoring, also known as rating scales (McMillan, 2007). Some rubrics look to assess students on a sliding scale, essentially a 1→ 5 or 1 → 10 scale where the target is the ability to do a task better with a corresponding increase in score. With an ICE rubric, students are being assessed on their ability to demonstrate different levels of understanding, not just an increase in proficiency.

Several other factors must be accounted for when designing an assessment system that applies to the teaching of the design process. While these are likely applicable to many other topic areas, they are deserving of special mention in light of the challenges in assessing

such a critical, yet holistic, mental process. Firstly, it is important that much of the assessment is performance-based. As described by McMillan, performance assessment can be defined as a "type of assessment in which students perform an activity or create a product" (McMillan, 2007). This mirrors the design process itself. This is supported by Brookhart who feels that "the more performance-based the assessments, the more the line between assessment and instruction blur" (Brookhart, 2003). This helps reach several key objectives. By using existing demonstrations (reports, prototypes, and presentations) that are already required in most design courses, students are evaluated on the least amount of deliverables possible. This harkens back to Ditcher's advice about ensuring legitimacy of the assessment tasks, avoiding 'busy work'. It is also imperative that the objectives of the course are reflected in the assessment. Brookhart stresses "if students are to improve… [they] must develop a concept of the learning goal" (Brookhart, 2003). Oehlers relates the task clearly to the teaching of design:

> "…we strongly believe that if students are to be given designs that are intended to foster an ability to tackle messy open-ended real-world problems, then an assessment scheme must be in place beforehand to guide the students towards the sorts of learning outcomes that are being sought." (Oehlers & Walker, 2006)

While authors such as McMillan (2003), Hill (1997), and Paulik & Krishnan (2001) support this relationship between assessment and learning objectives, Raucent goes further, explaining that it is important that course objectives are designed to foster the acquiring of new knowledge and competencies, and as such assessment should ensure it is this element that is being evaluated, not just the ability to apply previously acquired capabilities (Raucent, 2004). This evidence strongly supports ensuring that the learning objectives of a design course are reflected accurately and succinctly in the assessment scheme being used to evaluate students. One author even suggests that assessment itself should be treated as a “structured, open-ended design problem” (Rogers, 2002). This approach is not only beneficial to the assessor, who gains the benefits of employing the iterative and functional design process, but also helps in the development of the assessment scheme, as integration between the learning objectives and the use of the design process is unavoidable.

Creating a holistic and comprehensive assessment scheme, for a subject as challenging as the design process, is not without hurdles. Simply stated, “Design is a creative activity that depends on human capabilities that are difficult to measure, predict, and direct” (Commission on Engineering and Technological Systems, 1991). There exist several distinct challenges with the development of an

assessment scheme, including, but not limited to: challenges with existing levels of assessment training on the part of the instructors; challenges with familiarizing students with the assessment scheme; challenges of making the assessment scheme relevant and applicable, without sacrificing validity; and challenges of ensuring that the assessment is process-oriented and focused on the learning of the design process, not necessarily the result of the project.

Educational experts who practice in the field of assessment are able to state plainly, “classroom assessment training is lacking” (McMillan, 2003). A lack of instructor familiarity with current assessment techniques can, and often does, limit the flexibility and innovation that can be applied to assessment techniques. This is mirrored by Keefe who cites a review of several other studies that show uncertainty on behalf of the instructors with regard to using good assessment practices (Keefe et al., 2007). This uncertainty results in ‘standard’ or ‘traditional’ assessment methods being employed, which leads to the assessment of design courses often being similar to established courses in mathematics and engineering sciences rather than reflecting the open-ended and process-based nature of design. Traditional assessment methods are ingrained in most institutions as a support for the standard model of teacher who is the expert passing down information for the student to assimilate (Benjamin & Keenan,

2006). The matter is not helped by existing guidelines for engineering curricula which fail to offer criteria or direction for assessing professional skills, such as communication (Brinkman & Geest, 2003), or design. The lack of training and familiarity on behalf of instructors and programme developers represents a significant impediment for improving design education amongst engineering students.

In addition to a lack of instructor familiarity with new and high-quality assessment approaches, students also help to reinforce a problematic approach to design learning. Reeves points out that the grading component of a design course studied was the greatest source of dissatisfaction amongst instructors and students (Reeves & Laffey, 1999). While it can be argued that a great amount of student resistance to 'new' assessment methods can be attributed to familiarity with traditional systems, researchers point out that students (as well as instructors) fall into a trap of being heavily results oriented (Raucent, 2004). This results in assessment being heavily focused on the success or failure of a final product or system, rather than focused on the learning and mastery of the design process itself. Other authors point out that students frequently find fault with assessment of group work (i.e. design projects) rather than seemingly more superficial concerns such as adequate division of work (Rompelman, 2000). Student concerns about assessment, coupled with the

aforementioned shortcomings facing instructors, combine to increase trepidation about modifying assessment schemes away from the traditional methods.

Ensuring that the design process is being adequately assessed, on the basis of student mastery versus the success or failure of a specific design project, is particularly daunting. The problem first surfaces when one tries to quantify *the* design process. Due to the subjective nature of the process, it is hard to define one particular process as correct (Bailey, 2006). This leads to complications in the sharing of information, including successes and failures in design process assessment between practitioners, due to difficulty in deciding on a common syntax for the material. Further, the use of existing assessment instruments is not necessarily appropriate for the open-ended environment that accompanies design projects (Safoutin, 2000). Examining the futility of traditional assessment methods (i.e. tests) is made worse when combined with instructors' lack of training and innovation in assessment. An earlier paper, by Hill, bluntly states that the assessment of technological processes and the associated problem solving skills is difficult (Hill, 1997). This caveat should not be interpreted as a barrier to proper assessment of student mastery of the design process, but rather can be perceived as a challenge to engineering educators and design practitioners.

Chapter 3. Methodology

The methodology employed in this thesis is markedly different from many others. This study utilized primarily qualitative analysis techniques, requiring a different approach to experiment design and observation.

3.1. The Multidisciplinary Design Stream at Queen's University

The setting for the research was the Multidisciplinary Design Stream (MDS) at Queen's University at Kingston. The two-course, three-term design stream is an optional pairing of courses for students in any discipline who wish to improve their design capabilities during the course of their engineering education. The MDS consists of a third year course, *APSC 381: Fundamentals of Design Engineering*, which runs in the winter term of a student's 3rd year and serves as a prerequisite for the 4th year course, *APSC 480: Multidisciplinary Design Project*, a two-term industry-sponsored design project.

Both APSC 381 and APSC 480 consist of design projects being tackled by teams of students from at least two different disciplines. APSC 381 fuses extensive instruction of design methodology with a concurrent project to emphasise application for deeper learning. APSC 480 is primarily focused on the project, with additional advanced instruction in design and project management. Third year students

are supervised directly by a teaching assistant, experienced with the course and well-versed in design methodology, with the course instructor being actively involved in certain projects as demand requires, while the 4th year students are overseen by a faculty supervisor in consultation with an industry sponsor. Both courses emphasize key elements of engineering design: its multidisciplinary nature; the role of constraints and limitations in design including budgets, codes, and standards; the importance of communication, teamwork, and collaboration; the open-ended and iterative nature of design; and a stress on learning the design process, not only on product success.

These, among other, learning objectives became the focus of improving the assessment methods being employed within the design stream. With learning being so closely tied to assessment, it was believed that improvements to instruction, in the traditional sense, should be paired to developments in assessment. By appreciating the learning objectives of the course, which will be further discussed in the design of the rubrics, a holistic approach to course improvement can be developed.

In order to allow for as many students as possible to engage in the MDS, APSC 381 and APSC 480 are taught as evening courses, to avoid conflicts with students' discipline-driven schedules. This

instruction is complemented by student team meetings in both courses (as determined by the team, but emphatically recommended as weekly), mandatory team-supervisor meetings in APSC 480, as well as other engagements as necessary, including site visits, on- and off-campus interviews, client meetings, laboratory visits, and conference calls.

Students in both courses had access to instructors and teaching assistants through regularly scheduled office hours, e-mail, and other meeting times which were scheduled as necessary. There was no limit placed on student-instruction team interaction and many students took advantage of additional, out-of-class time to ask questions, seek feedback, and informally discuss aspects of their projects, the course, and other academic concerns.

3.2. Assessment Methods

In APSC 381, students were evaluated using a relatively traditional model for engineering project-based course assessment. While small changes had been made to tweak the course evaluation scheme during the four years that the course had been offered, it remained relatively stable, focusing heavily on both interim and final reports/presentations, with interim deliverables also taking a key role in a student's final grade. The course assessment table for the 2007-

2008 academic year can be seen below in Table 2 -APSC 381 Course Assessment (2007-2008).

Table 2 -APSC 381 Course Assessment (2007-2008)[1]

Class Participation	10%	• Based on both attendance and activity in class
Logbook	5%	• To be maintained throughout the course. Should contain all notes, ideas, rough calculations, etc. related to the project, and may include class notes and/or a learning log. (Please separate sections if including notes and/or a learning log)
Weekly Memos	10%	• One weekly memo is due for EACH TEAM according to the course Activities and Assignments • It is expected that each student will complete at least TWO weekly memos Memo Template
Progress Reports	5%	• One progress report is due for EACH TEAM according to the course Activities and Assignments Progress Report Template
Interim Report (or Mid-term Exam)	10%	• Due in Week 7 Guidelines for Written Report Marking Template Detailed Tips for Engineering Report Writing
Interim Presentation	5%	• To be presented in Week 7 Marking Template
Final Presentation	5%	• To be presented in Week 11 Guidelines for Final Oral Presentation Marking Template
Final Report	40%	• Due in Week 12 Guidelines for Final Written Report Marking Template
Statement of Work/Peer Assessment	10%	• Details/dates on the statement of work and peer assessments are pending https://services.appsci.queensu.ca/courses/apsc381/peerreview Statement of Work Description Statement of Work Template
TOTAL	100%	

In addition to students being made aware of the mark breakdown at the start of the course, they are provided with templates for some deliverables (such as memos and progress reports) that provide examples of formats to be followed, templates for final and interim

[1] Underlined text links to other supporting web pages when students view the SCA online. Some example templates can be found inAppendix 1.

reports that provide example headings and sections, as well as breakdowns of how their reports and presentations will be graded.

Although all of the course work (with the exception of self/peer assessments) is performed as a group activity, students are given individual marks. This is explained to them at the outset of the course, and students are instructed as to how their mark will be computed, with some deliverables being shared among the group and some marks counting towards a personal grade. At the same time, it is stressed to students that all of their marks will be assigned on the basis of demonstrated knowledge of the design process and design tools. This is an important distinction from some other design courses, such as the multidisciplinary project assessment found in Ivins (Ivins, 1997) and the primarily computer-programming based project discussed by Ringwood (Ringwood, Monaghan, & Maloco, 2005) which evaluate, among many factors, the success/failure and performance of a student team's design. While within both APSC 381 and APSC 480 the success of the final project is considered in a student's grade, it is not as explicit as in these other examples. The implicit success of a project is tied to student's abilities to demonstrate the learning they have achieved.

Despite the APSC 381 evaluation scheme's (henceforth known as the Standard Course Assessment or SCA), efforts to grade students on

their knowledge of the design process and the use of design tools, through anecdotal student feedback, the SCA was still being used to a great degree as a 'check-list' for students to ensure that they were providing the correct deliverables rather than focusing their energies on showing that they were meeting the learning objectives of the course.

As discussed previously, students spend their time working on what is being assessed (Brinkman & Geest, 2003), and rubric assessment methods are effective at focusing grading criteria upon learning objectives (McMillan, 2007).

To better complement the course objectives of APSC 381, and based upon the work of Strong and Fostaty-Young (2007), an ICE-style rubric was implemented as a comparison tool to evaluate which system, the SCA or the rubric-based Alternative Assessment Method (AAM), better fulfilled the goal of increasing student learning.

3.3. The Design Process Model

Currently, with APSC 381, a version of the design process based on course creator and instructor Prof. David S. Strong's experience as a professional design engineer is taught. This is complementary to many of the design process models that are promoted in several available design textbooks. In order to create an ICE-method rubric for the AAM, it was decided to use a modified version of Dominick et al.'s

design process as seen in their book *Tools and Tactics of Design* (2001). This model closely mirrored Strong's model and allowed for some clear, documented articulation of design education learning goals.

Originally, the ICE-method rubric created for the AAM was designed to be implemented in the 4th year course, APSC 480. This was later modified to be implemented in the third year course to increase the number of students involved in using the AAM, while maintaining a sample size that was going to be easy for one teaching assistant to provide quality feedback to project groups. Additionally the teaching assistant-student relationship, specifically the TAs' role as a project supervisor, is much closer in APSC 381 and allowed for the author to gain more insight into the students' projects and attitudes, creating a closeness which is essential in qualitative analysis (Patton, 1980). This closeness prevents exact repeatability of a qualitative analysis, such as is desirable in quantitative study. What is gained however is a unique set of perspectives relating closely to the entire study environment, and assuming a verifiable and rigorous process, quality results.

The original design of the AAM involved mirroring Dominick et al.'s four-phase version of the design process in eight rubrics. Each phase was divided into two rubrics, representing the 'key concepts'

and the 'key steps' that Dominick et al. define in their book. The original four phases were *Defining the Problem, Formulating Solutions, Developing Models & Prototypes, and Presenting & Implementing the Design*. *Defining the Problem* can be briefly described as outlining the problem facing a designer, and determining the need for a solution. *Formulating Solutions* involves brainstorming, conceptual and preliminary designs, and refinement working towards *Developing Models & Prototypes,* the phase within which students attempt to create physical or virtual models and/or prototypes and test them with the goal of learning from their results. The final stage of *Presenting & Implementing the Design* involves not only determining the suitability of designs for market, sale, and use, but also ensuring the long term viability of the designs by taking into account recyclability and repair concerns. These phases represented the basic four phases being taught in APSC 480. However, in moving the assessment scheme to the third-year level, modifications would be removed. Since students in APSC 381 are not required to design a prototype nor employ a detailed virtual or physical model, it was unnecessary to use the third phase, *Developing Models & Prototypes* in their evaluation[2]. The original framework of Dominick et al.'s design process was useful due

[2] Although students in APSC 381 are not required to create models or prototypes, they are encouraged to do so should they demonstrate significant progress and interest. If this is the case, students are provided with the resources, both institutionally and fiscally, to enable appropriate levels of prototyping and/or modeling, as has been the case in previous iterations of the course.

to its simple nature, but detailed approach to learning objectives. The detail, and hence usability, of Dominick et al.'s model is most evident when observing the division they create between 'key concepts' and 'key steps'. The *Key Concepts* portion of each rubric is designed to help to foster an understanding of and appreciation for the importance of a particular phase to the overall design. The concepts addressed in the *Key Concepts* rubric represent the core of the phase being assessed, striving to clearly demonstrate the learning objectives that the instructor would like to impart to the student. To complement this, the *Key Steps* rubric relates to the more tangible steps undertaken when progressing through the particular phase. These can take on a very practical element, in terms of using tools or interpreting results, but may also represent some underlying theories that are important for the student to master. By separating the overall learning objectives from more specific, task-based objectives and evaluating a student on both concurrently, the goal is for the student to gain an appreciation of both, while helping them to shift their assessment 'comfort zone' from the ingrained traditional assessment methods to a more holistic approach. This holistic approach involves evaluating students on their demonstrated improvements on reaching learning goals and course objectives, rather than grading them on an improvement in performance on just completing a deliverable.

3.4. Designing the Alternative Assessment Method

Once a design process model was selected on which to base the rubric, it was important to evaluate the learning objectives of the course and correlate the two to develop an assessment method that helps both the instructor and the student. The goals of APSC 381 were taken directly from the course website as seen below in Table 3 - Design Tools Taught in APSC 381 and Table 4 - Professional Skills Taught in APSC 381.

Table 3 -Design Tools Taught in APSC 381

Design Tools		
Design Methodology	Problem Identification	Market Research
Quality Function Deployment (QFD)	Conceptual Design Techniques	Design for Assembly and Manufacturing
Failure Modes and Effects Analysis (FMEA)	Reliability and Quality	Six Sigma Considerations
	Feasibility Studies	Prototyping

Table 4 - Professional Skills Taught in APSC 381

Professional Skill Set		
Project Management	Leadership Skills	Oral and Written Communication
Multidisciplinary Teamwork	Fundamentals of Business Finance and Marketing	Safety, Liability, Intellectual, and Regulatory Compliance

These objectives were complemented with information garnered from the APSC 381 course notes.

As mentioned earlier, two rubrics were developed for each of the phases of the design process. *Key Concepts* represent the relationship between each phase and the overall design process. *Key Steps* are the

tangible steps in which an engineering designer would likely become involved as they develop a design. The individual elements of these rubrics were created as a fusion between the steps outlined in Dominick et al. for each of the phases: the skills drawn from the book as being important for engineering students and practitioners; expertise in teaching and TAing by the author and supervisor D.S. Strong; and information collected from APSC 381 and APSC 480 course notes. It was important to maintain the theoretical nature of the *Key Concept* rubric and the more tangible nature of the *Key Skills* rubric to avoid confusion by the students as they use the rubrics and move through the design process. Also of great importance was the desire to avoid an exclusively "Good, Better, Best" form of rubric that would stray from the goal of using an ICE approach. It should be noted that some elements do not reach the "Extensions" level of abstraction that is part of the ICE methodology. This is due to an appreciation that some of the tangible skills that are present as learning objectives are more proficiency-based than some of the more conceptual learning goals. As a result, some rubric elements fail to reach the "Extensions" level, and some are reminiscent of a "Good, Better, Best" grading scale rubric. However, their placement within the rest of the rubric elements and the ICE structure lends a degree of weight and heft to elements that might otherwise not be perceived as

important to students. The assessment implications are discussed further in 3.6 Implementation of the Alternative Assessment Method.

Designing the alternative assessment method (AAM) followed a process similar to what was being taught to students in APSC 381. Beginning first with the notion that students' design capabilities could be improved by increasing their design proficiency through quality assessment, the needs of this assessment began to develop. Background research was conducted (as seen previously) and conceptual designs were established based on idea generation based on the research. Using an iterative process, the design of the AAM was refined to remove unnecessary duplication or overlapping of assessment elements. This helped improve the efficiency of the rubric by minimizing unnecessary elements. Further iteration was performed to improve language to remove ambiguity and prevent assessment elements from being overly prescriptive. Iteration developed with input from the multidisciplinary design stream instruction team, as well as comments received from the engineering design community on presented conference proceedings (Woodhall, 2007) (Woodhall & Strong 2007).

3.4.1. Phase One: Defining the Problem

3.4.1.1. Key Concepts

In the *Key Concepts* stage of the first phase, it was important to get the students started on the right footing for the rest of the project. As such there was a strong emphasis on the development of a thorough background body of knowledge through adequate research, a stress on discovering requirements, constraints and limitations, as well as on establishing a solid team relationship from the outset. Conceptual tools for developing the team direction have also been emphasised to help students appreciate fully how important defining the problem is to the overall track of the project. The first rubric can be seen below in Table 5 - Defining the Problem: Key Concepts.

3.4.1.2. Key Steps

The *Key Steps* stage is important to defining the overall course of the project because it puts the need for students to demonstrate into tangible requirements: deliberation of the problem statement; consideration of functional requirements based on customer need; attention paid to project constraints and limitations; development of a project plan that is reasonable and sensible. These steps are highlighted in the second rubric, Table 6 - Defining the Problem: Key Steps.

Table 5 - Defining the Problem: Key Concepts

Element	Ideas	Connections	Extensions
research doesn't limit options or scope	research covers basics of problem and potential solutions	research sources stretch beyond web based searching	research materials include interviews, surveys, review of existing solutions, search into patents, regulations, standards
	library resources are utilized, sources are academic/credible	there exists significant questioning and challenging of information	research does not exclude any potential solutions but remains open ended
uses appropriate tools	uses tools such as objective trees, sketches, etc	is able to convert outputs into tangible criterion for design (either functional requirements, additional 'bonus' features, or constraints/limitations)	strengths/weaknesses of different tools are highlighted, others are used to complement/correct for those strengths/weaknesses
			sketches, objectives, etc. are iterated as the project moves
recognizes differences between functional requirements and constraints/ limitations	requirements and constraints are clearly delineated and articulated	client suggested requirements/constraints are separated from user defined requirements/constraints	is able to iterate requirements over time if they change, and able to introduce new limitations as they arise
acknowledges team/interpersonal hurdles, uses appropriate strategies/tools to overcome	recognizes team strengths, potential weaknesses is knowledge	addresses concerns or disagreements early	work is fairly distributed, allowing for learning and growth by each team member as well as utilizing their strengths
	define working parameters for the group, including meeting times, communication methods	communication is open and positive in idea generation, brainstorm, design selection activities	team member responsibilities are clearly defined before each milestone/meeting and are met by deadline

Table 6 - Defining the Problem: Key Steps

Element	Ideas	Connections	Extensions
forming the problem statement	statement is loosely defined statement accurately reflects project needs	statement is multidimensional in nature; showing constraints and potential strengths	statement shows awareness of human factors, resource constraints, and client need statement is aware of potential biases from client needs, terminology
identifying functional requirements	takes client need and converts it into necessary product performance needs identifies the WHO as well as the WHAT of the problem	is able to separate needs from wants is able to determine what the end user needs (if not necessarily the client)	able to show potential strengths/weaknesses in relating different functional requirements is able to qualify which are most important to project success, which are the greatest hurdles
recognizing constraints and limitations	understands given constraints from client foresees operational concerns/pitfalls	is able to articulate other constraints/limitations not directly specified by client is able to see constraints/limitations for the life cycle of the project	is able to differentiate between true limitations and unnecessary or overcomeable hurdles is able to overcome limitations or turn them into strengths
defining a schedule and forming a team	group memos and progress reports are submitted on time and with appropriate formatting Gantt chart is clear, follows acceptable timelines, adequately explains project 'flow' team prepares a working agreement and abides by it for duration of project	memos show insight into group operations, progress reports adequately show project progress to date and future goals work is fairly distributed, providing opportunities for all members to actively contribute	memos and progress reports form a clear timeline of project completion and group development Gantt chart is revised as project progresses team dynamics issues are addressed and overcome

3.4.2. Phase Two: Formulating Solutions

3.4.2.1. Key Concepts

The overall objective of the Formulating Solutions phase is to refine the ideas that students have been developing, using design tools such as brainstorming, TRIZ (the theory of inventive problem solving), and various types of weighted evaluation matrices. At this stage, it is also important for students to ensure that they have included non-analytical but extremely important factors such as economics, risk, regulatory compliance, environmental concerns, and other elements that are included in the decision making process. This can easily be one of the most lengthy and daunting phases of the design process, and it is important to stress to the students how they should approach this phase methodically, using the tools available to them, rather than acting purely on 'gut' feeling or initial perceptions; they need to 'prove' their design choices.

3.4.2.2. Key Steps

The smallest of the six rubrics being used, the *Key Steps* rubric for the second phase is less 'deliverable' based than other phases. This denotes a shift in focus that results in assessment elements not being tied closely to one rubric over another. Rather students should be demonstrating these assessment elements throughout the term, in all of their deliverables. Students here need to demonstrate that they

have adequately defined their design parameters when making their choices, and that sufficient time and energy has been devoted to pursuing alternatives. Two of the elements of the rubric do not have an extensions-level objective. This is because the tasks of 'identifying alternatives' and 'evaluating/analyzing alternatives and selecting a solution' does not reach that the level of cognitive function as was intended in the ICE literature (Fostaty Young & Wilson, 2000). The *Key Concepts* and *Key Steps* rubrics can be seen below in Table 7 - Formulating Solutions: Key Concepts and Table 8 - Formulating Solutions: Key Steps.

Table 7 - Formulating Solutions: Key Concepts

Element	Ideas	Connections	Extensions
Multiple solutions are investigated	students investigate, discuss, and pursue several different options for design	ideas show different approaches to dealing with the problem	potential solutions are carried through
		potential solutions are aware of client need	both "origination" and "innovation" are explored
Brainstorming and decision making tools are used fully and appropriately	constructive brainstorming leads to innovative solutions	decision making tools such as QFD, weighted matrix, etc. are used to evaluated potential solutions	multiple tools are used, expertise (people or information) is sought out to aid the decision making process
	a decision is made on a design from potential ones based on information and reason		
Design issues are worked through to completion using appropriate tools and information	problems with chosen design are identified	TRIZ, FMEA and other tools are used to help work through potential design problems	design is complete and thorough
	solutions from similar designs/products/processes are investigated to determine possible solutions	ideas from different potential designs are integrated to create the best possible solution	insurmountable issues are identified and discussed
Non-technical factors are taken into account in choosing a solution	economics for each potential solution is included in the decision making process	economics of chosen solution receives fair consideration	economics of chosen solution is investigated, then improved to help the project
	potential impacts of the design on people, the environment, etc. are researched and discussed (risk)	patents, regulations, and 'people' factors are investigated and discussed	patents, regulations, and 'people' factors are investigated, and used to improve the design

Table 8 - Formulating Solutions: Key Steps

Element	Ideas	Connections	Extensions
Defining the design parameters	students find out the real user needs, through surveys, interviews, and research	user needs are separated from client needs	needs are used to create different design options
identifying alternatives	brainstorming and other idea generation tools are used to help create alternatives	lateral thinking is clear in the options pursued by the design team	
evaluating/analyzing alternatives and selecting a solution	an evaluation of alternatives is performed and a 'winning' design selected	design choice is based on client and user need, feasibility, and evaluation of design constraints	

3.4.3. Phase Three: Presenting & Implementing the Design

3.4.3.1. Key Concepts

Originally Phase Four, with the elimination of the prototyping and modeling assessment elements *Presenting & Implementing the Design* becomes the final phase used in this study. Although it is the final phase presented, its elements actually run throughout the course. Students should walk away with concepts that stress the review and iteration of the project during its life span, as well as upon conclusion of work, with special recognition for future steps and acknowledgment of shortcomings within the team and design. The team dynamics are also highlighted, showing an emphasis for cooperation and acknowledgement of group weaknesses. The project life cycle is also taken into account, with long term quality and product life concerns playing a part. These are shown in Table 9 - Presenting & Implementing the Design: Key Concepts.

3.4.3.2. Key Steps

The key steps elements for this phase is large, but very deliverable heavy. Because the AAM was designed to work in concert with the existing SCA and deliverables schedule, the key steps for this phase highlight many of the major deliverables. The important distinction is that the content of the presentations and reports that

make up the bulk of SCA marks is evaluated in various elements of the AAM. For example, if in an interim presentation a student discusses the brainstorming tools they used, this would not be part of their presentation mark, but rather would help demonstrate learning done in the *Formulating Solutions* phase. As a result, the report and presentation elements in the final phase have an emphasis on the language, tone, and clarity of the deliverables. This allows students to appreciate both an emphasis on the content of their presentations, as well as the communication skills that are essential to professional engineering (Voland, 2004). The elements that evaluate reports and presentations can be seen in Table 10 - Presenting & Implementing the Design: Key Steps coupled with elements that encourage a student to demonstrate their knowledge of production and implementation plans for their products, as well as an understanding of market and customer demand.

Table 9 - Presenting & Implementing the Design: Key Concepts

Element	Ideas	Connections	Extensions
Project Review & Iteration	project was reviewed at the end of the project and areas of strength & weakness are identified	weaknesses are identified and corrections are proposed	future problems with the design are acknowledged and discussed
Life Cycle & Quality Consideration	reliability, dependability, and maintainability are examined	disposability/recyclability are examined	disposability/recyclability solutions are developed
		solutions for reliability, dependability, and maintainability concerns are developed	all life cycle/quality considerations are developed into a comprehensive maintenance/life cycle plan for the client
Team Dynamics, Project Planning, and Individual Contributions	team dynamics are discussed	review of group discussions and work distribution is completed	impact on the project of group dynamics is discussed
	self assessment/statement of work is completed	self and peer assessments are accurate and fair	analysis of planning tools, review of planning process used and its impact on the project
	peer assessments are completed		

Table 10 - Presenting & Implementing the Design: Key Steps

Element	Ideas	Connections	Extensions
Present Interim Design	presentation is accurate, clear, and well presented presenter is clear, articulate, patient and rehearsed	the presentation tells a logic story of the design presenters evenly divide the work and share their efforts in their area of 'expertise'	the presentation acknowledges successes and shortcomings presentation is a persuasive demonstration of learning completed and learning still yet to be completed
Present Final Design	presentation is accurate, clear, and well presented presenter is clear, articulate, patient and rehearsed	the presentation tells a logic story of the design presenters evenly divide the work and share their efforts in their area of 'expertise'	the presentation acknowledges successes and shortcomings presentation is a persuasive demonstration of learning completed and areas of future development
Interim Report	report has appropriate spelling, grammar, formatting, and length references and research is accurate, appropriate, and properly cited	report is clearly laid out, understandable, and attempts to answer the readers questions	report is concise, smooth-flowing, and effective in presenting the design and progress to date to the client
Final Report	report has appropriate spelling, grammar, formatting, and length references and research is accurate, appropriate, and properly cited	report is clearly laid out, understandable, and attempts to answer the readers questions	report is concise, smooth-flowing, and effective in presenting the design and final product, as well as future considerations to the client
Implementation/Production	implementation plans are developed for all aspects of the design	implementation from a client as well as user perspective is understood and acknowledged	implementation plan seeks to solve potential problems
Market & Distribute to Customer	Understanding of Customer distribution, sales, and service systems	Relates marketing/economic concerns to client and user needs	

3.5. Qualitative Analysis

A qualitative research methodology was adopted for use in this study. There are several reasons for a qualitative approach over a quantitative one. These include: the ability to more holistically appreciate the students' perspectives; providing a detailed description of the implementation of the AAM; the ability to understand the situation as a whole, in the students' own terms; the goal of developing detailed accounts for a subset of a specific population. Qualitative research differs from quantitative approaches, allowing the researcher "to understand more about human perspectives" while "providing a detailed description of a given event" (Leydens, Moskal, & Pavelich, 2004). This approach helps advance the body of work on engineering educational assessment by providing a broad base for improvements to be made in the future. Patton goes further to explain one of the core differences in qualitative research.

> "Qualitative designs are naturalistic in that the researcher does not attempt to manipulate the research setting. The research setting is a naturally occurring event, program, relationship, or interaction that has no predetermined course established by and for the researcher. Rather, the point of using qualitative methods is to understand naturally occurring phenomena in their naturally occurring states." (Patton, 1980)

Observing and interpreting students' opinions within the naturally occurring state ensure that the information is legitimate and useful. This heavily contrasts with experimental research where the investigators strive to control as many of the conditions as possible, limiting the number of variables being influenced during the trial (Patton, 1980). The current lack of information supporting the environment surrounding rubric-based assessment drove the necessity to include the "detailed descriptions" that Leydens depicts. Understanding people in their own terms is a distinct element of qualitative research (Patton, 1980). Due to the highly descriptive and text heavy nature of the rubric, and the way in which subsequent feedback is provided, it is important to appreciate students' feelings, interpretations, and opinions in their own terms, helping to refine the rubrics for future use. These interpretations provide the detail required for the specific subset of a population (engineering students engaged in multi-disciplinary design projects) that make qualitative methods appropriate over quantitative methods (Leydens et al., 2004).

Qualitative methods are not without their detractions however. While quantitative results provide numerical descriptions of human perceptions that lack the detail available in qualitative findings (Leydens et al., 2004) , they are shorter, and often easier to analyze than a qualitative approach which is more variable in content, and

lacking a systematic pattern to responses (Patton, 1980). Criticism of qualitative research usually relates to a seeming lack of rigor or a misunderstanding of its purposes. As a result of its inherent differences, the approaches to establishing trustworthiness are different then quantitative counterparts (Leydens et al., 2004). These different approaches will be discussed below, and then implemented in the

Analysis & **Discussion** chapter. The use of qualitative methods in engineering education is made more difficult by the fact that the majority of engineering educators have quantitative research backgrounds (Leydens et al., 2004) , which can unduly influence their implementation and the adoption of their findings.

3.5.1. Ensuring a Qualitative Environment

Part of valuable qualitative research methodology is to ensure that the qualitative analysis is performed in an environment where a research attempts to get close to the study and its subjects. As Patton describes,

> "The strategic mandate to be holistic, inductive, and naturalistic means getting close the phenomenon under study. The evaluator using qualitative methods attempts to understand the setting under study through personal contact and experience with the program." (Patton, 1980)

Patton further explains that the evaluator should not make attempts to manipulate or control program developments, but instead adopt the changing reality that might occur during the research study (Patton, 1980). This dynamic approach to research and its eventual conclusions differs somewhat from a typical quantitative approach. However, this does not detract from the validity of a qualitative methodology. As described below, steps must be taken to ensure the trustworthiness of qualitative analysis.

3.5.2. Implementation of a Qualitative Analysis

In order to properly implement a qualitative research methodology, it is important to ensure that the execution is rigorous and adheres to the stringent 'best practices', similar to more familiar quantitative methods to which most engineering education researchers are accustomed. In his book "Qualitative Inquiry and Research Design: Choosing Among Five Traditions", John W. Creswell discusses five standards that should be applied to all research, both qualitative and quantitative in nature, as a list of questions that an evaluator should have of a research study:

1) Assess a study in terms of whether the research questions drive the data collection and analysis rather than the reverse being the case.
2) Examine the extent to which the data collection and analysis techniques are competently applied in a technical sense.
3) Ask whether the researcher's assumptions are made explicitly, such as the researcher's own subjectivity.

4) Wonder whether the study has overall warrant, such as whether it is robust, uses respected theoretical explanations, and discusses disconfirmed theoretical explanations
5) The study must have “value” both in informing and improving practice and in protecting confidentiality, privacy, and truth telling of participants.

(Creswell, 1998)

These five qualities have been addressed in this study, as summarized below. The research questions, as the basis for the trial, begin with the background evidence presented earlier. A combination of research findings led to the question of how a rubric-based assessment scheme could be properly implemented to improve student mastery of design skills. Combining educational research into the effects of assessment upon educational outputs (deep-appreciation for learning objectives), with a lack of design proficiency in graduating engineers (primarily based on E.E. May), directed the use of the AAM. The data collection and analysis techniques discussed in this chapter, and their results found in the Analysis & Discussion chapter strive to show how rigorously acceptable qualitative inquiry procedures were applied. Researcher subjectivity is inherent in a qualitative methodology, as qualitative analysis is so closely linked to context. The author’s

background as a young male, raised in a working-middle class and relatively large family, is important to providing depth and detail to the interpretations made to the data in this study. A more in-depth biography can be found in Appendix 2, creating an acknowledgement for potential biases in interpretation. Additionally there is a level of bias that enters into the analysis as a result of the designer of the rubric-based system, the evaluator of student work, and the qualitative researcher all being the same person (the author) as well as the subject students' teaching assistant. While this does lend a level of bias, Patton (1980) points out that it is important for qualitative researchers to be close to the subject(s) of study. The fourth criterion, the overall warrant of a study, can be measured by the stout nature of the qualitative analysis techniques described below, employed to ensure robustness and rigor. Lastly, the measure of the study's value can be seen plainly by contrasting the overall outcomes of the study and the recommendations at the end of the thesis, against the previously existing deficiencies outlined in the background section.

In attempting to determine the best qualitative methodology to apply when performing an analysis of the student information, various approaches were compared. Creswell presents a comprehensive comparison for five traditional approaches. He lists and describes these as follows:

- Biographical – a study of an individual and their experiences through oral retelling or archival materials
- Phenomenology – a study of the meaning of the lived experiences for several individuals relating to a phenomenon, or concept
- Grounded Theory Study – an attempt to generate or develop a theory about a phenomenon that relates to a particular situation
- Ethnography – a description and interpretation of a cultural or social group or system
- Case Study – an exploration of a 'bounded system' over time through detailed, in-depth data collection; the case being bounded by time and space

(Creswell, 1998)

A quick review of these five basic qualitative approaches helps to guide which qualitative data collection and analysis tools would be most appropriate. Biographical studies are not appropriate due to the amount individuals involved (as opposed to one particular student's experiences). Despite this group being the subject of study, a phenomenological study is inappropriate as these types of study usually involve exploring the structures of human consciousness (Creswell, 1998). Although this might have a role in improving student

mastery of the design process, the goal here was to determine the role that rubric assessment schemes play. Grounded Theory has gained popularity amongst many social scientists and is rooted in an approach to generate a theory about a particular situation out of observations about it (Creswell, 1998). Its core approach can be compared to a reverse of the traditional scientific method which begins with a theory, and then is tested through experimentation to prove or disprove its existence. As no theory is sought regarding the implementation of the alternative assessment method, the grounded theory approach is also unacceptable. Ethnography is more heavily suited to observations and interpretations of a group's behaviours, as a demonstration of their culture, rather than as a test framework for an educational experiment (Creswell, 1998). A Case Study approach however provides several tools for collecting and analyzing data from the implementation of the rubric assessment method. In order to properly use a case study approach, it is important to have multiple sources of information, which lead to the use of three different feedback mechanisms from the students involved (Creswell, 1998). This further lends itself to improved verification of the data, a topic to be discussed later. It is also used to bind the case, which was done by confining the study to a set group of students over the length of one term within the course APSC 381. By reviewing the principal methods of qualitative inquiry, a

model was found that lent itself to the development of data collection and analysis methods.

When designing a qualitative evaluation program, Patton stresses that there are several different approaches available to a researcher. These are made of three principle elements, the type of inquiry, the type of measurement, and the type of analysis (Patton, 1980). It was determined that the “Pure Qualitative Strategy” would be most appropriate for this study. This strategy is composed of naturalistic inquiry, qualitative measurement, and content analysis. Naturalistic inquiry requires that the researcher does not manipulate the research setting (Patton, 1980). This is an important element for this study for two principle reasons. First it allows the students’ environment and perceptions to add context to their responses, more so than would be available in a sterile research setting. Secondly, from a pure logistical standpoint, it allowed for easy observation without the potential problem of student complaints over which assessment method was applied to them (assuming that a control and subject group would be established, with each group being exclusively evaluated using one method over the other). The qualitative measurement involved in a pure qualitative strategy has the advantages discussed earlier about providing context and meaning to the observations by using the participants’ own words. For this study

one quantitative survey was implemented, but this was to verify the information using a principle called triangulation which will be discussed shortly. Content analysis allows for the interpretation and evaluation of the text itself that participants are presenting (Patton, 1980). This contrasts to a statistical analysis which requires quantitative data.

The use of qualitative information involves four phases. In addition to the data collection phase, Patton describes the remaining three as analysis, interpretation, and evaluation. He goes on to describe them as non-technical processes with no formal universal rules to follow. Generally speaking, analysis is the process of bringing order to the data, interpretation entails attaching significance and meaning to the ordered data, and evaluation involves assigning value to the interpretations (Patton, 1980). Although the collection methods and analysis techniques will be described below, their results, interpretations and evaluations can be found in the Analysis & Discussion chapter.

3.6. Implementation of the Alternative Assessment Method

The AAM rubric was introduced to 31 students of the APSC 381 class containing 96 students in the winter term of the 2007-2008 academic year. The class previously supplied preferences for upwards of 10 different projects of an available list of 24 options. Students were

broken into teams of 4 (with two exceptions, one team of 3 and one of 5) that were comprised of students of at least two disciplines. These teams were then divided amongst three teaching assistants, at random, with one exception, where a particular project's requirements made a specific TA necessary. The teams that were being supervised by the author were those that were exposed to the AAM, while the other two-thirds of the class were only exposed to the SCA.

Students in the subject group were made aware of the SCA with the rest of the class during the first lecture of the term, before they were divided into their teams. The course instructor reviewed the SCA with the class, including elaboration on the templates and marking schemes being employed by the instruction team, with time allowed to address any student questions. Once students were divided into their teams, the subject group arrived early for the following class at the author's request. These students were distributed a survey as shown in Appendix 3.

Students were asked their student numbers only for the purposes of correlating responses between surveys, and were assured that in no way would their responses relating to the AAM be tied to their final grade in APSC 381 in any way.

Students were shown the SCA again, and asked to fill in a handout with their initial impressions. They were then handed each a copy of

the AAM, including all six rubrics, and given a few minutes to peruse the handout. Students were then asked to fill in the second and third questions relating to the AAM and the usefulness of the AAM vs. the SCA. Students were then walked through the AAM in detail, with the author providing explanation as to the difference between Key Concepts and Key Steps, the continuous nature of the rubrics, an elaboration of the ICE-method being employed, and examples of what would constitute reaching all the learning objectives for random elements in each of the rubrics. Students were provided time to ask questions and then they were asked the second and third questions from the survey again, having them fill in their responses on the back of the sheet. Finally, for a reference purpose only, it was asked if the student has previously used a rubric assessment method before in any classes.

After the survey was collected, students received an explanation of how the dual-marking nature of the course deliverables would work. In order to maintain fairness and equity amongst official marks in the class, students would have to submit deliverables according to the course syllabus, and using the existing marking schemes. However, student teams would also be assessed using the rubrics to determine if they were meeting or exceeding course learning objectives. The onus was placed on the students to demonstrate their learning within the

standard course deliverables. This meant that the author was first grading student work based on the SCA, and then re-evaluating student work using the AAM and providing students feedback each week. The means for capturing this feedback was by way of a rubric-sheet that had comments and suggestions. Students could compare this to the fully completed rubric they were given at the start of the project to evaluate where they needed to go and areas requiring improvement. Coupled with this, students were provided verbal feedback as necessary when work was being returned to them, and were encouraged to contact the author any time for advice or clarification on either the SCA requirements or the usage of the AAM rubrics.

The feedback that students were provided attempted to confine as closely to the *Ideas, Connections, Extensions* framework as possible, but in some cases this was not necessarily possible. One of the most important elements of the AAM's design was the use of Dominick, et. al's *Key Concepts* and *Key Steps* division. This served to separate some elements of the students' learning goals into higher level concepts and more straightforward, technical, course objectives. As a result some elements of the AAM focused upon measuring an increase in proficiency. Additionally, some elements in the AAM *Extension* phases might be perceived as being an increase of proficiency over the

Connections level, but this was due to an effort to avoid becoming overly prescriptive. It was explained to students that to achieve *Extensions* level it was necessary to show the synthesis of knowledge and the development of unique learning based upon previous assessment elements, however what was listed on the rubric was merely a guide to show what *might* be acceptable to achieve the *Extensions* level. When students were evaluated week after week using the AAM, they needed to demonstrate synthesis of knowledge in order to achieve the *Extensions* level. Those groups that failed to do so in a particular week received both oral and written feedback helping them to understand what might lead to the next level.

Students' opinion and usage of the rubric was measured in other ways as well. After interim reports were returned and interim presentations completed, students were surveyed about their usage of the rubric when working on these deliverables. Students were also asked to grade their fellow students using the rubrics during the final presentations. The teams present in one of two groups, resulting in the control group evaluating about half of their peers and helping provide feedback through the use of hand-out marking sheets. The subject teams were only required to mark the other subject teams presenting, which allowed them more time to complete the rubrics. This exercise

was to increase student appreciation for using the rubrics from a grading perspective.

The goal of the three deliverables was to first capture student opinion, acceptance, and thoughts about using the rubric and what it offered them in an attempt to increase their stake in the evaluation process. The use of the mid-term surveys was to evaluate if the assumptions and interpretations from the initial survey were being followed through, and lastly the student-completed rubrics were to evaluate if the students had developed the patience and/or ability to engage in peer-assessment using a relatively complicated assessment tool. Multiple methods allowed for not only easy tracking of changing student opinions, and the development of new insights, but also helped to validate the results as discussed below.

The three surveys were designed in a similar manner to both the AAM and the design structure that was being outlined to students in APSC 381. A draft of an initial survey was developed by the author, attempting to acquire information about AAM use from students. From this initial survey, ideas evolved from brainstorming and were refined to their final product through iterative design and consultation with course instructor, Prof. Strong. Constraints such as student willingness to participate, demanding time constraints, a need for thick, rich description (as set out in Patton), and the necessity to avoid conflicting

with students' existing course requirements were all taken into account. The product was a series of surveys that attempted to capture as much viable context as possible, providing insight into how students were using the AAM, how they felt it stood up against the SCA, and if they were truly able to use it for peer evaluation (a proxy to gauge personal understanding of what the AMM was attempting to evaluate).

3.7. Qualitative Description

The first pieces of information that were gathered on the student attitudes towards the AAM resulted from the survey seen in Appendix 3. Following Patton's process for constructing case studies, it was first important to assemble the raw data. This involved entering, verbatim, student responses to the questions into a spreadsheet. It was important to capture the students' comments exactly as they were written because "detailed, thick description" supplements the validity of the information being used (Creswell, 1998). This first stage allows for analysis and interpretation to begin. It is then important to begin constructing a case record. This is a method of organizing, classifying, and editing the data to a "manageable and accessible package" (Patton, 1980). Using the holistic-inductive approach, that is the hallmark of good qualitative research (Patton, 1980), led to the development of the case record. Rather than "imposing pre-existing

expectations" (Patton, 1980) the raw data was laid out, question by question, and general trends began to form. It was specific words and phrases of the student responses that allowed for the development of identifiable groupings for each question. As interpretations of the responses developed organically, no hard and fast pattern seemed to develop immediately. While many represented continuums from one extreme to the other for particular questions, others offered insight into student motivations, opinions, and enfranchisement with their educational experiences. Other responses acted as standalone indicators, unique from those of a student's peers. As Patton suggests, once the case record is completed, which allows for interpretation and annotation of some responses in order to make the data more useable, a case narrative should be developed. This narrative, located in the Analysis & Discussion chapter, is an evaluation of the interpretations made in the case record, and should provide a holistic picture of the program through the eyes of those who experienced it.

3.8. Qualitative Verification

Verification of qualitative analysis consists of two basic elements. First there is a measure of the confidence that the researcher has in their analysis of the data. The second is a measure of external validity, by presenting the information and analysis so that others can verify the findings on their own (Patton, 1980). To improve the confidence in

the information, three principle qualitative verification procedures were undertaken: rival explanations, negative cases, and triangulation.

"Rival explanations" is a method of searching for alternative theories that might be supported by the data. Patton suggests that this method be approached both inductively and logically. This means that not only must the evaluator look for other methods of organizing the data that could lead to a different set of findings; they must also develop alternative possibilities and then determine if they are supported by the data (Patton, 1980). Although the caveat is made that a clear "yes or no" answer is not likely, it is important to document and consider "the weight of evidence" in making a decision related to alternative theories. The lack of support of alternatives helps to prove the standing findings being developed by the evaluator (Patton, 1980).

The method of negative cases is, in essence, an analysis of outliers and deviations within the data set. While qualitative analysis allows for the development of trends and their subsequent interpretation, by studying the negative cases evaluators can be led to "the most important analysis" (Patton, 1980). This technique is crucial to a study such as this, which produces some strong outlying student opinions, creating the basis for future improvements to the AAM and its implementation.

The last qualitative verification method utilized was triangulation, which is the result of comparisons made between either methods of data collection or keeping methods constant between different data sets (Patton, 1980). Due to the nature of this study, it was decided that the most effective method of triangulation would be to use several slightly different methods, and compare their results in order to add weight to the outlying cases and strengthen the validity of the qualitative conclusions made. As a result, three slightly different surveys were used. The first, being entirely qualitative, was used to gauge student attraction to the AAM. The second, being partly quantitative, allowed for easy interpretation of student activity with the AAM, enabling the contrasting of activities with intentions while avoiding any bias introduced by repeating the same questions. The last survey, being a participatory qualitative exercise, allowed for students to demonstrate their enfranchisement, further validating conclusions drawn from the first two tasks.

Through the use of these three verification methods, the results produced and discussed in the Analysis & Discussion chapter can be compared to well established procedures for quality qualitative analysis. Detailed descriptions of the verification results can be found in the aforementioned section.

The methodology and techniques used for this thesis are different than many others. However, the fusion of research techniques is indicative of a cross-disciplinary study such as this. Initially the experimental setup would appear to lend itself to the introduction of confounding variables, being factors that might cause the appearance of correlation, but in fact convolute the findings. Concerns that the author was the designer of the AAM, the designer of the surveys, and the surveyor can be overtaken by reiterating Patton's expertise on qualitative study:

> "The strategic mandate to be holistic, inductive, and naturalistic means getting close the phenomenon under study. The evaluator using qualitative methods attempts to understand the setting under study through personal contact and experience with the program." (Patton, 1980)

This requires that the evaluator be heavily involved in all elements of the phenomenon, in this case gauging student opinion and usage of the AAM. Closely adhering to the methods of experienced qualitative professionals is important to provide confidence in the analysis of the data.

Chapter 4. Analysis & Discussion

4.1. Ensuring a Qualitative Environment

For effective qualitative analysis, there are two essential elements to creating a rigorous qualitative environment. It is important for those performing the analysis to adhere rigorously to the techniques and methodologies established by professionals in the field, whose practice and previous work lends to the legitimacy of researcher's efforts. The confidence gained in solid methodology is rewarded by helping to satisfy the second element of a qualitative environment, which is external validity. This occurs through peer review and broad availability of data and information so that others can draw their own conclusions. Despite the inherent subjectivity of qualitative analysis, by using well established procedures and making the data available, the researcher's work should maintain the standards of a productive qualitative environment.

4.2. Qualitative Analysis

Students responded through three different surveys, each with differing response rates. Within a qualitative environment each response should be treated as unique and insightful, however for informational purposes, the response rates for the different surveys can be seen below in Table 11 - Survey Response Rates.

Table 11 - Survey Response Rates

	Survey 1	Survey 2	Survey 3
Distributed	30	31	93
Returned	29	21	65

Within each of the surveys there are also differing response rates for distinct questions. Some students answered all of the questions presented them, but others failed to complete responses in some cases.

4.2.1. Survey 1

The first survey provided to students was to gauge their interest, familiarity, and appreciation for rubric-based assessment methods. As suggested by Patton, every effort was made to avoid “imposing pre-existing expectations” (Patton, 1980). Analysis of this part of the case study involved first assembling the case data. This involved copying, verbatim, student responses to the six survey questions, into a computer spreadsheet for improved portability of the information. A copy of the verbatim responses can be seen in Appendix 4. Next, the information was assembled into a case record. The case record process is very involved and forms the basis for the first section of the case study. The case record involves editing the raw data, and organizing it, in this case, thematically. By doing this, a case narrative is able to be constructed. The case record process is described below, with a copy

of the case record attached in Appendix 5. The case narrative follows, drawing a “readable, descriptive picture” making the information accessible to the reader (Patton, 1980).

4.2.1.1. Case Record

In formulating the case record, student responses to questions were laid out and organized thematically. Each question did not have a pre-set group of categories, but following established procedures in Patton (Patton, 1980) for developing categories, several major themes began to emerge. The case record acts, as Patton points out, “[as] a condensation of the raw case data organizing, classifying, and editing the raw case data into a manageable and accessible package” (Patton, 1980). Each of the questions has its own case record, and consists of organizing the same responses in several thematic patterns. These patterns helped to develop the conclusions drawn below. Coupled with the conclusions are the justifications for the thematic arrangements which together create a case narrative.

4.2.1.2. Question 1

The first question, “What are your initial impressions of the existing assessment scheme?” was asked of students before they had seen the AAM, and was based on their knowledge of the SCA as discussed in the previous class by the course instructor. A total of 26 responses were received and several broad themes materialized. The

first broad category comprised 10 responses that made some mention of the SCA being *typical* or *standard*. Some illustrative phrases can be seen in Table 12 - Selected Phrases from Survey 1 below.

Table 12 - Selected Phrases from Survey 1

Standard	General	Well Defined
Cut and Dry	Basic	Expected

Amongst student responses there was some variability in comments as other themes began to emerge. Notably there was some shift in student opinion as to the level of detail associated with the SCA. Some described it as “very formal”, “rigid marks”, and having “detailed requirements”. This is contrasted by a number of responses describing the SCA as very general. Although not all students discussed the specificity/generality of the SCA, the majority supported the specific side of things, while a minority thought it was “not that descriptive”, “generic”, and lacked “clear expectations”.

Student comments expressing outward dislike of the SCA were minor, with only two students seeming to have a strong distaste for the assessment scheme in place.

With eleven different students commenting on the final deliverables, the feedback strongly suggested a dislike of the heavy weight for the final report. Some comments were more general acknowledgements of the end-of-term heavy weighting, such as students who said “emphasis on report overall” and “most marks from

final deliverables" whereas others suggested that the final report was worth too much, with one student suggesting that the SCA "does not take into consideration work done, just how the final report is".

In practice the intent of the SCA is to assess students on the work they do and their ability to learn the process involved in design, rather than the performance of their final product. Although this is the intent, the measurable elements in the SCA can be considered one-dimensional, in that they do not themselves add to a greater understanding of the material. This one-dimensionality seems to have influenced the comments student provided, with some of them failing to appreciate the process-over-product approach despite having this intention explained to them in class.

The weight of comments discussing the final deliverables is complemented by a similar number of responses discussing the interim deliverables. Some students complained about the relative weighting of deliverables, such as "strange that memos are worth the same as interim report" and "presentations should be weighted higher as they are an effective form of communication". A minority, but an articulate minority, expressed their disappointment in the SCA due to its inability to fully capture their level of learning, as exhibited by one student who said the SCA had "minimal marks for demonstration of progressive learning".

The first question showed overall that students had a range of opinions about the SCA and its use in class, many focusing on its shortcomings rather than its positive elements. Overall many students found fault with the relative weightings of deliverables, and what they perceived to be a lack of appreciation for the work they were doing throughout the term.

4.2.1.3. Question 2

Students were then asked “What are your impressions of the rubric-based assessment scheme?” This question was asked before the students were given a thorough explanation of the AAM and how it was to be used. The students were told little about the AAM at this point, and were allowed to read it over for a few minutes before commenting. Twenty-eight responses were received to this question and three major themes began to emerge.

The first detail that was obvious in students’ responses was a continuum in opinions about the ease or difficulty in using the AAM. Seven students commented generally on the ease of use that the AAM provides with such remarks as “easier to understand” and “easier to make sure points are covered”. One of the most telling comments was a student who said that the AAM made it easier to distinguish what is expected and what exceeds expectations. This implies a strong appreciation and knowledge for the extensions phase, without even an

explanation being required. Three students however felt that the AAM would be more difficult to use than the SCA. One enlightening comment came from a student who said “you took something very simple and made it difficult”. This comment is particularly interesting because it suggests an appreciation for the increased complexity of the AAM, but contrasts with general student opinions who either said positive things, or nothing negative, suggesting this acknowledgement was in the collective consciousness, but lacked the negative weight that this student associated with it.

The overall opinions of ease and difficulty can be further evaluated in relation to student comments which show a gamut of responses, which ranged from suggesting that the increased detail would be beneficial to the course and student projects all the way to those that felt the increased detail would be a hindrance. Some felt that the AAM offered a “detailed guideline of expectations”, that it “defines in detail what is required to get a specific mark”, and “lets students know what tools and ideas are required to get to the extensions level”. These 12 responses were contrasted by 8 from students feeling that the “large number of key concept elements is confusing”, that the AAM “looks like a lot more work”, and that it would be hard for students to “classify/ qualitatively describe where the project is”. Interesting, out of the responses to this question, is

the acknowledgement by some students that the AAM works to assess students on process and effort made towards learning objectives. It is also intriguing how many students framed this within a negative connotation. One student put it plainly, the AAM was “evaluating people on skills shown, not on actual product produced”, however in light of the rest of their comments, the implication was that this was counter to the objectives of the course.

Ten different students made comments relating to the process-over-product nature of the AAM. These comments, while not expressly solicited in the question, were appreciated and insightful, especially when contrasted with the conspicuous absence of anymore than the odd comment from the first survey question. Students stated frankly that they liked how the AAM made “learning objectives more clear”, “immediately presented a path for excelling”, and “nicely outlines the learning objectives of the course”. The comments that were negative in tone, but supposed that assessment of process-over-product was a bad thing, were especially insightful. These comments suggested that even without in-depth explanation of how the AAM would be used, students who were not supporters of a process-based learning focus were able to distinguish the AAM’s usefulness in this regard.

4.2.1.4. Question 3

Students were then asked, before hearing a detailed explanation of the AAM's implementation plan or usage, "Which system do you believe achieves the course objectives and learning goals of the course? Why?" Of the 29 responses received relating to this question, far and away the majority felt that the AAM better served the goals of targeting course objectives and learning goals. It is important to note that the students received no more information on these objectives and goals, beyond what was briefly outlined in other then the introductory lecture for the course. Fifteen students expressed preference for the AAM due to its ability to hit upon course learning objectives. Many were explicit in their support, saying the "rubric contains all of the course objectives and goals" and the AAM "tells you what the learning objectives are" while others were less explicit, making statements such as the AAM "promotes more in-depth understanding of the design process" and it "evaluates you on the skills you learn". An additional 9 comments were received that promoted the AAM due to the improved feedback that would be provided to them. It "acts somewhat as a guide" and "provides a learning path", providing feedback that one "can use to determine how to improve." A minority of students were ambivalent on the matter, with one student suggesting the systems complement each other and

another suggesting that both systems achieve the same goal. Three students preferred the SCA, feeling it was “to the point”, that grades would be higher with the SCA, and that it was “more clear”.

The students’ quick and frank discussion of the AAM’s perceived advantages of improved feedback and adherence to course objectives and learning goals strongly suggests that even without involved explanation or lengthy discussion, students were capable of quickly appreciating the reasons for using a rubric-based assessment method such as the AAM. This runs counter to what was discussed earlier about the process-over-product intent of the SCA, which some students were unable to recognize despite being provided with an explanation.

4.2.1.5. Question 4

After answering the first three questions students were given a comprehensive explanation of the AAM. It was made clear to them how it would be implemented in class, how it would be evaluated, how the ICE-approach was utilized, and what specific elements of the rubric would mean in terms of assessment. Terminology that might have been confusing or unclear was elaborated upon and students had the opportunity to ask questions relating to the SCA and the AAM. Students were then asked to flip their response sheets over, and answer questions 2 and 3 again, in light of the new information. Thus

the students were again asked “What are your impressions of the rubric system?” This question elicited 25 responses and 4 blanks. The responses were more definite in their language. A larger number of students expressed their concerns about the AAM while most still advocated its use. Supportive comments fell into three major justifications. Some felt that the rubric better hit upon course objectives, such as a student who commented that the AAM “specifically identifies important areas”. Other students felt that the rubric-based system made the assessment clearer, having a more defined structure. This camp commented that the “key steps component will add structure and direction to the project” and it would be easier “to see what needs done and what markers are looking for.” Lastly, some students advocated the AAM because it promoted a higher level of learning, peppering responses with phrases such as “encouraging creativity”, “promoting further investigation into topics, not just skimming”, and “helps encourage learning.” Eight students made comments suggesting that the AAM was going to be difficult or hard to use. Most of the comments related to the perceived subjectivity that would be exhibited by the marker when evaluating student work. Many felt it would be “fairly difficult to actually assess with” and that it was “more complicated than it needed to be”. This type of comment increased over the same question before the

explanation, implying that students were possibly overwhelmed with the explanation of how the AAM was to be used. To counter this, students would likely benefit from more practical examples and guidelines to show them that the system is less subjective than the SCA.

4.2.1.6. Question 5

Students were also asked after the explanation to answer again question 3, “Which system do you believe achieves the course objectives and learning goals? Why?” Of the 28 surveys turned in, 20 had responses to question five and 8 were blank. The responses tended to be in a continuum with just one major theme, stretching from the majority (17 responses) who preferred the AAM, to a minority that were ambivalent (2 responses) and only one student that preferred the SCA . While some of the majority responses were simple “prefer the rubric”-type answers, some provided more detail, suggesting that the rubric provided better guidance towards course objectives and would help students develop their skills better. The two neutral cases differed distinctly. One felt that the two systems complemented each other, implying a desire to see both used to assess the course, while the other student felt that the AAM would be good for instructors, but not necessarily help students. Lastly, the only

student to voice a preference for the SCA did so with little detail or explanation.

This preference for the AAM suggests strongly that students appreciate the definition of learning goals, the clear path to improvement, and the degree of detail with which the AAM operates. However, it should be contrasted against the comments made in the previous question, which saw many areas for improvement necessary in the AAM.

4.2.1.7. Question 6

The last question asked was designed to put student opinion of rubric, particularly ICE-based systems, in context within their pre-established opinions or experiences. Students were asked “Have you ever used a rubric assessment system before? If yes, what were your impressions?” This question sought to test the waters of whether students had positive or negative experiences in the past and whether or not this played a role in their responses. It was known to the author that the majority of students had experienced an ICE-based rubric assessment system when they took the course *APSC 190: Professional Engineering Skills* in their first year of engineering study, which is highlighted in Strong & Fostaty Young (2007). A minority of students (2 responses of 29 completed) professed they didn’t think that they had ever used one, which is a possibility as not all students surveyed

necessarily took APSC 190. The majority of students (11) responded that they had used a rubric previously, but generally their comments were inconclusive on whether or not it was a positive experience. Most comments related to experiences in APSC 190, with descriptors such as the “difference was not very noticeable”, it “depends on the marker in a lot of cases” and one even acknowledging that they “did not take full advantage” of the rubrics in other courses. Other students (9) felt that they did not enjoy their previous rubric-assessment experiences. Many found the rubrics “less helpful”, faced concern over the skill levels of TAs and professors to be able to use the rubrics, and found that the “goals were unclear”. Some students (7) felt that their experiences with rubrics were positive. Interesting is the contrast between some who disliked the ICE rubric in APSC 190 and some that demonstrated an appreciation for it in the same course.

The reasons for the spread of opinion, particularly within a single course experience, suggest that factors other than the rubric itself created a positive or negative experience for the students. These external factors could be the team environment in which the student worked, the instruction team (TAs, and professors) tasked with assessment duties, or some other, unknown agent.

The narrative created above helps to provide insight into student experiences with rubric-based systems, with their appreciation for a

course's learning objectives, and their feelings and beliefs relating to its use in design engineering environment.

4.2.2. Survey 2

The second survey that students participated in was a mixed-methods one, which combined some quantitative questions with qualitative, open-ended response opportunities. A copy of the second survey can be found in Appendix 6. The survey consisted of 5 questions which allowed for a response from 1 → 5 and two open-ended questions that the students were asked to fill in their own responses. This survey was very useful at gauging students' usage of the rubric during the term, and their opinions on how it affected their interim presentation and report work.

The scale for the questions was listed as 1→ 5, with "Not at all" located to the left of the 1, indicating it was the lowest marker, through to "Relied on them heavily" or "Very much so" on the right of the 5, indicating the highest possible score. Some students however indicated that the text on either side of the numbers was their preferred score, circling it. For cases such as these the student's score was assumed to be the lowest possible (either a 1 or a 5) in the case record, while in the raw case data they are recorded as a 0 or a 6 respectively.

This survey was provided to students at the end of class and they were asked to return it the following week. Several students returned studies late and many failed to return them at all. As a result only 21 responses were returned out of a possible 31. Several students failed to put indicators on their sheets so that their responses could not be compared to other surveys or those of their teammates. The raw case data can be seen in Appendix 7 and the case record can be seen in Appendix 8.

4.2.2.1. Questions 1 & 2

The first two questions dealt with the rubrics' usage during the preparation of the interim report, which is one of the most significant deliverable tasks in the course despite its relatively low weighting (10%) in the overall course mark as part of the SCA. Students are advised that this interim report (which is due in week 7, following 6 weeks of class and a one-week reading break) serves as the basis for their final report, stressing that the more complete the interim, the more feedback students can receive, and the easier it will be to complete their final report. The first question asked students "Did you or your group consult the rubrics during the development and preparation of the interim report?" and the second question asked "Did you find the rubrics helpful during the development and preparation of the interim report?" Using these questions as pairs helped to eliminate

ambiguity from responses and better support or contest the use of the rubrics. Histograms of student responses to the two questions can be seen below in Figure 1and Figure 2.

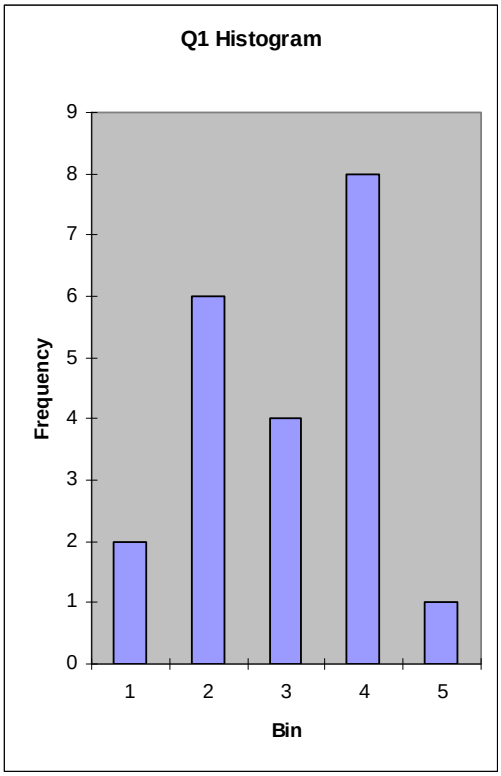

Figure 1 - Survey 2 Question 1 Histogram

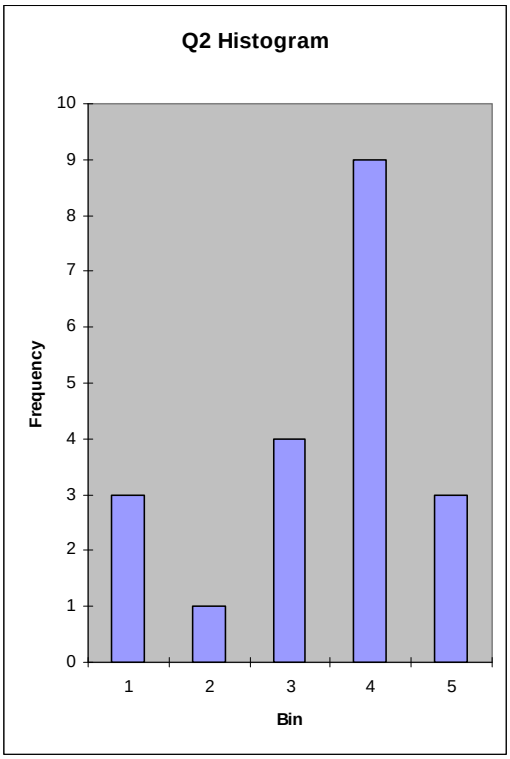

Figure 2 - Survey 2 Question 2 Histogram

When asked whether or not students or teams were using the rubrics while working on their reports, 13 of 21 respondents indicated that they used it at least moderately (score of 3 or higher). When determining if the rubrics were helpful in crafting the report, 16 of 20 respondents found them at least moderately useful.

4.2.2.2. Questions 3 & 4

The third and fourth questions were similar to the first, but instead of gauging rubric usage and usefulness during report writing, they were attempting to gain insight into value gained while preparing interim presentations. Question 3 asked “Did you or your group consult the rubrics during the development and preparation of the

interim presentation?" and question 4 asked "Did you find the rubrics helpful during the development and preparation of the interim presentation?" Histograms for questions 3 and 4 respectively can be seen below as Figure 3 and Figure 4.

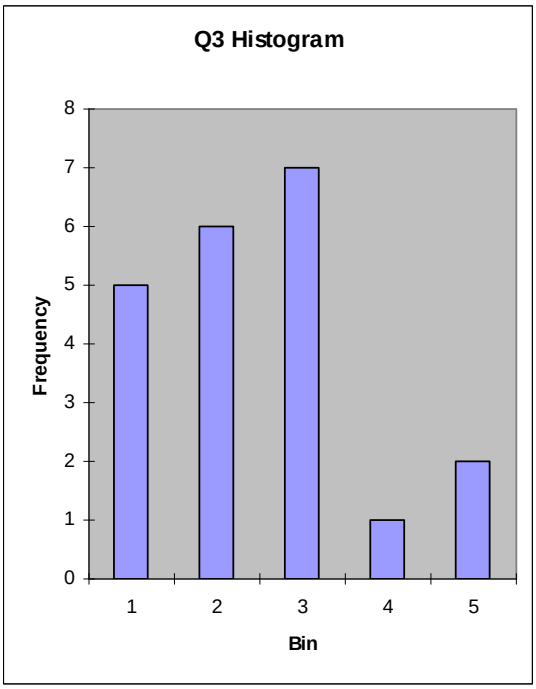

Figure 3 - Survey 2 Question 3 Histogram

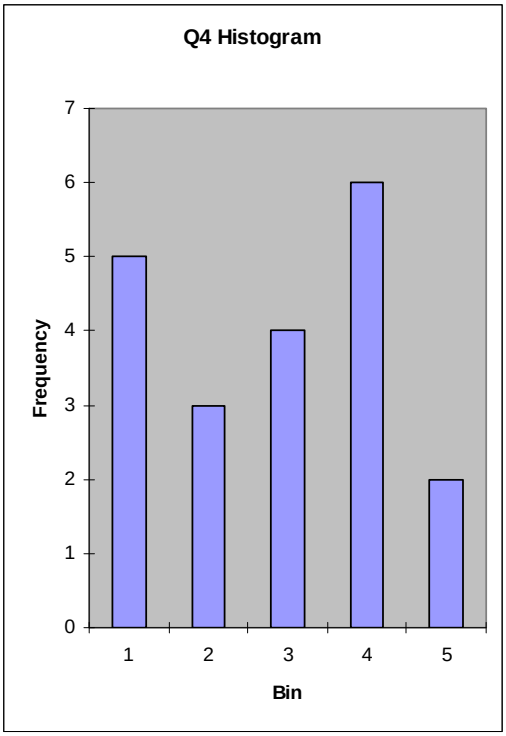

Figure 4 - Survey 2 Question 4 Histogram

Students responded to question 3 with 10 of 21 feeling that they used the rubrics during presentation preparation at least moderately (a minimum score of 3) while 12 of 20 responding to question 4 felt the rubrics helped at least moderately (again a score of 3 or more).

The lower usage and utility of the rubrics to the presentations are likely due to two reasons. First students generally put less effort into the presentations than the reports, anecdotally suggesting they often rush the presentation preparations due to timeline commitments from other courses as well as a lack of associated marks compared to other deliverables. Secondly, students might have used the rubrics less for the presentations than the reports because they might have already been aware of rubric scoring elements for their reports and

basing their presentations on their reports they did not need to refer back to the AAM as much.

4.2.2.3. Question 5

The last quantitative question students were asked was “Did you find the rubric feedback on your presentation and report helpful as you move forward with your project?” This question aimed to determine if the students were using the feedback they were getting week after week to help move the project towards completion, in addition to referring to the fully-completed rubric that was given to them at the start of the course. A histogram of student responses can be seen below in Figure 5.

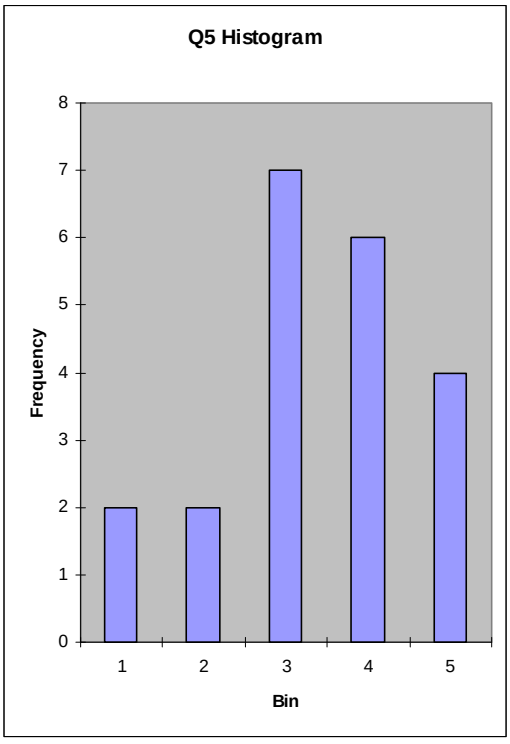

Figure 5 - Survey 2 Question 5 Histogram

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Students strongly felt that the feedback was helping them with their project, with 17 of 21 respondents indicating at least moderate (minimum score of 3) assistance gained from the weekly feedback.

This positive response to question 5 is a strong indicator that the feedback was helping students throughout the term. Contrasted against the first four questions, even if students weren't creating their deliverables with the AAM as a guide, they were finding the feedback beneficial. The lack of associated marks with the AAM is probably a large factor in students not spending a great deal of time using it as a preparation guideline. Despite the lack of effort in using the rubric, the feedback would help students' performance when evaluated by the SCA, resulting in the responses to question 5, showing high appreciation for the constructive criticism.

4.2.2.4. Questions 6 & 7

After the 5 quantitative questions, students were asked to respond to two, open-ended questions. The first asked students to "Please comment below on how you would improve the rubric or the feedback in relation to the interim report" while the second asked "Please comment below on how you would improve the rubric or the feedback in relation to the interim presentation." Using the same methods as the previous qualitative questions, responses were arranged so that themes could develop intuitively, as can be seen in

the case record found in Appendix 8. The responses can be classified in two major categories, with a significant amount of the answers capable of dual classification. There exists a continuum of responses relating to the usefulness/helpfulness of the rubric from very positive to negative. Additionally many of the responses offer advice for improvement. When responding to the first qualitative question about improving the rubric or the feedback with regard to the report, several students voiced positive feelings such as “it was good; clearly laid out so that improvements could be pursued” and “it looks good as it is”. The majority of the comments focused upon acknowledging the rubric as good, but recommending improvements. Developments suggested include:

- More detailed explanation
- Addressing the length of the rubrics
- Instead of showing what students have done, show what they need to do
- Removing the blank sections; highlighting completed sections and leaving in-situ uncompleted ones as seen on the fully-completed rubric example
- Increasing the detail provided when something has gone “wrong”

These suggestions were very helpful in understanding how students employ the rubric. Evidently, the presence of blank spaces was a concern, with a few students mentioning it in their responses. Initially the intention was for students to compare their partially-filled weekly feedback sheets against the fully-completed rubric handout from the start of the course as a method of determining progress completed and future steps. Instead students felt that the blanks were perceived as unnecessarily negative and suggested that an alternative approach be tried. Some suggestions were initially contradictory and would need substantial effort to address. While a number of students suggested that the rubrics were too long, others advocated for an increase in the detail provided.

The second qualitative question, mirroring the first but targeted at the interim presentations, received more blank responses (6 as opposed to 2 for the first question). This might suggest survey fatigue or an implicit assumption that their response from the first question would affect the change anticipated. Amongst the students that did respond to the question, many of the responses were in the same vein, predictably, as the first question. A few students stated that the rubric was fine the way it was, while several more commented that they liked it but offered suggestions. Proposals to remove the blanks recurred, but presentation specific comments were also received. One

student advocated for more categories relating to presentation skills (such as clarity, volume, speaking habits, etc) to be included in the rubrics. Although there were fewer objections about the length of the rubrics, there were a comparable number of responses asking for an increase in the level of detail.

Students' qualitative responses suggested general acceptance of the rubric, and the implication that if there were marks associated with it they would increase their efforts to achieve the scoring elements. The suggestions for improvements provided by the students not only help in improving the rubric for future uses, but are also indicative of the students' level of acceptance for a rubric-based assessment system. The level of recognition for the rubric and the willingness to help improve it, rather than suggest dropping it or drastically changing, it implies a strong affinity for the AAM.

4.2.3. Survey 3

The final piece of survey data was collected as part of a student completed rubric that was given to students during their final presentations. For final presentations the class was split into two halves, with each group of students presenting in one half, and then listening to the rest of the presentations in their section. The opportunity for students to provide feedback to their peers on presentation performance is already a part of APSC 381. For the

subject group using the AAM, a different feedback mechanism was utilized. For the rest of the class, students filled out the same marking sheets as the instructors, the results then complied, and feedback provided the following class to each team on how they did. Students in the subject group were given a rubric sheet that had columns of target elements, and beside them spaces for comments, as the one seen below as Table 13 and Table 14.

As with the other qualitative information sources, the analysis for the student-completed rubrics followed Patton's guidelines for analysis and interpretation. Each student was asked to fill out one rubric package (containing all six rubrics used in the course) for their peers that were using the AAM in their presentation section. In that way, each student was responsible only for filling out 3 rubric packages and were relived from marking the other 8 presentations that evening. This resulted in a potential 93 returned surveys, however only 65 were received.

Rubrics were modified to remove elements about the report production specifically or other elements that students were not expected to demonstrate in the presentations. This was to help cut down the amount of elements that students would be required to evaluate as well, alleviating false expectations of perceived 'missed' presentation elements.

Table 13 - Peer Evaluation Rubric 1

Defining the Problem						
Key Concepts / **Element**	**Ideas**	**Comments**	**Connections**	**Comments**	**Extensions**	**Comments**
research doesn't limit options or scope	research covers basics of problem and potential solutions library resources are utilized, sources are academic/credible		research sources stretch beyond web based searching there exists significant questioning and challenging of information		research materials include interviews, surveys, review of existing solutions, search into patents, regulations, standards research does not exclude any potential solutions but remains open ended	
uses appropriate tools	uses tools such as objective trees, sketches, etc		is able to convert outputs into tangible criterion for design (either functional requirements, additional 'bonus' features, or constraints/limitations)		strengths/weaknesses of different tools are highlighted, others are used to complement/correct for those strengths/weaknesses sketches, objectives, etc. are iterated as the project moves	
recognizes differences between functional requirements and constraints/ limitations	requirements and constraints are clearly delineated and articulated		client suggested requirements/constraints are separated from user defined requirements/constraints		is able to iterate requirements over time if they change, and able to introduce new limitations as they arise	
acknowledges team/interpersonal hurdles, uses appropriate strategies/tools to overcome	recognizes team strengths, potential weaknesses is knowledge define working parameters for the group, including meeting times, communication methods		addresses concerns or disagreements early communication is open and positive in idea generation, brainstorm, design selection activities		work is fairly distributed, allowing for learning and growth by each team member as well as utilizing their strengths team member responsibilities are clearly defined before each milestone/meeting and are met by deadline	

Table 14 - Peer Evaluation Rubric 2

Key Steps / Element	Ideas	Comments	Connections	Comments	Extensions	Comments
forming the problem statement	statement is loosely defined statement accurately reflects project needs		statement is multidimensional in nature; showing constraints and potential strengths		statement shows awareness of human factors, resource constraints, and client need statement is aware of potential biases from client needs, terminology	
identifying functional requirements	takes client need and converts it into necessary product performance needs identifies the WHO as well as the WHAT of the problem		is able to separate needs from wants is able to determine what the end user needs (if not necessarily the client)		able to show potential strengths/weaknesses in relating different functional requirements is able to qualify which are most important to project success, which are the greatest hurdles	
recognizing constraints and limitations	understands given constraints from client foresees operational concerns/pitfalls		is able to articulate other constraints/limitations not directly specified by client is able to see constraints/limitations for the life cycle of the project		is able to differentiate between true limitations and unnecessary or overcomeable hurdles is able to overcome limitations or turn them into strengths	
defining a schedule and forming a team	group memos and progress reports are submitted on time and with appropriate formatting Gantt chart is clear, follows acceptable timelines, adequately explains project 'flow' team prepares a working agreement and abides by it for duration of project		memos show insight into group operations, progress reports adequately show project progress to date and future goals work is fairly distributed, providing opportunities for all members to actively contribute		memos and progress reports form a clear timeline of project completion and group development Gantt chart is revised as project progresses team dynamics issues are addressed and overcome	

While digesting the information provided in the rubrics, there developed two major differences in the way feedback was provided. Some students circled the elements that students had achieved, where others wrote comments into the “comments” boxes on the handouts. Another set of divisions can be made amongst the completed packages, separating them into “no comments”, “some/few comments” and “rich description” groups. This second set of divisions helped develop the most insight into student usage of the rubrics.

The “no comments” group was the smallest of the divisions (18 of 65 completed packages), and included two subsets. The larger subset contained 13 packages which had either circles or checkmarks to indicate successful achievement of a particular area. These 13 completed all the rubric sheets in the package. However, 5 of the responses used either checkmarks or circles, but failed to complete all the rubrics, leaving a large number of elements blank (to the degree that it was clear that the students clearly were not indicating that a team had failed to reach even an *Ideas* level of understanding, but instead that they just failed to grade that particular team appropriately). Two of these packages even included a mix of a few checkmarks and one or two comments scattered around the rubric, but nothing that was conclusive enough to suggest they fully engaged in the marking exercise.

The second largest grouping (containing 22 packages) can be classified as “some/few comments”. The classification protocols for this grouping involved several criteria. A package would fit here if it used a combination of a few comments as well as some checkmarks or circles, noting an improvement in response over the previous group. A package could also be considered for this section if it involved a number of constructive feedback elements, but left one or two of the three rubric sheets blank. Finally, a package that contained lots of comments, but which were mostly limited to surface-level feedback of “good” or “yes” in scattered boxes, would classify as having “some/few comments”.

From these subgroups we can draw inferences about how the students were using the rubrics. The fact that the largest subgroup (10) consisted of packages that used mostly checkmarks/circling with a few additional comments suggests, when combined with the substantive number of packages that used virtually no comments from the previous grouping, that the students could have used an increased level of instruction on how to use the rubrics effectively. One package in particular offers important insight:

> “It’s really hard to do this during so short a presentation (7 min), trying to read everything and listen to presenters is very challenging”

This acknowledgement of the time constraints likely played into most students’ ability to use the rubrics as an effective marking tool, and as such likely diluted the quality of their answers. It should be noted however that with practice the marking scheme does become easier to use, as the author marked the subject groups’ presentations simultaneously using the AAM and the SCA with little difficulty after extensive practice throughout the term to this point.

The time-pressures and lack of practice can be further supported by the subgroup that provided some quality feedback but failed to fill out all of the rubrics. This group of six packages ranged widely in the degree of constructiveness that was conveyed in the feedback. Some bordered on having “no comments” while others were able to fill out one or two of the rubrics with some substantial interpretations of the presenters’ work. Comments included “great consideration of environmental aspect” and “brainstormed prev. ideas to combine/subtract to good final design”. One package included the line “looks like this group studied the rubric” as a comment outside of the elemental feedback areas. These comments indicate that if given sufficient training, or at least increased practice time with the rubrics

students are capable of capturing student learning as demonstrated in presentations, arguably the most difficult deliverable to assess using the rubrics.

The conclusion, that increased training or practice with the rubrics would increase its viability as a peer-feedback mechanism, is advanced by the final subgroup; those with minimal, surface-level feedback. These packages contained mostly element response boxes that were filled with “good” and other one word responses. Often the boxes were filled with key words from the elemental descriptions and what students said in their presentations that fit each box. Rather than offering a method of active feedback, such as suggesting how to improve, most students hit upon the significant aspects and left it at that. This suggests that students are able to assess their peers, and are able to relate presentation subject matter to the AAM, but lack the time or practice to utilize it fully.

The last major division for student packages can be classified as “rich description”, containing 25 of the 65 completed. The largest sorting factor for this division was not a breadth of answers, with all the elements for all the rubrics filled out, but rather the presence of depth to the responses that were given. Constructive feedback included comments such as “More attention to this [element] would have made things more clear”, “life cycle analysis would have been

great here", and "by widening the acceptable range the user may be compromised". These comments are both insightful and helpful to the presenting teams. This demonstrates that students are capable of providing quality feedback to their peers, despite the shortness of the presentations and the length of the rubrics. Coupled with the comments from the other groups, it would stand to reason that with a little more training and practice with the AAM, students would be able to use it as a quality feedback mechanism for their peers. This increased practice and familiarity would also likely increase student appreciation for the AAM, improving their ability to use it for their own projects.

One student, whose 3 packages were easy to identify due to a distinctive ink used to fill them out, provided responses that could be classified as "rich description". Most importantly they took the opportunity to provide feedback to the author on issues surrounding the use of the rubric for assessing peer presentations.

Recommendations included:

- Contains too many boxes
- Contains too many words in the boxes; text is too small
- There aren't obvious separators in the table
- "What should I comment on first?"
- Vague for presentations
- The *Key Steps* sections seem to be the most appropriate
- Improvements to the handouts (pages stapled together was tricky)

These comments implied that some of the previously drawn conclusions were being unduly influenced by factors mostly external to the rubrics themselves. This student's vocal objection to the layout of the packages (double-sided and stapled, small font, etc) implies the possibility that many of the students who provided little to no feedback might have been deterred from providing more on aesthetic or functional grounds. As this likely played at least a minor role, and is something that is easily remedied, it should be corrected for future implementations of the AAM.

Due to unclear instructions, it is impossible to correlate packages to each other to determine how a particular team marked their peers (with the exception of the aforementioned distinctive ink case). While the intention was for students to indicate both the team that was

presenting and the student that was marking, students failed to do more than indicate which team was presenting (and in some cases even forgot to do that). As such, it is impossible to correlate packages to determine if assessment fatigue was a factor, or conversely if practice progressively improved feedback. Assessment fatigue is a condition that results when a subject is required to fulfill a repetitive task several times, resulting in poorer performance as time goes on (Gray & Sharp, 2001). It is likely that in marking three different teams with the rubrics, students began to become indifferent towards the end, resulting in weaker quality feedback. Although this cannot be substantiated by correlating student packages together, it can be supported by the author's experiences of filling out a great deal of rubrics each week. In order to ensure accuracy and fairness, the author would mark and then re-mark student deliverables using the rubric at two different times each week. Additionally each, deliverable was marked in a different order to avoid assessment fatigue. Although this subsided over the duration of the term due to increased familiarity with using the AAM, it is likely that the students suffered from the same weariness that afflicted the author.

There are some conclusions that can be gained by comparing and contrasting the results of the three surveys against one another. A technique referred to as triangulation was used to confirm or improve

upon the conclusions drawn from case records. This method of comparison is discussed subsequently in the verification section and is a common and well accepted technique amongst qualitative researchers.

4.3. Verification

One of the most important elements of qualitative analysis is the verification process. Verification mirrors the term *validity* in quantitative research. Creswell insists that it is necessary to use the term verification, as it is comparable to validity, but it "underscores qualitative research as a distinct approach" (Creswell, 1998). As discussed in the Methodology chapter there are two principal factors that allow for authentication of a qualitative analysis. The external validity can be addressed using two techniques previously discussed: "rich, thick description" and "clarifying researcher bias" (Creswell, 1998). These two techniques allow for external verification of the information to be confirmed, by showing at the most base level what information went into the analysis. The second verification element is the measure of confidence in the analysis performed. To ensure this confidence Creswell recommends using two of several possible methods. The author has utilized three methods in this study: rival explanations, negative cases, and triangulation. Overall the verification methods used here serve this discrete group of findings. Qualitative

studies conducted under different circumstances (be they different participants, researchers, course, etc.) will likely result in different responses from participants. These differing responses can be interpreted differently by a researcher, leading to different conclusions. The goal of a qualitative study however is to use verifiable analysis (using the methods described below) to add to the body of information on a subject by taking all of these unique factors into account. By presenting the data in its entirety, in conjunction with researcher biases and the research methodology, knew knowledge and insight is gained.

4.3.1. Rival Explanations

When verifying a qualitative analysis with rival explanations, it is important to look for alternate theories that might be supported by the data. The researcher should be looking for other methods of organizing the data as well as looking at alternative possibilities and determine if the data supports the alternatives (Patton, 1980). Each of the input sources (surveys 1 through 3) will be discussed with rival explanations presented to ensure confidence in the approach.

4.3.1.1. Survey 1

When observing data from survey 1, one is able to create several alternate possibilities for student responses to the questions. The first question, “What are your initial impressions of the existing

assessment scheme?" seeks to determine student impressions of what is currently available to them. As Patton describes, it is important to draw this out to several logical conclusions and then determine if the data supports these conclusions (Patton, 1980).

One logical conclusion is that students are unhappy with the current assessment scheme, possibly due to a previously bad experience. If this conclusion is taken to its reasonable extent, one would expect student responses to highlight perceived problems with the marking schemed based on these past experiences. Students would also likely show an interest in any deviation from the norm in their course assessments to avoid repeating these previous bad experiences. When observing the comments that students have made, they seem to acknowledge the conventionality of the SCA, however they fail to outright comment that it is like a bad experience. Many do comment that it is a "standard, general marking rubric seen for most project based courses" and that it "looks like almost every marking scheme I've seen in university". Further to this students, fail to support the potential that they would welcome any change, regardless of its perceived potential for improvement. A number of students do comment with potential improvements for the SCA, such as a decrease in the weighting of the final report or an increase in the weighting for peer evaluations. What is conspicuously absent is a call for a

fundamentally different method, be it rubric-based or otherwise. It is due to the lack of evidence purporting bad experiences with the SCA, other than mild suggestions for modifications, which allows this conclusion to fail the rival explanations test.

Another conclusion could be that students either really enjoy or really dislike courses that weigh heavily on reports and presentations. As previously discussed, some students commented on the final deliverables' weightings, with some suggestions on how they could be changed. Despite this advice on changing the weights, there is no direct evidence that students prefer or reject a course based on its deliverable weightings. Evidence that would suggest this would be quotes from students that use terms like "prefer" and "enjoy" or "dislike" and "avoid". The absence of this information, coupled with students offering generally objective observations, results in the disproving of this conclusion.

Similar would be the conclusion that students do not enjoy courses that focus the bulk of the marking on group related projects. Although some students suggest that the weightings surrounding peer evaluations and other group-based deliverables should or could be modified, there again is a lack of language that suggests a dislike for group based courses.

The lack of evidence to support alternate conclusions such as students' displeasure with current assessment practices (and therefore a desire for anything different), a preference or avoidance of courses with heavy weightings on final deliverables, or an avoidance of courses with a high component of group work denotes that they fail the rival explanations test.

These alternate conclusions can also be drawn for the other questions in survey 1. Questions 2 and 3, asking students their initial impressions of the rubric-based system, and which they believe will better achieve the course objectives and learning goals, leave themselves open to several substitute deductions.

One possible rival explanation is that students are indifferent towards the rubric-based system, finding it not worthy of their efforts. This is quickly disproven by the abundance of comments relating, positive or negative, towards the usage of the rubric. If students were to have been ambivalent towards using the rubric, one would expect the comments to be much more neutral in their wording.

Coupled with the third question on the survey, the second question could lead to the alternate conclusion that students' answers were misinformed or improper due to unfamiliarity with rubric assessment, or the ICE approach. This is even more likely when taken in the context that students answered the second and third questions

after only briefly looking at a copy of the rubric, without explanation of the details or the process with which it would be implemented. Student comments however disprove this premise when they point out that the rubric is “more detailed”, that it “nicely outlines the learning objectives for the course” and that it provides “guidance instead of open-ended goals”. The fact that these statements align with the intentions of using the AAM indicates that students were able to pick up on the significant constituents of the rubrics. Although some students seem to be unsatisfied with the AAM, a few comments rightly point out that the rubric has *a lot more to do with how you get to the solution rather than how good the final solution is*. Despite the negative tone in which students framed these comments, they do not show a misinformed or unfamiliar student, causing this alternate conclusion to stumble.

The fourth and fifth questions suggest other alternate conclusions. Three major rival themes can be logically drawn from the two questions about the AAM following a detailed explanation of its intentions and use. One might assume that the details provided led students to find the AAM too difficult or hard to use. Other rival explanations might conclude that the AAM is not accurate enough to assess their learning or that they would oppose it due to an implied perception of an increased workload on their part.

The first logical inference would be that after hearing the lengthy explanation, students would determine that the AAM was too difficult or hard to use. It could easily be assumed that after an explanation of the ICE approach, a detailed explanation of the rubrics, and some terminology definitions, could easily result in a student being turned off towards putting an effort into meeting assessment targets. In looking for supporting remarks from students, it appears that some might maintain such a belief. One student felt strongly that the only way in which an assessor could adequately reach these goals was to either follow them around while they were working on the projects or for a TA to conduct student interviews throughout the term. Another student plainly pointed out "… I feel like that will be hard to grade because it is based on the markers deciding what shows knowledge as opposed to considering certain techniques with specific assignments". Other students continue to support this rival explanation, however when their answers from the fourth question are contrasted against those of the fifth, only one student voices concerns over the difficulty in using the AAM and then follows it up with a demonstrated preference for the SCA. In all cases but two, students who denoted the difficulty in using the AAM felt that they would still be better served by using it. In the two contrary cases one student failed to declare a preference and the other student preferred to use the SCA, mentioning

they were “not a big fan of the ICE scheme personally”. This student also stated a preference for the SCA before the explanation in class. This squashes the assumption that the explanation and subsequent re-asking of the preference question would result in a shift away from the AAM. Although the threat of student disenfranchisement due to a lengthy explanation and utilization discussion is perceived to be real, in practice only the smallest minority of students felt the AAM was ill-suited to their educational needs. In fact, the discussions played no role in shifting student opinion away from the AAM.

Two other conclusions could possibly be drawn from the comments students provided in questions four and five. One could expect students to find that, after the explanations, their concerns about fidelity were not properly assuaged and in fact the AAM is not as accurate as the SCA in determining their course mark. The comments that could be construed as supporting this conclusion are similar to those in the previous rival explanation. In that case, many of the concerns focused on the instructor’s ability to properly gauge what students have done, and if they have successfully demonstrated the necessary learning. While the previous outlier case remains, with a student preferring the SCA, and another student choosing not to state a preference, there is one student who offers some insight into this alternate conclusion. This student prefers the AAM, but

straightforwardly points out that they think “a few trial runs will be required for any given professor to be able to accurately evaluate students… ”. This evidence, while partially supporting the conclusion that students would find the AAM inaccurate enough to prevent its adoption, is mitigated by this student’s stated preference for the AAM.

The final rival explanation that could be logically drawn from the asking of questions four and five is that students would object to a perceived increase in work required by the AAM. In practice most of the increase in workload for using a rubric-scheme is on behalf of the assessor. However, this might not stop a perception that there will be more work involved. Even the sheer size of the rubrics (several pages, vs. a half page for the SCA) could be enough to discourage some, let alone an explanation of how much of the onus to demonstrate learning is placed on students’ deliverables. However, this rival explanation lacks support in the responses to either question. It could be expected to find comments suggesting “will make deliverables more difficult”, “seems like a lot of work”, or similar remarks to this affect. To the contrary, some students point out more difficulty for the assessor, but fail to mention difficulties on behalf of the students.

Although initial evidence might seem to substantiate rival explanations, such as a lack of support due to perceived difficulty in using the rubric or an associated lack of accuracy in producing a

student mark, these were overcome once the answers were placed in the proper context. Another rival explanation, suggesting that students might feel like their efforts to achieve rubric objectives might be drastically increased, failed to garner even the most tacit support. This lack of rival explanations verifies the conclusions discussed earlier; that in the eyes of students, the AAM better achieves course objectives, makes assessment more clear, promotes higher levels of learning, and is the preference amongst students over the SCA.

The final question on the first survey fails to warrant a rival explanations test. As this question was merely to contextualize the students' answers to the previous 5 questions, with the main focus on determining if a previous experience was positive or negative, little can be logically concluded beyond the stated comments.

4.3.1.2. Survey 2

The rival explanations method can be used to address the open ended questions of the rubrics' utility, as asked in Survey two. Rival explanations can be used to support the conclusions drawn from the two open-ended qualitative questions included in the survey. The two qualitative questions focused on determining feelings about the rubrics utility in developing the interim reports and presentations. One of the major conclusions drawn can be supported using rival explanations. As previously discussed, the feedback that students were offered was

determined to be a sign of positive support for the AAM, reinforced with suggestions for even further improvements. The counter-case could easily be assumed, that students were making suggestions for improvements because they felt the AAM inferior to the SCA, and that by making suggestions they could shape it more like traditional assessment schemes. If this rival explanation was to stand, it could be assumed that comments would tend towards shaping the AAM with more exact criteria for each of the deliverables, so students could know what they were 'worth'. This decision of whether or not to attach weightings to deliverables is one of the biggest, and likely the most glaring, divergences between the two assessment schemes. However student responses failed to support this rival explanation, instead offering proof against it. With the exception of one student who felt the rubric wasn't simple enough, several students asked for more definition and more categories for assessment in the rubric so that they could further hone the skills and learning objectives in which they were excelling and/or flagging in. This lack of support for the rival explanation, purporting a desire to make the AAM more traditional, allows it to falter and the original conclusion of students being more apt to help improve the rubrics because they prefer them, to stand strong.

4.3.1.3. Survey 3

The third study elements were the student completed rubrics during the interim presentations. Although these were very useful in drawing conclusions about students' ability to use the rubrics, the rival explanations technique is not effective in supporting the conclusions. The previously discussed analysis focused primarily on classifying student rubrics based upon degree of completion and quality of feedback provided. From this, inferences were developed, such as the concept that with increased practice students would improve at using the rubrics to provide feedback to their peers. The only rival explanation cases that could be tested are those that are diametric opposites to the original conclusions, and these are tested previously. The logical and inductive way in which the conclusions were drawn already states the counter cases in the analysis, rendering further counter-proofs unnecessary.

The rival explanations method is very powerful in helping to support the conclusions developed earlier in the analysis. By developing contradictory or alternate cases and then actively seeking their proof, the validity of the original conclusions is tested. While not suitable for every facet of the study constituents, it was helpful in verifying some of the findings, and will be further complemented by the use of negative cases and triangulation.

4.3.2. Negative Cases

The use of negative case analysis is discussed in both Patton (1980) and Creswell (1998). Creswell's approach suggests that to appropriately utilize negative case analysis, the researcher engages in a process of iteration and revision, integrating information to improve the working hypothesis. This is further improved once outliers and exceptions are eliminated and the hypothesis has been worked until all cases fit (Creswell, 1998). This has been the case with the analysis discussed previously. As the author worked through the data presented in the case record, the initial hypothesis and findings were altered and improved to accommodate negative cases. Patton discusses the negative case approach more plainly, illustrating how the strength of a researcher's conclusions is benefited by further analyzing the instances that do not necessarily fit the pattern (Patton, 1980). Included below is a brief review of these conclusions, as well as some increased analysis supporting these findings.

4.3.2.1. Survey 1

The analysis of the first survey benefited from the use of negative cases to support and refine the conclusions developed. When students were responding to a question about their initial impressions of the AAM, before receiving any major direction or explanation about its use or its implementation, one student commented that "you took

something very simple and made it difficult". As most students made generally positive comments, or at least did not say anything overtly negative, this stood out from the pattern. However, this refined the conclusions drawn from this question, leading the author to deduce that students were able to appreciate the increased complexity of the AAM. This also led the author to propose that this recognition of complexity might have been widely present in the collective consciousness but failed to receive the negative connotation that this particular student voiced. Even as a seemingly 'misfit' comment, when contrasted with the overall pattern, valuable insight can be gained when performing a negative case analysis in support of qualitative conclusions.

Other patterns emerged in this survey that experienced a case that was different from the norm. Such is the case of students who responded with a very negative connotation that the AAM assessed "people on the skills shown, not the actual product produced". Although these negative connotations stood out from the rest, the hypothesis remained unchanged. The ability of students to recognize, without instruction, the process-over-product focus of the AAM was a major goal of its design, and was clearly present in student opinion.

When asked which system better achieved the course learning goals, there were three comments that stood out from the norm.

These students preferred the SCA to the AAM, primarily due to its more poignant and clear nature. While the conclusion that students are able to pick up on many of the intended advantages of the AAM stands, these outlying opinions serve to bracket the advantages with a need for increased clarity and succinctness to benefit all students.

Students had the intentions and the usages of the rubrics explained to them, and then were asked again for their thoughts and preference between the rubrics and the SCA. While many advocated for improved quantity or quality of the feedback they were to receive, there were some that suggested the AAM would be difficult to use. Of these, most were related to the perceived subjectivity involved on behalf of the assessor. By analyzing these negative cases, it was concluded that some students were likely overwhelmed by the explanation of how the AAM was to be used, making it seem to be more complicated than it actually was. To counter this, it was proposed that students would benefit from some practical, concrete examples and some more refined guidelines to demonstrate the reduced subjectivity when compared to the SCA.

A prime example of how negative cases helped shape conclusions developed earlier in the analysis is seen by examining the responses to the final question of the first survey. This question sought to determine whether or not students had used rubrics previously, and

if it was a positive or negative experience. While most had used rubrics, there was a strong divergence amongst those with positive and those with negative experiences. The range of justifications included in these responses forced the author to abandon the effort to find a unifying trend. Instead what was gained was insight into how a myriad of factors can influence students' appreciation or resentment for a non-conventional assessment method. These support the conclusion that preference or aversion for rubric-based assessment methods is likely linked to some external factor unrelated to the rubric itself.

4.3.2.2. Survey 2

Negative case analysis was also applied to the qualitative questions on the second survey. Many of these conclusions were previously discussed, but are worth briefly highlighting. The most telling were the negative cases that stood out from the generally positive comments on the utility of the rubrics for developing the presentations and the reports. While the general trend was for students to express satisfaction with the AAM and the feedback provided by the author, a few expressed difficulty or displeasure. While the original hypothesis was that students appreciated the feedback, the negative case analysis helped to refine this assumption. By examining the outlying student opinions, the original hypothesis can

be modified to include caveats that some students do appreciate the feedback, but others are turned off due to a lack of clarity. This opens the door for future iterations of the AAM to simplify some of the language and categories, including perhaps providing more specific detail in currently ambiguous areas.

4.3.2.3. Survey 3

Much of the negative case analysis has been discussed in line with previous analysis of the ways in which students completed their peer-assessment rubrics. While in the previous negative case analyses there were a minority of outlying responses, in this pool of data the categories were assembled in such a way that it is tricky to gain much more from the minority records than what has been previously discussed. The dominant trend within the data was for students to respond, at least partially, to the request to use the rubrics to provide feedback to their peers. As mentioned previously an entire grouping of students failed to use the rubrics to engage in the marking exercise. These negative cases helped to shape the conclusion that students could have been negatively affected by a lack of time with which to assess, by too small a sample from which to draw conclusions (i.e. the presentations were too short), or by a lack of practice and training in using the rubrics. However, due to the majority of the class being able to engage at least in some superficial way in the marking exercise, it is

also possible that these students just chose not to utilize the opportunity for any number of reasons including boredom, resentment or apathy.

The use of negative case analysis has helped to bolster confidence in the findings found earlier in this chapter. By placing special emphasis on the comments that might seem to be outliers, the findings are refined and improved so that final recommendations can be gathered.

4.3.3. Triangulation

As discussed in the Methodology chapter, triangulation of methods[3] was used in this study to improve the confidence in the conclusions drawn. This resulted in the use of three differing methods for extracting students' thoughts, feelings and motivations in relation to the AAM and its implementation. It is important to realize that triangulation is not a magic-pill solution to resolving and improving confidence in qualitative analysis. Instead qualitative and quantitative data "will eventually answer different questions that do not easily come together to provide a single, well integrated picture of the situation" (Patton, 1980). However, what a mix of qualitative and quantitative methods can do is offer improved clarity to conclusions,

[3] Triangulation of Methods does not necessarily imply the use of three different techniques. Rather it involves more than one technique, with no upper limit on how many become part of the analysis.

avoiding pitfalls that might affect the confidence in the findings of a qualitative researcher.

Within the second survey it is possible to use a triangulation approach due to the mix of quantitative and qualitative questions. This allows for the results to be contrasted against one another and for deeper conclusions to be drawn. As previously discussed, the negative cases can provide “the most important analysis” (Patton, 1980). Some key results became obvious when members of a team were contrasted against one another to look for glaring differences in their responses to the quantitative questions. Once these teams were identified, the students’ qualitative responses were compared with their quantitative responses and those of their peers. A team in which this occurred experienced a drastic variation in responses to all 5 quantitative questions and both qualitative ones amongst their four teammates. One team member expressed “the rubric is a waste of time” and scored all of the quantitative elements as 1s or 2s, mirroring another team member whose qualitative comments were not as forthcoming but who scored similarly, with only one question reaching a score of 3. Another member scored 2s thorough 4s, and a 5 for the fifth question, asking whether the feedback was useful. This above-average survey also provided very in-depth feedback regarding the usage of blanks on the feedback sheets, providing two suggestions for improvement

(removing/minimizing blanks or increasing the amount of explanation provided on how the feedback works). The fourth teammate scored the quantitative questions with 2s through 4s, and a 3 for the question about feedback utility. While it is unfortunate that the negative surveys in this case did not provide deep insight into the rubrics' effectiveness, there are other notions that can be extracted. This deviation within a team suggests that some students feel very strongly about changes to assessment in one way or another. Even without having marks associated with it, and requiring very little effort on behalf of the student, some still found the AAM to be a "waste of time". Alternatively, many students enjoy the feedback and find it useful when working on their course deliverables. The lack of a complete whitewash by any one team suggests that those students who appreciate and are able to use the AAM can, at the least, influence their teammates into using the rubric's feedback to the team's advantage, even when lacking the incentive of associated marks. It also suggests that the rubric can have an effect on a student's feelings towards the AAM, with other factors held constant (project, TA, etc). One team had three teammates with similar (generally positive) answers to the quantitative questions, with simple and positive responses to the qualitative questions. However the fourth teammate expressed average to below average

usefulness/helpfulness in questions 1→ 5 while suggesting in question 6 that “instead of showing what we have done, show where we need to improve.” This helps for improvements by indicating that not all students use the contrasting method (that is comparing the partially-filled feedback sheets to the fully-completed rubric from the start of the term) to successfully assess their standing in achieving scoring elements. Another team had strikingly similar results. Two of the three surveys received had teammates sharing average to below average acceptance of the rubric in the quantitative questions, and the third survey showing very positive results. One of the below-average quantitative surveys suggested that more detail was required as to where the students “went wrong”. The other below-average survey mirrored the student from the previous group by suggesting that the blanks left on the feedback form were not helpful and that they needed clarity on what to do in the future to improve. This further supports the previous findings that not all students respond well to the contrast method and that more detail needs to be provided in the feedback to ensure that students understand what they need to do in order to excel. The teams that offer the most varied responses can easily be the most insightful, offering astute and perceptive comments for students’ motivations and contributing worthwhile suggestions

By examining the combined results of the three different survey tools, many of the conclusions begin to emerge from more than one source. Conclusions that were strengthened by triangulation include some of perhaps the more important findings. Included amongst this group was the determination that students were easily able to recognize the value of assessing the higher levels of learning within the AAM. In the first survey some students clearly stated their acknowledgement of the advantage the AAM offers over the SCA in terms of identifying, recognizing, and encouraging higher levels of learning. In the student-completed rubric, respondents are capable of capturing student learning and offering quality, insightful feedback to their peers on many of the *Extensions* level elements.

All three surveys strongly suggest that several functional and aesthetic components of the AAM need to be modified before it could become widely and effectively utilized. Conclusions drawn from the negative cases and direct student feedback lean towards improving the precision of the language in the rubric elements and improving the layout when students are given handouts to increase clarity. Improvements to student training and practice in using the rubrics, including perhaps using more concrete examples and demonstrations on how a sample would be evaluated is clear across all three surveys.

A rigorous and thorough analysis of student case data, including strict verification procedures leads to several strong and complete conclusions.

Analysis of the first survey shows student opinions tending to suggest the SCA was typical and traditional. Weighting of deliverables emerged as an issue, as well as the interesting result of showing how some students failed to see the process-over-product approach of the SCA despite having it explained to them in class. Most students supported the aims of the AAM, improved focus on learning goals and increased feedback, while some felt that clarity and subjectivity would be a concern. Predisposed opinions towards rubrics failed to conclusively affect student preference for the AAM.

Students found in the second survey, for the most part, the feedback from the AAM useful, even if they did not consult the rubrics during development of major course deliverables. Students also took an active role in the assessment process, offering suggestions for improvements to the AAM for future use.

The final deliverable shows that students are capable of engaging in meaningful feedback and criticism of their peers' work using the AAM. This leads to the conclusion that students understand how the AAM works, but that they would benefit from increased time and training in using it specifically as a peer-feedback mechanism.

Students do however appreciate the higher level learning objectives and are able to articulate them to their peers.

Using three verification techniques, rival explanations, negative cases, and triangulation, helped to lend confidence to the already thorough analysis. These methods helped to refine and improve the conclusions developed in the case narratives.

The raw data, its analysis through the presentation of case records, and the development of case narratives supported by strict verification techniques follows Patton's process of data collection, results, interpretations, and evaluations for the proper use of qualitative information (Patton, 1980).

Chapter 5. Conclusions & Recommendations

5.1. Conclusions

From the surveys that students completed, a general feeling of acceptance for the AAM was visible, with students stating both implicitly and explicitly that they preferred it to the SCA. Amongst the students, the vast majority had, as expected, used a rubric based system (many an ICE-based system in particular) for course assessment in the past.

One of the most interesting findings was student interpretations of the end goals of each of the assessment methods. When students were asked for their opinions of the Standard Course Assessment, several commented on how it appeared to assess students on the functionality of their final product, rather than on the quality of the process they used to get through the design. Interestingly, an explanation outlining the exact opposite case was explicitly described to students a week before they were asked this question. In class, it was made clear to students that while a successful project was a goal of the course, the assessment (using the SCA) focused on measuring their performance at using the design process and demonstrating effective application of design tools and techniques. When students were asked about the AAM, they volunteered that they thought it adequately assessed process over product. This conclusion was

reached with little explanation of the AAM and appeared to be based on merely a brief reading of the system. This suggests that even though explanation of the use of the SCA was intended to highlight the importance of process over product to students, its one-dimensional nature prevented it from achieving a key goal. The AAM was able to underscore a process over product approach with no explanation at all.

Students failed to overwhelmingly utilize the rubric when constructing their major interim deliverables (a presentation and a report). However the majority did use it to at least some degree, suggesting that students perceived some usefulness in the AAM. In understanding that students put their efforts into work that is assessed, it is logical to conclude that if the work marked with the AAM was graded, then students would likely put more effort into consulting and using the rubric during the course.

Most students felt that the detail of the AAM was going to be helpful as they moved forward with their projects, while some felt it would be a hindrance. This spread of opinion suggests that an alternate method of conveying detail could be used, allowing for the simplification of some parts of the existing rubric. By appropriately weighing these two conflicting characteristics, a balance could be struck to appeal better to all students.

Regardless of student effort in using the rubrics during creation of interim deliverables, the majority appreciated the weekly feedback they received. Most importantly, this improved and increased feedback should be qualified as instruction time, as assessment should be considered an important part of instruction, not as administrative overhead, or as another negatively implied activity. Students also felt that the AAM better articulated course objectives and learning goals. This was an express purpose when designing the AAM, so these responses are crucial in realizing the goals of the study.

While an attempt was made to further engage students in the rubrics' mechanics by having them take on a role in assessing their peers using a modified version of the AAM, overall it was not a resounding success. Some students showed they were capable of providing insightful and relevant feedback to their peers, while others failed to engage in the process, at even the surface level. This implies that the AAM is not necessarily the best for peer-feedback, however more if students received more practice and training using the rubrics, they might improve their abilities to peer-evaluate.

One of the strongest outcomes that emerge from this research is an endorsement by students of the rubric system as a viable alternative to a traditional course assessment system within the context of a multidisciplinary design course. Most importantly, the students

appreciated the concept of breaking down the learning goals and course objectives into *Key Concepts* and *Key Steps* and utilizing the ICE-approach to show the multifaceted nature of a design project. The increased feedback was found to be useful, made possible by increasing the resolution of the marking system; more detail was made available ahead of time and followed up with quality comments and criticisms.

5.2. Recommendations

As with any design, an important step is to revisit the design after implementation of the testing to modify and improve it as necessary. Such is also true with the design of an assessment system. There are two principal areas for improvement: the rubrics themselves, and the implementation.

Many of the suggestions for improving the rubrics came from students. One of the largest areas that needed resolving was a deviation between students who felt the rubric had enough, or needed more detail, and those who felt that it was too detailed, to the point of being a hindrance to its utility. While the feeling of too much detail is certainly justified, it is likely that if a grade was to be associated with the rubrics, students would likely seek more detail as they try to achieve as many learning objectives as possible. However, there is the ability to use a simplified version. Although it would take some effort

to develop, two complementary rubric systems could easily be used. Much like the SCA, which contains assessment elements, linked-to examples and templates, the AAM could utilize a simple rubric, with very rudimentary elements being highlighted within the ICE-framework. From this a more detailed rubric could be developed, for use when students are having trouble with some of the language or require clarification. While this might lead to confusion over the degree to which students are achieving elements, ideally the more detailed version would be used primarily to help assessors elaborate aspects of specific learning objectives to students. This would help provide even better formative feedback.

One of the easiest areas to improve in the use of the AAM was the delivery of the material. With only one-third of the class using the rubric and the intention not to disclose the contents to the balance of the class made, it was challenging to administer the AAM. Using the program across the entire class would allow for better examples to be provided within lecture material. It would also allow for a more open environment for students to ask questions, rather than the previous method of meeting the author before, during, or after class. Opening up the dialogue could lead to further, collaborative improvements to the system, as well as lead to the airing of questions, so students who

are not as comfortable with a direct approach could gain from their classmates' queries.

Other improvements suggested by students deal with how the feedback is delivered. Suggestions include clarification on what students need to do to progress, rather than just what they have done previously. To allay this concern, a small improvement in the feedback being delivered could be made. Week over week, when students received feedback they would obtain indication of those elements that they successfully completed, and some comment similar to "close to achieving, but need to better demonstrate" for those elements that they were only close to completing . To counter this, the assessor could easily provide feedback at the next highest abstraction level for each assessment element. By putting detailed suggestions in the rubric at the next level beyond what has already been demonstrated, the students know what they need to do to advance. Another complaint by some students was that they didn't like the blank spaces on the handed-back rubrics. These were seen as unnecessarily negative by some (it appears as if nothing has occurred early in the course) and others seemed to dislike consulting back with the original, completed rubric they received. To combat this, the assessor could change the feedback given to students. Completed elements could be highlighted with a shaded background. 'Next Step' elements (what

students need to do to advance) could be bolded, and any uncompleted elements could be left as on the original. This would help students to better determine where they are, what they need to do, and where they need to go.

5.3. Further Study

From this research study, there are several interesting avenues for future investigation. As one of the goals of using a rubric-based ICE-approach system was to improve the level of deep learning that was demonstrated by students, the long term effects of using a rubric system could be measured. This would involve assessing students design capabilities at the start of their fourth year capstone project and comparing those students which used the AAM versus those that just used the SCA in APSC 381. The assessment of design capabilities is becoming more common place, noting research done by E.E. May (2006) and Frank & Strong (2008) making year-over-year examination more commonplace.

Rubric-based assessment systems could also be tested in other design environments. This particular study focused on an intensive design fundamentals course involving engineering students working in multidisciplinary teams. Work examining how students use the rubrics in advanced level design courses (such as capstone courses like *APSC 480: Multidisciplinary Design Project*) or in courses where students

interact with those of different fields, such as law or business, other than just engineering (as is the case of *APSC 400:Technolgoy, Engineering And Management*, a course offered through the Chemical Engineering department at Queen's). These courses offer different environments that would require the design of a rubric system specifically targeted towards their individual learning goals.

References

Bailey R, S. Z. (2006). Assessing engineering design process knowledge. *INTERNATIONAL JOURNAL OF ENGINEERING EDUCATION, 22*(3), 508-518.

Benjamin, C., & Keenan, C. (2006). Implications of introducing problem-based learning in a traditionally taught course. *Engineering Education, 1*(1), Higher Education Academy Engineering Subject Centre

Brinkman, G. W., & Geest, T. M. v. d. (2003). Assessment of communication competencies in engineering design projects. *Technical Communication Quarterly, 12*(1), 67-81.

Brookhart, S. M. (2003). Developing measurement theory for classroom assessment purposes and uses. *Educational Measurement: Issues and Practice, 22*(4), 5-12.

Brzustowski, T. (2004). Science and engineering research Canada: Design engineering and the innovation strategy. Presentation at the 2004 CDEN Conference, McGill University, Montreal. Retrieved November 5, 2004, from http://www.cden.ca/2004/CDENMontreal20040729.ppt#422,11,Slide 11

Canadian Academy of Engineering. (1999). *Evolution of engineering education in Canada* Retrieved from http://www.acad-eng-gen.ca/publis/evolution_a.pdf

Canadian Council of Professional Engineers. *Canadian engineering accreditation board.* Retrieved August 19, 2008, from http://www.engineerscanada.ca/e/ccpe_boards_2.cfm

Commission on Engineering and Technological Systems. (1991). Executive summary. Washington, D.C.: National Academies Press. Retrieved from http://www.nap.edu/catalog.php?record_id=1774

Creswell, J. W. (1998). *Qualitative inquiry and research design: Choosing among five traditions*. Thousand Oaks, Calif.: Sage Publications.

Cross, N. J. (2000). *Engineering Design Methods: Strategies for Product Design* (3rd ed). Chinchester, N.Y.: Wiley.

Ditcher, A. K. (2001). Effective teaching and learning in higher education, with particular reference to the undergraduate education of professional engineers. *INTERNATIONAL JOURNAL OF ENGINEERING EDUCATION, 17*(1), 24-29.

Dominick, P. G., Demel, J.T., Lawbaugh, W.M., Freuler, R.J., Kinzel, G.L., & Fromm, E. (2001). *Tools and tactics of design*. New York: Wiley.

Dym, C. (2004). Design, systems, and engineering education. *INTERNATIONAL JOURNAL OF ENGINEERING EDUCATION, 20*(3), 305-312.

Dym, C. L., & Little, P. (2000). *Engineering design: A project-based introduction*. New York: John Wiley.

Eggert, R.J. (2002). Engineering Design Education: Surveys of Demand and Supply. *2003 ASEE Annual Conference and Exposition: June 2003 Staying in Tune with Engineering Education* (p 1901).

Fostaty Young, S., & Wilson, R. J. (2000). *Assessment & learning: The ice approach*. Winnipeg, MB: Portage & Main Press.

Frank, B., & Strong, D. S. (2008). Survey-based assessment of design skills development in engineering project courses. Paper presented at the *Canadian Design Engineering Network Conference 2008,*

Gibson, I. S. (1998). Assessment criteria for undergraduate project work in engineering design. *European Journal of Engineering Education, 23(3),* 389.

Gray, D., & Sharp, B. (2001). Mode of assessment and its effect on children's performance in science. *Evaluation and Research in Education, 15*(2), 55.

Hill, R. B. (1997). *The design of an instrument to assess problem solving activities in technology education*. Blacksburg, Va.: Technology Education Program, Virginia Polytechnic Institute and State University.

Ivins, . (1997). *Interdisciplinary project work: Practice makes perfect?*. New York, N.Y.: Institute of Electrical and Electronics Engineers.

Keefe, M., Glancey, J., & Cloud, N. (2007). Assessing student team performance in industry sponsored design projects. *Journal of Mechanical Design, 129*(7), 692.

Leydens, J. A., Moskal, B. M., & Pavelich, M. J. (2004). Qualitative methods used in the assessment of engineering education. *Journal of Engineering Education, 93(1), 65.*

May, E. E. (2006). *Engineering design education: Education meets industry.* Thesis, Master of Science (Engineering), Queen's University.

McMillan, J. H. (2007). *Classroom Assessment*. United States of America: Pearson Education.

McMillan, J. H. (2003). Understanding and improving teachers' classroom assessment decision making: Implications for theory and practice. *Educational Measurement: Issues and Practice, 22*(4), 34-43.

Oehlers, D. J. (2006). Sequential assessment of engineering design projects at university level. *European Journal of Engineering Education, 31(4),* 487.

Oehlers, D. J., & Walker, D. (2006). Assessment of deep learning ability for problem solvers. *International Journal of Engineering Education, 22*(6), 1261-1268.

Olds, B. M., Moskal, B. M., & Miller, R. L. (2005). Assessment in engineering education: Evolution, approaches, and future collaborations. *Journal of Engineering Education, 94*(1), 13-25.

Patton, M. Q. (1980). *Qualitative evaluation methods*. Beverly Hills: Sage.

Paulik, M. J. & Krishnan, M. (2001). A competition-motivated capstone design course: The result of a fifteen-year evolution. *Education, IEEE Transactions on, 44*(1), 67.

Pellegrino, J. W., Chudowsky, N., & Glaser, R. (Eds.). (2001). *Knowing what students know: The science and design of educational assessment* Center for Education, National Research Council.

Petroski, H. (1996). *Invention by design : How engineers get from thought to thing*. Cambridge, Mass.: Harvard University Press.

Raucent, B. (2004). What kind of project in the basic year of an engineering curriculum. *Journal of Engineering Design, 15*(1), 107-121.

Reeves, T. C., & Laffey, J. M. (1999). Design, assessment, and evaluation of a problem-based learning environment in undergraduate engineering. *Higher Education Research & Development, 18*(2; 2), 219.

Ringwood, J. V., Monaghan, K., & Maloco, J. (2005). *Teaching engineering design through Lego mindstorms*. Abingdon, Oxfordshire: Carfax Pub. Co.

Rogers, G. (2002). Assessment for continuous improvement: What have we learned? *INTERNATIONAL JOURNAL OF ENGINEERING EDUCATION, 18*(2), 108-109.

Rompelman, O. (2000). Assessment of student learning: Evolution of objectives in engineering education and the consequences for

assessment. *European Journal of Engineering Education, 25*(4; 4), 339-350.

Safoutin. (2000). *A design attribute framework for course planning and learning assessment*. New York, N.Y.: Institute of Electrical and Electronics Engineers.

Strong, D. S., & Fostaty Young, S. (2007). Effectively assessing professional engineering skills. *Canadian Design Engineering Network Conference.*

Ullman, D. G. (2003). *The Mechanical Design Process* (3rd ed.). Boston, MA.: McGraw-Hill.

Voland, G. (2004). *Engineering by design* (2nd ed.). Upper Saddle River, N.J.: Pearson/Prentice Hall.

Woodhall, T. F. C. (2007). Designing a Rubric to Assess the Problem Definition Phase of Student Design Projects in Upper Year Engineering Courses. *American Society for Engineering Education, St. Lawrence Chapter Conference*

Woodhall, T. F. C. & Strong, D. S. (2007). Designing a Rubric to Assess the Modelling Phase of Student Design Projects in Upper Year Engineering Courses. *Canadian Design Engineering Network Conference*.

Appendix 1

Example Marking Templates

APSC 381: Interim Oral Presentations

Team: _____

Date: _____

Presenters: _____

Presentation (Visual)	• Professional appearance • Audio-visual aids used effectively	/5
Presentation (Oral)	• Speaker(s) clarity, volume, effectiveness • Natural presentation • Clear pronunciation, accurate grammar • Enthusiastic and interested	/5
Organization	• Logical progression of presentation • Prepared in advance • Thought given to format, layout, objective	/5
Content	• Quality of the "story" • Clear yet concise explanations • Focused – staying on topic	/5
General Impression	• Appropriate length • Effective use of presenters • Response to questions	/5
	OVERALL GRADE	**/25** **/5**

APSC 381: Final Written Report

Team: _____ Date: _____

FORMAT OF REPORT		
Technical Accuracy	• Grammar • Spelling • Paragraph format	/10
Writing Style	• Clarity • Efficiency • Effectiveness	/10
Report Format	• Follows the format of the provided template • Appropriate length/content of each section	/10
References	• Proper formatting (esp. figures, etc)	/10
Bibliography	• Sufficient references • References beyond the web • Patents, books, articles?	/10
Appendices	• Effective • Properly referenced	/10
BODY OF REPORT		
Background Research	• Literature searches • Patent research • Regulatory compliance background • Has the topic been well explored?	/10
Design Process	• Use of design methodology • Correct use of techniques and tools	/10
Idea Generation/Creativity	• Exploration of several ideas • Original ideas or concepts • Effective use of existing ideas and technology	/10
Rationale for Choosing Idea	• Sensible, logical • Technique driven • Economic considerations • Environmental considerations • Social impact • Sound engineering assumptions and analysis	/10
Idea Development	• Component selection • Scientific/Mathematical proof of functionality • Appropriate sketches	/10
Future Developments	• Recommendations for future work • Do you think your design would work? Why? • Discussion of what you would do next given time and money	/10
Project Management	• Evidence of good project management skills • Current Gantt chart and/or discussion of critical path	/10
Engineering Economics	• Capital, expense, item cost estimates • Sources, assumptions, reasonableness	/10
Engineering Science	• Consideration of science in design • Reasonable assumptions • Modeling/Analysis	/10
Figures	• Effective use of sketches, figures, pictures, schematics	/10
	OVERALL GRADE	/160 /40

Comments/Suggestions:

Appendix 2

Author's Background

In order to appreciate my interpretations of the data collected, and attempt to ensure academic rigor, it is important for me to disclose my background, as it biases and influences my interpretations. This is not to say that the information collected from students is in any way tainted, but creates an environment of transparency with regard to the interpretations.

To begin, I am a well-educated, Caucasian, single male of 25 years old. I am a first-generation Canadian, through my father's side. He emigrated from the United Kingdom early in his childhood, the youngest of three siblings. My father's family emigrated due to a combination of economic instability coupled with employment difficulties faced by my grandfather as a Roman Catholic anywhere outside of Liverpool, England. After moving around to a number of cities shortly after their immigration my father's family eventually settled in Hamilton, Ontario. My mother was raised her entire life in Hamilton, a primarily industrial large city at the south-west end of Lake Ontario. Although neither of my parents attended post-secondary education, I was strongly encouraged to do so from a young age, something for which I strove much of my life. My father's upbringing in particular has influenced me, with his father serving at length in HM Royal Navy and other posts, taking him around the world. My father has worked as an electrical planner and scheduler at Dofasco's Hamilton operations, one of the largest steel mills in Canada for my entire life, and continues to do so. As one of Hamilton's largest employers, this is also where I also had the opportunity to work as a summer student after my first year of university. My mother acted as a homemaker, raising my three younger siblings and me for most of my youth, before re-entering the workforce in a variety of part-time capacities, including retail and administration.

As a youth, I greatly enjoyed camping and involvement in the Scouts Canada movement, where I gained many leadership skills. In high school, I participated actively in the debating club, as well as becoming heavily involved with amateur cycling. Upon graduating high school in Hamilton, where I'd spent my entire life, I enrolled at Queen's University at Kingston where I graduated in 2006 with an honours science degree in Civil Engineering as well as a second degree, a bachelors of arts in geography. Between my 4th and 5th years I was given the opportunity to spend several weeks at the

Queen's International Study Centre at Herstmonceaux, England where I took a few courses and allowed me the opportunity to visit the ancestral region of my forefathers. After this experience and completing my final year of study, I enrolled in my current master's program in Civil Engineering. My education has been self-funded (through the cooperation of government student loans and financial support from Queen's), assisted with personal funds obtained by working part-time & summer positions, mostly in the restaurant/entertainment sector, continuously since the age of 16.

My interest in design engineering education came as a confluence of several sources. My favourite courses were usually those with a design component, even in first year. I found the 'traditional' course set up to be boring and uninteresting, even if the lecture material was appealing. Most enjoyable were courses that emphasised oral presentations and written reports. A heavy involvement with student government gave me an appreciation for changes that can be made to improve the educational experience both by students and faculty. This was demonstrated in my involvement with committees related to student aid and in- and out- of classroom experiences at the student government, faculty, and university level. After an experience working with my current supervisor as a student, in the auspices of the Faculty of Applied Science *Summer Projects Office,* I learned of opportunities for engineering education research and sought a position as a Master's of Science student.

My upbringing in a fairly traditional, yet globally aware family has instilled me with a unique set of values that focus on the need to advance improvements while simultaneously appreciating a strong sense of tradition and history, making Queen's University an ideal place for me to complete both my undergraduate and graduate education.

Appendix 3

Survey of Student Opinion on the Standard Course Assessment, Alternative Assessment Method, and Rubric Assessment Usage

Student Number:

What are your initial impressions of the existing assessment scheme?

What are your initial impressions of the rubric based assessment scheme?

Which system do you believe achieves the course objectives and learning goals of the course? Why?

What are your impressions of the rubric system? (Not on the handout sheet, but asked after students had the rubric system explained in detail to them and they filled it in on the back of the paper)

Which system do you believe achieves the course objectives and learning goals more completely? (Not on the handout sheet, but asked after students had the rubric system explained in detail to them and they filled it in on the back of the paper)

Have you ever used a rubric assessment scheme in a class before? If

yes, what were your impressions?

Appendix 4

Verbatim student responses for Survey 1.

Table 15 - Survey 1 Student Responses

ID#	What are your initial impressions of the existing assessment scheme? (pre rubric)	ID#	What are your initial impressions of the rubric based assessment scheme (pre explanation)	ID#	Which system do you believe achieves the course objectives and learning goals of the course? Why? (pre explanation)
46	It is nice to have a layout of exactly what is expected through the term. I feel that weekly progress reports and memos are an unnecessary time consumption for already over busy students.	46	I am always sceptical of rubric scoring because it leaves my actions up for interpretation. It very nicely outlines the learning objectives of the course.	46	I think that the grades will be lower using the rubric then the traditional scheme. It gives more insight into the student moving through many design steps instead of only one final product.
80	Final report is worth too much. The percentage allocated to me usually helps me figure out how much time to spend. Nothing for research.	80	Good guide on what looking for. "Guidance" instead of open ended goals and expectations.	80	I like the way the rubric sets clear goals but I find it a bit qualitative. I'd prefer if it broke down each part as a percentage of final grade.
54	Pretty satisfied. It mostly assess students based on how well they do their report or exams rather then the process of getting the work done (emphasise more on the final result then the processes involved).	54	This rubric scheme is definitely focused more on the process or steps required to get the work done. This system would be helpful in _____ whether a personnel development has been made over a certain project. More progress tracking oriented system rather then final-report based system.	54	The two systems complement each other.
52	The final report seems to be worth a lot, and I'm not sure how the work/effort of each individual will be truly represented in the marks they receive.	52	I find it hard to classify/qualitatively decide where the project is i.e.. What box they fit into. While there is some structure to design, I find if I'm constantly checking a rubric I'm hindering my creativity.	52	I think that the 'new' one might help taking the design to the next level, since you can decide what column you're in and then decide what you have to do to extend beyond there.
59	It's the same style as every other course this year. It focuses on what is submitted and its format, not as much on content.	59	It ensures your content is what is graded, not just format. Looks like it promotes further investigation into topics, not just skimming the surface.	59	The new one as it promotes more in-depth understanding of the design process, and promotes extending work outside of the usual comfort zone.
45	There is heavy mark loading at the end of class, that seems odd for a class based on ongoing professionalism (25% ongoing, 15-20% interim, <15% final—weird).	45	Use of the ice system is good: reinforces utility. The use of the design process incorporation is good. Splits up the methodology of the design process cogently. The ice system is well applied to the deliverables instead of just a sliding scale for things like "clarity:10".	45	The rubric clearly utilitizes the ice system very well. Explicitly shows the learning objectives.

Table 16 - Survey 1 Student Responses

ID#	What are your initial impressions of the existing assessment scheme? (pre rubric)	ID#	What are your initial impressions of the rubric based assessment scheme (pre explanation)	ID#	Which system do you believe achieves the course objectives and learning goals of the course? Why? (pre explanation)
53	A lot rides on the final report (40%). Progress reports are different then memos? Presentations aren't worth much.	53	Easier to understand where marks will come from/where to aim. Large number of key concept elements, confusing. More helpful to student.	53	Rubric contains all of the course objectives/goals while current assessment only contains certain deliverables that may have used the objectives taught in the class.
81	Typical university rubric, not real world environment scheme (people don't actually do this in real life). Puts my personality into a box - i.e.. Cramps my style - not able to express to personal extent. Easy to follow - 'neat little package.	81	'ICE' is a good idea - gives step by step room for improvement and suggestions. 'ICE' makes me cringe because my TA who used this in first year APSC100 didn't really know how to mark according to this. Neat but still forces me to put myself "into a box".	81	2nd one (by far) because it neatly allocates what you must do to succeed. 2nd one is more 'real world' in a sense that Idea --> extensions is how companies and pristine individuals grow and perform.
8	It seems pretty standard. Certainly what I would expect. Rigid marks are gained by fulfilling clearly defined points (in most cases)	8	Could be difficult to quantify. Objectives seem clearly defined.	8	New rubric clearly states differences between good, better and best. We could use that to determine how we can improve. Both gives us an idea of what to do and how to do it.
91	High weighting for final outcomes; minimal marks for demonstration of progressive learning.	91	Immediately presents a required path of excelling in the course; easy to differentiate between what is expected and what exceeds expectations.	91	I believe the rubric system achieves the learning goals of the course because it provides a learning path as opposed to the old scheme which delineates grading.
88	Seems balanced.	88	Easier to make sure points are covered; easier for prof/TA to grade.	88	Rubric is much better defined; summarizes necessary components of reports, etc.
47	Very formal and structured; everything is given a numerical grade (percentages); there is no give in the old system (all are given a concrete percentage); work effort has been neglected (minus statement of peer assessments); only one mark is assigned to weeks of work.	47	Very broad, basically evaluating people on the skills shown not on the actual product/deliverable produced; will be able to mark people on effort, not product; work is marked during every step.	47	I believe the new one because it evaluates you on the skills you learn. The old method only gives you a good grade if you made satisfactory written or oral deliverables.
44	It looks like the same as any other assessment scheme I have seen before; it does seem to cover all bases.	44	I have used the ICE evaluation before, and to be honest, I wasn't a huge "supporter" of it; I also thought it made requirements much more ambiguous	44	I like the first system since its to the point and I feel as though it is less subjective and much more objective (thus taking the marker out of the equation, i.e.. Marker doesn't greatly influence marks).
21	It seems like a classic cut-and-dry marking scheme; defines where marks will be rewarded w/out going into too much detail.	21	Much more elaborate; does not show allotment of marks; defines in detail what is necessary to receive a specific 'mark'.	21	They both probably achieve this, however, the rubric based assessment has clearly defined what is expected in each category, so it will achieve this easier.

Table 17 - Survey 1 Student Responses

ID#	What are your initial impressions of the existing assessment scheme? (pre rubric)	ID#	What are your initial impressions of the rubric based assessment scheme (pre explanation)	ID#	Which system do you believe achieves the course objectives and learning goals of the course? Why? (pre explanation)
20	Find it strange that memos are worth the same as interim report; doesn't leave much room for changes; seems like we are marked on what we already can do, not what we get from the course.	20	I like how it is broken down into the stages of the project, and lets the student know what tool s and ideas learned in the course to use to reach the extensions level.	20	I like the rubric as it tells the student how to achieve a good mark, and acts somewhat as a guide.
90	The expectations are not all clear; there is a lot of text; I think key words/most important words should be bold.	90	I like that it has the 'ICE' system laid out; I like that it is not point form (easier to read); some terms not clear (e.g.. What does a well presented design consist of ?)	90	The 2nd rubric one makes my learning objectives more clear. The first seems like a list that would be given to a prof/TA to mark assignments in a fair manner. It appears to be a list of things they look for.
60	It is okay for this course, however like in many courses, majority of the weight is on the final. However for this course majority of the marks distributed evenly to actually show the work done during the term. However does not take into consideration work done just how the final report is.	60	Look like a lot of work; breaks everything down into smaller components so that every area can be evaluated.	60	Tom's does because it look like all the aspects that David is talking about in class.
61	The presentations are too low a grade (5% each!!); the final report is worth a lot!!	61	You took something that seemed very simple and made it complicated.	61	I think the old assessment is better to me; seems more clear.
62	Detailed requirements make it easier to meet and achieve a good mark.	62	Learning goals are more clear (soft skills); sometimes it is easier to determine exactly where improvements need to be made; makes it more clear as how to go "above and beyond".	62	For me, a good mark is important, but a detailed rubric could achieve the same goal; may be more difficult to nail the technical aspects of the report.
11	The presentation and final report marking schemes seem very thorough and looks like it will be a great guide. There also seems to be an emphasis on the report in terms of the overall course assessment, may not accurately reflect the importance of other communication (memos, logbooks, presentation).	11	This marking scheme seems like it will be a good guide in terms of giving something to strive for, it seems less arbitrary.	11	I think the second one will better achieve the course objectives; I think that it w ill give groups the option to excel on based to not knowing exactly what it will take to get a good mark, so they just do exactly what they have to … and for all of the reasons that you said.
10	The current assessment scheme seems to be fairly comprehensive. There are a few criteria that I do not fully understand - i.e.. What is "evidence of good management skills"?	10	I find it much easier to understand. Adds structure, I especially like the key steps component.	10	I like the new system, because it adds a sense of structure and focus to the project.

Table 18 - Survey 1 Student Responses

ID#	What are your initial impressions of the existing assessment scheme? (pre rubric)	ID#	What are your initial impressions of the rubric based assessment scheme (pre explanation)	ID#	Which system do you believe achieves the course objectives and learning goals of the course? Why? (pre explanation)
83	Very subjective (i.e. you can get a 3/5 or a 5/5 depending on how marker feels).	83	Much more detailed; tasks are very descriptive; not as intimidating without numerical grades.	83	The rubric does because it provides much more feedback in areas where you excelled and areas where you need improvement.
89	Existing assessment scheme is basic; not too detailed/descriptive; generic.	89	More focused on design project; detailed guideline to what is expected; provides many details.	89	The rubric based assessment achieves the course objectives because it focuses on the development of the design project, what is expected and how each section will be graded.
82	Typical; complete; well specified/defined items.	82	Intuitive; extensive.	82	The new rubric relates more to the fundamentals of engineering design.
22	Standard engineering marking scheme; feedback? Is there any? a lot of marks in different places; not that descriptive; areas of improvement?	22	Very descriptive!!-> feedback! Shoes areas where you'd _____; instead of numerical evaluation, more descriptive.	22	'ICE' scheme. It shows that you're work is not solely based on marks, but rather the understanding of the overall course. Able to extend your learning goals.
67	Look like almost every marking scheme I've seen in university, most of marks (>50%) came from final deliverables (in this case presentation and report) other marks based on work throughout the term.	67	Seems to have a lot more to do with how you get to a solution rather then how good the final solution is; it looks more subjective, rather then just having a checklist of things you have to do.	67	Rubric-based assessment; makes it much clearer what you're expected to learn, and looks as though you get marks for learning certain skills, whereas the existing scheme seems to just give marks for doing things, doesn't necessarily ensure that the desired skills are actually learned.
69	Standard, general marking rubric seen for most project based courses; clear and concise, shows us what I need to do to achieve the mark I want.	69	Very detailed; no clear mark distinguishing your grade; clearly demonstrates an "ideas" mark vs. an "extensions" mark.	69	Rubric system will better achieve course objectives as they a re very clearly outlined in the rubric; however rubric lacks a weighting system so I don't know what each element is worth.
70	30% of marks are just coming to class and writing about what you are doing; most important is the final report.	70	Shows what you need to learn, how it is important.	70	The rubric based system because it tells what the learning objectives and grades you on scheduling it.
68	I think the presentations should be weighted higher as effective communication in engineering is very important; peer reviews should maybe also be weighted a little higher to motivate team members to work effectively and to the best of their abilities in a team environment.	68	It seems like a lot more detail is expected/ required in the rubric based assessment scheme.	68	I think the rubric based achieves the course objectives better as it requires extensions beyond the basics. In a sense it requires 'to go above and beyond' covering every aspect of engineering problems.

Table 19 - Survey 1 Student Responses

ID#	What are your impressions of the rubric system? (post explanation)	ID#	Which system do you believe achieves the course objectives and learning goals? (post explanation)	ID#	have you ever used a rubric assessment system before? If yes what were your impressions?
46	I think that if someone were able to follow me around all term and understand my methodologies then the rubric could be effective. Given that isn't possible I am concerned that the rubric could accurately represent what I take from the course. Maybe if the TA had interviews with the individual students throughout the term they may be able to more accurately gauge their progress.	46	I think that this system is ultimately better for evaluation purposes, but I also think that a few trial runs will be required for any given professor to be able to accurately evaluate students without specific deliverables.	46	I have only ever had essays graded on a rubric scale.
80	I know what is expected of me. This will make planning of the project easier.	80	The rubric achieves the objectives and both complement each other.	80	I was in an independent school so avoided the Ontario rubric. In elementary (public) school we had 'benchmarks' that were graded on a rubric but it was not provided ahead of time, so goals were unclear. We were just told to do it to the best of our abilities and then it was graded. it was also frustrating because they were created by the government so it was in English; I was in French immersion.
54	After learning more about what the rubric based assessment scheme is, I believe this scheme achieves the course objectives and learning goals more then the existing assessment scheme. Frankly, this kind of assessment scheme is what I have been looking for all this time in my courses, but never found any. I think this system would be more useful in tracking the progress of the skills achieved during the course.	54		54	Not to this extent. We had this assessment scheme in apsc100 (only a small part of it, not too detailed).
52	I still don't believe it improves on the previous one as an assessment tool. However it does provide more guidance during process.	52	As said before, the 'new' one well probably help more.	52	My impressions were that while it was very descriptive, meant to help/guide me, the marker couldn't easily pick out random 'extensions'.
59	I think it looks good. About the same thoughts as previous.	59	Still the rubric style, it really promotes in depth design which is what this course is really about. Cliché, it makes you think outside the box.	59	Yes. It very much depends on the marker in a lot of cases, this seems better/less subjective in that respect though.
45	The rubric will provide a resource to show what to show and why.	45	The 'ICE' model really shows the logical reasoning behind each learning objective.	45	I did, the 1, 2, 3, 4 system used in the TDSB [Toronto district school board]. It worked well in elementary school.

Table 20 - Survey 1 Student Responses

ID#	What are your impressions of the rubric system? (post explanation)	ID#	Which system do you believe achieves the course objectives and learning goals? (post explanation)	ID#	have you ever used a rubric assessment system before? If yes what were your impressions?
53	Repeats itself, but is very clear, if not concise, about what is expected of us in the course. Again, gives student very good goals for deliverables.	53	Rubric contains a lot more general learning concepts that are from course, where as marking scheme doesn't even mention.	53	Yes, but often did not include as many criteria and was less then helpful.
81	Good impressions (same as before) - more real world marking style - still puts me 'into a box'.	81	2nd, obviously. We want to be as prepared for real world environments as possible and ICE expresses that better then the skills rubric.	81	'ICE' is much better then what we had/have. TAs and teachers need to be well educated as to what idea, connections and extensions really are. I'm so fucking sick of the typical skill rubric.
8	I like it. It seems to be both useful as a grading scheme and learning tool. It should help me strive for 'extensions' phase.	8	I believe the rubric will be the better system.	8	Yes, I believe it was not implemented well and I did not form a good impression.
91	Provides clear boundaries for types of learning associated with the course and how to achieve them.	91	New system = better; same reason.	91	Yes, 'ICE' in high school. Enjoyed it; allowed me to perform better and learn more.
88	Same as before explanation; easier to judge what TA/prof is looking for in deliverables.	88	Rubric should allow marker to better judge progress.	88	Yes, but difference was not very noticeable.
47		47		47	Yes; some are great because it gives you good marks based on skills; some cons are that some rubrics can get too vague or cannot cover all the skills learned; no finite ways to find where their assignments will go.
44	My opinion has not changed. I still think that the 'ICE' method is too subjective.	44	I still like the first assessment better than 'ICE'.	44	Yes, I have. Didn't really like it.
21	It seems more elaborate, and easier to understand where marks are coming from. But at the same time, would my transcript give an I, C, E mark or percentage?	21	I still feel the rubric system defines the objective better.	21	190 marked like this for journals, etc.

Table 21 - Survey 1 Student Responses

ID#	What are your impressions of the rubric system? (post explanation)	ID#	Which system do you believe achieves the course objectives and learning goals? (post explanation)	ID#	have you ever used a rubric assessment system before? If yes what were your impressions?
20	The rubric is very comprehensive, covering the project from start to finish. As I said before, it acts as a guide for the student more then just a marking scheme.	20		20	ICE was used for 190, but it wasn't as extensive and helpful as that
90	I like that the rubric method allows students to demonstrate knowledge at any part of the class, however, I feel like that will be hard to grade because it is based on the markers deciding what shows knowledge as opposed to considering certain techniques w/ specific assignments; I like that it is more concise.	90		90	Not this type of rubric; I have always had project specific assessment.
60	Seems excellent and it actually tests a student better than the old system. Looks at every component that is being taught in class therefore ensuring that students are actually working.	60	Prefer tom's; same reason as above.	60	No! (maybe) (not sure)
61	I still think it far more complicated then it really needs to be…I'm not a big fan of the ICE scheme personally.	61	Same as before.	61	Ya, in high school (1-4), 4 being the best; I liked it more then ICE
62	Will help to go beyond expectations; encourage learning; exact technical requirements not as specific.	62	I think this will help achieve instructors' goals ; may not tangibly help students (reflection on report).	62	Yea; objectives were difficult to meet.
11		11		11	We used a rubric assessment in CIVL 210. It really took are lab reports and assignments beyond just learning the basic concepts.
10	I prefer the rubric based system. I believe that the "key steps" component of the system will add structure and direction to the project.	10		10	I have had one. I do not believe that I took full advantage of it

Table 22 - Survey 1 Student Responses

ID#	What are your impressions of the rubric system? (post explanation)	ID#	Which system do you believe achieves the course objectives and learning goals? (post explanation)	ID#	have you ever used a rubric assessment system before? If yes what were your impressions?
83	It is a very detailed rubric that is easy to follow and specifically identifies important areas of the design project; easy to see what needs to be done and what the markers are looking for.	83	Rubric system is better.	83	Yes; rubrics were a better marking scheme.
89		89		89	Yes, the rubric assessment works well if clear indication of what is being graded is given. In APSC 190 (the first time in university this rubric was used) I was given a mark of 'H2O' because the TA didn't like my idea - the thing being marked was a journal on my classes that week.
82		82		82	Yes, the rubric provide new ideas which can be incorporated into writing the final report.
22	Good! Should be used in a design course like this. Able to extend your learning.	22	ICE Same reason. Seems to demonstrate better overall objective of the course; developing skills better.	22	Yes. In high school. Only problem that I had was the grey marking scheme. Parents didn't understand that well where the marks came from. And APSC190.
67	Really different, seems like it will be fairly difficult to actually assess people with.	67	Still rubric, marks are not allocated based mainly on a few big deliverables, instead on demonstrating learning throughout the term.	67	I don't think so.
69	Impressions remain the same; rubric is very detailed; lack direction in achieving the mark I want.	69	Rubric system; due to more detail.	69	Yes. Rubrics typically lacked enough detail, and course direction was somewhat obscure.
70	Encourages creativity; promotes higher learning rather then memorization.	70	Rubric ICE; it is much clear to show what should be learning; performance is laid out in the beginning.	70	Yes, helpful, a lot of grading.
68	It still seems similar to my initial ideas.	68	I think the rubric marking scheme will better achieve the course objectives.	68	Yes, in APSC 191; I thought it was good, but more work as it required a little more work.

Appendix 5

Case Record for Survey 1

Student responses have been edited and modified only for grammar and clarity. Responses are organized thematically, with questions denoted from each other by shading. The general theme is in bold, with notes about the theme below. Continuums can be read from left to right, wrapping around to the row below if necessary. Student ID numbers are located above each response. Subcategories within a theme are separated from each other by a vertical double line.

Table 23 - Case Record Survey 1 Question 1

What are your initial impressions of the existing assessment scheme? (pre rubric) 26 responses					
Typical/Standard	**82**	**44**	**81**	**21**	**67**
no order just looking for key words/themes related to typical/standard	typical complete well defined	same as others covers bases	typical not real world easy to follow	classic cut and dry not much detail	like most most marks on final
89	**22**	**8**	**59**	**69**	
basic not detailed generic	standard not descriptive areas of improvement?	standard expected clearly defined points	same focus on format not on content	standard general clear; concise	
Detailed --> General	**47**	**82**	**8**	**88**	**69**
for entries that mentioned something about the specificness or generalness, working on a scale from agreeing with detail towards generality	very formal structured	typical well specified well defined items	expected standard rigid marks clearly defined points (in most cases)	balanced	standard clear concise what I need to do to get the mark I want
62	**21**	**11**	**10**	**89**	**22**
detailed req'm easy to achieve good mark	cut and dry defines where marks will be rewarded w/out too much detail	very thorough great guide	comprehensive few criteria I don't understand	not too detailed/ descriptive generic	any feedback? not that descriptive
83	**52**	**90**			
very subjective	effort of an individual isn't represented in mark	expectations are not clear lots of text key words should be in bold			

Table 24 - Case Record Survey 1 Question 1

Like --> Dislike					
only one or two seem to have outright distaste/enjoyment for the rubric					
Advice on Fixing/ Complaint about marks					
Final Deliverables	**67**	**11**	**60**	**54**	**70**
some comment relating to the final deliverables… generally no great love for the system, just complaints	most marks from final deliverables	emphasis on report overall may not accurately reflect the importance of other communication (memos, logbooks, etc)	majority of weight on final (like most courses) does not take into consideration work done, just how the final report is	more emphasis on final result then the process involved	most important is final report
53	**45**	**52**	**80**	**61**	**91**
a lot rides on the final report	heavy mark loading at the end of class that seems odd for a class based on ongoing professionalism	final report seems to be worth a lot	final report is worth too much	the final report is worth a lot!!	high weighting for final outcomes

Table 25 - Case Record Survey 1 Question 1

Interim Marks & Ind. Efforts	**61**	**91**	**52**	**68**	**47**
some comment making a suggestion to improve the interim marking scheme or comment complaining about how its improper	presentations are too low a grade	minimal marks for demonstration of progressive learning	not sure how the work/ effort of each will be truly represented in the mark they receive	presentations should be weighted higher because they are a form of effective communication.	work effort has been neglected (minus statement of peer assessments)
				peer reviews should be weighted higher to motivate team members	only one mark assigned to weeks of work
80	**53**	**22**	**20**	**70**	**54**
percentage allocation helps me determine what to work on; nothing for research	presentations aren't worth much	areas of improvement?	strange that memos are worth the same as interim report	30% of marks are just coming to class and writing about what you are doing	emphasises more on the final result then the process involved
		a lot of marks in different places	seems like we are marked on what we already can do, not what we get from the course		

Table 26 - Case Record Survey 1 Question 2

What are your initial impressions of the rubric based assessment scheme (pre explanation)

28 responses

Numbers are Student Identification Numbers

Easier --> Harder	**10**	**53**	**80**
a continuum of responses that suggest that the rubric will be easier to those that insist it will be more difficult the than old system	easier to understand adds structure	easier to understand where marks will come from more helpful to the student	"guidance" instead of open ended goals
88	**91**	**81**	**20**
easier to make sure points are covered easier for prof/TA to grade	easy to differentiate between what is expected and what exceeds expectations	ICE is a good idea	I like how it is broken down into project stages
8	**61**	**52**	
could be difficult to quantify	you took something very simple and made it complicated	hard to classify/ qualitatively decide where the project is if I'm constantly checking a rubric I'm hindering my creativity	

Table 27 - Case Record Survey 1 Question 2

Detailed: Good --> Bad	**10**	**89**	**83**
a continuum of responses that discusses how the detail is beneficial to the course/project and moving towards finding it hindering.	much easier to understand	more focused on design project	much more detailed
	adds structure	detailed guideline of expectations	tasks are descriptive
		many details	
21	**22**	**91**	**62**
much more elaborate	very descriptive	shows required path for excelling	learning goals are more clear
defines in detail what is necessary to get a specific mark	more descriptive	easy to differentiate between expectations and exceeding expectations	easier to determine where improvements need to be made
			more clear how to go above and beyond
20	**11**	**90**	**59**
I like the breakdown into project stages	seems like it will be a good guide for something to strive for	not point form (= easier to read)	ensures content is graded, not just format
lets students know what tools and ideas to get to extensions level	less arbitrary	some terms not clear	promotes further investigation into topics, not just skimming

Table 28 - Case Record Survey 1 Question 2

54	69	8	53
definitely more focus on the process or steps	very detailed	could be difficult to quantify	easier to understand where mark will come from
more progress tracking oriented than final report based system	no clear mark distinguishing your grade	objectives seem clearly defined	large number of key concept elements: confusing
	clearly demonstrates ideas v extensions mark		more helpful to student
44	**47**	**60**	**68**
made requirements much more ambiguous	very broad	looks like a lot of work	it seems like a lot more detail is expected/ required
	evaluating people on skills shown, not actual product produced	breaks everything down into smaller components	
	will be able to mark people on effort, not product		
67	**52**		
seems to have a lot more to do with how you get to a solution rather than how good the solution is	hard to classify/ qualitatively decide where the project is		
more subjective, rather than just having a checklist of things you have to do	some structure to the design		

Table 29 - Case Record Survey 1 Question 2

Process over Solution	**20**	**62**	**91**
comments that emphasize process-over-product, as well as those that mention specifically how it outlines the learning objectives	I like it broken down into stages of the project	learning goals are more clear	immediately presents a path for excelling
46	**67**	**47**	**54**
nicely outlines the learning objectives of the course	a lot more to do with how you get to a solution rather than how good the final solution is [TONE IS NOT POSITIVE]	evaluating people on the skills shown not on the actual product/deliverable produced will be able to mark people on effort not on product [TONE IS NOT POSITIVE]	definitely more focused on the process or steps required to get the work done
59	**89**	**70**	
ensures your content is graded, not just format	more focused on design project	shows what you need to learn, what's important	

Table 30 - Case Record Survey 1 Question 3

Which system do you believe achieves the course objectives and learning goals of the course? Why? (Pre Explanation)	29 responses Numbers are Subject Identifiers		
Those that prefer the rubric due to hitting course learning objectives	**53**	**90**	**70**
going from most explicit in its support of expectations to less	rubric contains all of the course objectives/ goals	makes learning objectives more clear	tell you what the learning objectives are
	current assessment only contains certain deliverables that may have use the objectives taught in class	makes marking assignments fair	
88	**89**	**68**	**69**
clearly utilizes the ICE system very well	achieves the course objectives cause it focuses on the development of the design project	achieves the course objectives better	will better achieve course objectives as they are very clearly outlined
explicitly shows the learning objectives	shows expectations and how everything will be graded	requires extensions beyond the basics	however rubric lacks weighting so I'm not sure what things are worth
		requires 'to go above and beyond'	

Table 31 - Case Record Survey 1 Question 3

22	11	67	80
shows that work is not based just on marks, but on understanding of the course	better achieve the course objectives	makes it much clearer what you're expected to learn	rubric sets clear goals
able to extend your learning goals		you get marks for learning certain skills	a bit qualitative
		old system gives marks for doing things, not necessarily what skills are actually learned	prefer it if it broke each part down into a percentage of final grade
60	**82**	**59**	**47**
tom's does because it looks like all the aspects that dave is talking about in class	the new rubric relates more to the fundamentals of engineering design	promotes more in-depth understanding of the design process	new one evaluates you on the skills you learn
		promotes extending work outside the comfort zones	old method was based on satisfactory delivery of written or oral work

Table 32 - Case Record Survey 1 Question 3

Those that prefer the rubric due to more feedback that is provided	**83**	**20**	**91**
	provides much more feedback in areas where you excelled and areas where you need improvement	tells student how to achieve a good mark	achieves the learning goals because it provides a learning path
		acts somewhat as a guide	old scheme which delineates grading
8	**52**	**21**	**10**
clearly states differences between good, better, and best	new one will help taking design to the next level	both achieve this	adds structure and focus to the project
can use that to determine how to improve	you can decide what column you're in and then decide what you have to do to extend beyond there	rubric is more clearly defined on what is expected in each category, making achievement easier	
both give us an idea of what to do and how to do it			
88	**81**		
rubric is better defined	2nd one (by far)		
summarizes necessary components of reports, etc	neatly allocates what you must do to succeed.		
	more real world		

Table 33 - Case Record Survey 1 Question 3

Those that prefer the SCA	**44**	**46**	**61**
	to the point	grades will be lower using the rubric	seems more clear
	less subjective/ more objective	gives more insight into the student moving through many design steps instead of only one final product	
	takes the marker out of the equation		
Those that say both work well	**54**	**62**	
	the two systems complement each other	a good mark is important, but a rubric could achieve the same goal	
		may be more difficult to nail the technical aspects of the report (on rubric)	

Table 34 - Case Record Survey 1 Question 4

What are you impressions of the rubric system? (post explanation)		
	25 responses	
	4 blanks	
Rubric --> better hits course objectives	**54**	**83**
going from most explicit to more implicit	achieves the course objectives and learning goals more then SCA	specifically identifies important areas
	what I've been looking for in terms of assessment in courses but never found	
60	**91**	**67**
actually tests a student better then the old system	provides clear boundaries for types of learning associated with the course and how to achieve them	repeats itself
looks at every component that is being taught in class; ensuring students are actually working		but is clear about what is expected in the course
		good goals for deliverables

Table 35 - Case Record Survey 1 Question 4

Rubric --> More Clear/ Acts as a Guide/ Adds Structure	**10**	**83**
more explicit to more implicit	"key steps" component will add structure and direction to the project	well defined, easy to follow
		specifically identifies important areas of the project
		easy to see what needs done and what markers are looking for
20	**53**	**8**
very comprehensive, covering project from start to finish	88	useful as a grading scheme and as a learning tool
acts as a guide more then just a marking scheme	gives student very good goals for deliverables	
52	**80**	**21**
does not improve on previous as an assessment tool	I know what is expected of me	more elaborate, easier to understand where my marks are coming from
does provide more guidance during the process	make planning of the project easier	
45		
rubric will provide a resource to show what to show and why		

Table 36 - Case Record Survey 1 Question 4

Rubric --> promotes higher level learning/ extended learning	**22**	**70**
more explicit to more implicit	able to extend your learning	encourages creativity promotes higher learning other than just memorization
59	**62**	**8**
promotes further investigation into topics, not just skimming	help encourage learning exact technical requirements not as specific	should help me strive for 'extensions' phase
91	**54**	
provides clear boundaries for types of learning associated with the course and how to achieve them	this system would be more useful in tracking the progress of the skill achieved during the course	

Table 37 - Case Record Survey 1 Question 4

Hard to Use/ Bad/ Don't Like	**67**	**46**
	seems like it will be fairly difficult to actually assess people with	if someone were to follow me around all term and understand my methodology then the rubric would be effective
		I'd be concerned that the rubric could accurately represent what I take from the course
		maybe if the TA had interviews with individual students through the term to accurately gauge their progress
61	**44**	**69**
more complicated then it needs to be	ICE is too subjective	rubric is very detailed
not a big fan of ICE		lack of direction for the mark that I want
90	**52**	**21**
it will be hard to grade because it is based on the markers deciding what shows knowledge as opposed to considering certain techniques w/ specific assignments	don't believe it improves on the previous one as an assessment tool	would my transcript get a grade of I, C, E, or a percentage

Table 38 - Case Record Survey 1 Question 5

Which system do you believe achieves the course objectives and learning goals? (post explanation)			21 responses	8 blanks		
Rubric --> SCA	**60**	**83**	**91**	**8**	**67**	**67**
starting with those that prefer rubric explicitly to those that like a complement to those that like the SCA/ Old system	prefer rubric	rubric system is better	new system = better	new system is better	rubric defines objective better	marks are not allocated on a few big deliverables marks are for demonstrating learning throughout the term still rubric
69	**68**	**22**	**70**	**52**	**59**	**99**
rubric system; due to more detail	rubric will better achieve course objectives	demonstrates better overall objective of the course develop skills better rubric	much clearer to show what we should be learning performance is laid out from the beginning	new one will help more	rubric promotes in depth design	ice model shows logic behind learning objectives
88	**53**	**81**	**46**	**80**	**62**	**44**
rubric should allow for better judging of progress	rubric contains more general learning concepts marking scheme doesn't mention learning concepts	rubric ice expresses real world skills better than SCA	rubric is better for evaluation purposes a few trial runs will be necessary before it can be accurately used	rubric achieves objectives they complement each other	help achieve instructor goals not necessarily help students	I like SCA better then ICE

Table 39 - Case Record Survey 1 Question 6

Have you ever used a rubric assessment system before? If yes, what were your impressions		29 responses	
Yes, Have used before and liked	**91**	**11**	**83**
	ICE in high school	CIVL 210	rubrics were better
	enjoyed it	took lab reports beyond just basic concepts	
	allowed me to perform better and learn more		
45	**67**	**68**	**70**
Toronto district school board in elementary school	rubric provided new ideas that could be incorporated into the final report	APSC 191	helpful
rubrics worked well then		good, but required more work	a lot of grading
Yes, used before and disliked	**53**	**81**	**52**
	did not include as many criteria	ICE is better then what we had	while it was descriptive the marker couldn't pick out random 'extensions'
	less helpful	so fucking sick of a typical skill rubric	
		need to make sure TA s and Profs are educated as to what ideas, connections, extensions are	
88	**44**	**61**	**62**
lacked enough detail	didn't really like it	high school	objectives were difficult to meet
course direction was somewhat obscure		I liked it more than ICE	
8	**80**		
not implemented well	were not provided with the rubric ahead of time		
did not form a good impression	goals were unclear		
	we were just told to do our best and got graded on it		
	English prepared rubric for French immersion school		

Table 40 - Case Record Survey 1 Question 6

Yes, comment inconclusive	**88**	**59**	**89**
	difference was not very noticeable	depends on the marker in a lot of cases	works well if clear indication of what is being graded is given
		this seems less subjective/ better in that respect though	complains about 190 mark
22	**46**	**21**	**90**
in high school	only ever had essay marked on a rubric scale	190 marked like this for journals	not this type of rubric
grey marking scheme, parents didn't know where marks were coming from			always project specific assessment
and 190			
47	**20**	**54**	**10**
some are great because it gives you good marks based on skills	ICE was use for 190	not to this extent	I've had one
some cons are that some rubrics can get too vague or cannot cover all the skills learned	not as extensive or helpful as that	we had for APSC100, but only a small part, not too detailed	I don't believe that I took full advantage
no finite way to determine how assignments will go			
No, haven't used before	**60**	**67**	
	No! (Maybe) (not sure)	I don't think so	

Appendix 6

Survey 2

Please fill out the following questions regarding the use of the rubric assessment scheme during the creation of your interim reports and presentations. Please bring a copy to class on Wednesday. You're cooperation would be much appreciated. ~Tom

Did you or your group consult the rubrics during the development and preparation of the interim report?

Not at All 1 2 3 4 5 Relied on them heavily

Did you find the rubrics helpful during the development and preparation of the interim report?

Not at All 1 2 3 4 5 Very Much So

Did you or your group consult the rubrics during the development and preparation of the interim presentation?

Not at All 1 2 3 4 5 Relied on them heavily

Did you find the rubrics helpful during the development and preparation of the interim presentation?

Not at All 1 2 3 4 5 Very Much So

Did you find the rubric feedback on your presentation and report helpful as you move forward with your project?

Not at All 1 2 3 4 5 Very Much So

Please comment below on how you would improve the rubric or the feedback in relation to the interim report

Please comment below on how you would improve the rubric or the feedback in relation to the interim presentation

Appendix 7

Survey 2 Raw Case Data

Table 41 - Survey 2 Raw Case Data

Student ID	Did you or your group consult the rubrics during the development and preparation of the interim report?	Did you find the rubrics helpful during the development and preparation of the interim report?	Did you or your group consult the rubrics during the development and preparation of the interim presentation?	Did you find the rubrics helpful during the development and preparation of the interim presentation?	Did you find the rubric feedback on your presentation and report helpful as you move forward with your project?
52	2	3	3	4	4
54	4	4	3	3	4
53	4	4	2	3	5
11	0		0		3
9	0	0	1	1	3
20	2	3	2	2	4
21	4	4	3	3	4
81	3	4	3	4	6
83	4	4	4	4	4
80	3	3	1	1	3

Table 42 - Survey 2 Raw Case Data

Student ID	Did you or your group consult the rubrics during the development and preparation of the interim report?	Did you find the rubrics helpful during the development and preparation of the interim report?	Did you or your group consult the rubrics during the development and preparation of the interim presentation?	Did you find the rubrics helpful during the development and preparation of the interim presentation?	Did you find the rubric feedback on your presentation and report helpful as you move forward with your project?
59	2	4	3	4	5
62	4	4	3	2	3
82	4	5	5	5	3
	4	4	3	2	3
88	2	3	2	3	3
	2	2	1	1	2
89	6	4	6	5	2
91	3	5	2	4	4
45	4	5	2	4	5
61	2	0	2	0	1
60	3	0	0	0	1

Table 43 - Survey 2 Raw Case Data

Stu ID	Please comment below on how you would improve the rubric or the feedback in relation to the interim report	Please comment below on how you would improve the rubric or the feedback in relation to the interim presentation	Stu ID	Please comment below on how you would improve the rubric or the feedback in relation to the interim report	Please comment below on how you would improve the rubric or the feedback in relation to the interim presentation
52	A little explanation on who we could use the rubric before the report would have been useful.	the same applies to the presentation	89	ideas for subheading; definitions for considerations	I liked how it was done --> maybe a little longer time to give presentation
54	More detailed explanation. However, it is already good enough.	more detailed explanation on the best way using the rubric related to presentation	62	it was difficult to hit all the extensions listed in the interim, although it wasn't necessary to meet them all, was difficult to decide which ones/how many were expected	
53		more detailed criteria	82	it was good	it was good
11	It gives comprehensive feedback as to how we can improve and encourages exploration of the topic. That being said, I do find it quite long.	additional categories for presenters (clear, volume, habits) style, content, connections to course objectives			
9	Too much jargon, not simple enough.	see above	88	needs more detail on where we went wrong	both were fine
20	The feedback was great, however the rubric wasn't thought about too often when writing the report.	same as for the report		it is hard to follow, too much text, too many pages	
21	I thought the rubric was well done, we just didn't base our future reports too heavily on it because marks weren't distributed exactly as this rubric suggests. However, we did use it to improve the structure and details of our reports.	Again, the rubric is well done. We simply looked where more marks could be made based on the rubric criteria, and applied it to our final presentation	59	the rubric is very useful, but the layout can often confuse the group. By leaving blanks it can often look like the evaluation is more negative then it truly is. To alleviate this issue two solutions could be either to 1) redesign the evaluation spreadsheet to minimize blanks 2) explain the layout further when introducing marking scheme (as it is new and unfamiliar)	same as above
81	It was good. Clearly laid out so that improvements could be pursued.	no way I can think of for improvement	91	instead of leaving sections not achieved blank, include them and highlight sections that have been achieved	same as above
83	It looks good as is.	it was sufficient. Maybe include more details but it was not a big deal	45	more of it --> I understand this is a tall order, but I think that effective group implementation of reflections on the feedback is the critical procedure. More feedback means more incentive to fix	more categories for comments w/ the expectation of actually having to fill them out. I.e. The fact that TAs did read peer feedback helped ensure that the feedback was legit
80	instead of showing what we have done, show where we need to improve.		61	I find the rubric is a waste of time	
52	A little explanation on who we could use the rubric before the report would have been useful.	the same applies to the presentation	60	explanations of each phase could be better; they were a little confusing (not explained properly)	

Appendix 8

Table 44 - Survey 2 Case Record

Please comment below on how you would improve the rubric or the feedback in relation to the interim report

Find It useful--> not useful

ID	Responses
82	It was good
81	No way I can think of for improvement
21	Again, the rubric is well done. We simply looked where more marks could be made based on the rubric criteria, and applied it to our final presentation
45	The feedback was great, however the rubric wasn't thought about too often when writing the report
59	The rubric is very useful, but the layout can often confuse the group. By leaving blanks it can often look like the evaluation is more negative then it truly is. To alleviate this issue two solutions could be either to 1) redesign the evaluation spreadsheet to minimize blanks 2) explain the layout further when introducing marking scheme (as it is new and unfamiliar)
83	It was sufficient. Maybe include more details but it was not a big deal
88	Both were fine
54	More detailed explanation on the best way using the rubric related to presentation
53	More detailed criteria
52	A little explanation on how we could use the rubric before the presentation would have been useful
91	Instead of leaving sections not achieved blank, include them and highlight sections that have been achieved
11	Additional categories for presenters (clear, volume, habits) style, content, connections to course objectives
45	More categories for comments w/ the expectation of actually having to fill them out. I.e. The fact that TAs did read peer feedback helped ensure that the feedback was legit
89	I liked how it was done --> maybe a little longer time to give presentation
9	Too much jargon, not simple enough
62	
61	
60	
80	

Table 45 - Survey 2 Case Record

Please comment below on how you would improve the rubric or the feedback in relation to the interim presentation

Find It useful--> not useful

ID	Responses
82	it was good
81	no way I can think of for improvement
21	Again, the rubric is well done. We simply looked where more marks could be made based on the rubric criteria, and applied it to our final presentation
45	the feedback was great, however the rubric wasn't thought about too often when writing the report
59	the rubric is very useful, but the layout can often confuse the group. By leaving blanks it can often look like the evaluation is more negative then it truly is. To alleviate this issue two solutions could be either to 1) redesign the evaluation spreadsheet to minimize blanks 2) explain the layout further when introducing marking scheme (as it is new and unfamiliar)
83	it was sufficient. Maybe include more details but it was not a big deal
88	both were fine
54	more detailed explanation on the best way using the rubric related to presentation
53	more detailed criteria
52	a little explanation on how we could use the rubric before the presentation would have been useful
91	instead of leaving sections not achieved blank, include them and highlight sections that have been achieved
11	additional categories for presenters (clear, volume, habits) style, content, connections to course objectives
45	more categories for comments w/ the expectation of actually having to fill them out. I.e. The fact that TAs did read peer feedback helped ensure that the feedback was legit
89	I liked how it was done --> maybe a little longer time to give presentation
9	too much jargon, not simple enough
62	
61	
60	
80	