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# Engineering Projects: Industry connections and Engineering Tools

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## CONTEXT

Engineering capstone projects are the pinnacle of the student's education. This project is the culmination and application of the various skills and concepts learned throughout the course. The graduate attributes are also demonstrated. A student's project acts as an effective talking point for use in an interview.

## PURPOSE OR GOAL

Having a selection of projects for students to choose from reduces obstacles, can allow alignment with a student's values, and allows them to solve the issue quickly. Providing these projects takes considerable time behind the scenes to ensure they align with learning outcomes and achieve the correct complexity and breadth to be effective. Once in the classroom, the projects offer a challenge for equitable assessment. Setting up a transparent system for student and educator alike is discussed within.

## APPROACH OR METHODOLOGY/METHODS

A two-pronged approach is useful for having a sufficient supply of projects: industry projects and internal projects. Industry projects provide problems that industry does not have the resources to solve. This provides a valuable training tool for the students. Engagement with industry builds relationships for future developments.

## ACTUAL OR ANTICIPATED OUTCOMES

The study will highlight an emerging concept, the Project Rating Score for securing projects, correctly sizing them for the course, and examining how this impacts student success. Many projects are available but understanding how to filter these and set the correct expectations for all parties involved can be a big challenge. A reflection on a student/client contract will be discussed to help improve alignment with all parties. A first look at the concept for a Project Rating score system shows promise in application.

## CONCLUSIONS/RECOMMENDATIONS/SUMMARY

This will be a demonstration of best practices from personal experience for capstone project development. Each institute has different requirements, but this paper hopes to showcase a new perspective from an academic that recently moved from industry. The Project Rating Score will go into trial use to begin the data collection phase of the project.

## KEYWORDS
industry, collaboration, teaching tools

# Introduction

One of the final obstacles that all engineering students must face before graduation is the completion of the capstone project. A culmination of learnings rolled into one last challenge, which takes the theories and concepts learned and applies them to a real, open-ended project. This project is the final growth opportunity in the academic journey and hopefully is aligned directly with their ambitions and next phase. These projects should include a customer and should evaluate graduate attributes as well as technical engineering knowledge and skill. There are two main types of customer-lead capstone projects: industry and internal projects. These both have positives and offer different challenges for procuring and solidifying a proper project and marking the students fairly and accurately.

# Method

A project-based course offers different challenges to the student and educator alike. Each project is unique, and each outcome will be as well. Projects offer open-ended questions and student apply their knowledge and learning in a distinctive way. Badir et al. (2023) found real-life project-based learning through industry involvement in capstone design courses provides benefits to students, faculty, and industry practitioners. Project-based learning creates opportunity for endless outcomes and so creates a challenge for marking and equity.

Having spent a career in product development, continuous improvement and reflection are part of constant improvement and change for class. This aligns perfectly with the action research method. Dickens and Watkins (1999) show by using the methodology of action research, practitioners could research their own actions with the intent of making them more effective. This approach is like what is found in industry, for fast iteration and feedback loops, honing in on effective solutions. First looking at the projects themselves but focusing on the future and developing techniques to make projects as equitable and transparent as possible.

From the initial contact with a perspective customer to the final marks of a project, there is a lot to consider for a consistent and equitable assessment. The Project Rating Score is a new idea in development to bridge the customer and student gap as well as allowing for transparency on the overall scope of projects which can be varied and quite large.

## Projects

Projects are a valuable teaching tool but come with varying levels of complexity, breadth, ownership, and criticality. These all must be balanced to provide a positive outcome for all parties involved: students, educators, and the project's customers. The educator has the main responsibility of finding this balance. Leaning on professional experience is the one way to get this balance correct. Do not expect each project to perfectly achieve success for all participants. This makes conversations with customers critical upfront. Setting the correct expectation helps make the balancing act simpler.

## Customer

There are four types of customers that can provide a problem for a student project. These include industry, internal projects, entrepreneurs, and students themselves. Each brings unique benefits and different challenges for collection. Engineering firms should be the prime focus for obtaining a project. The direct link into industry shows collaboration between education and industry, but the customer should be well versed in creating successful project scopes as well as establishing and managing realistic project timeframes. These research and development projects may be overly ambitious, and the educator may need to restrict complexity for a better chance at success.

The next customer to consider is internal to the university or polytech. There are research projects and educational needs all over the place. Look at what educational or fabrication equipment might be required in the future. Can these requirements turn into a project? If the

 

project falls within a different area of the educational institution, negotiation is required to find a successful scope. Either of these customers already understand students and the pros and cons of collaborating with them to solve problems.

Another type of customer is entrepreneurs. This group is filled with people and small business that are looking for any type of assistance. These customers can vary wildly in experience and expectations. Its critical to outline what the projects can and cannot achieve. Showing these customers what has been completed in previous projects and being upfront with successes and failures can set the correct prospects for the project. The project is primarily for engineering students, not for a product development firm or engineering consultancy. This distinction should be made apparent from the beginning.

A final customer consideration should be allowing students to create their own proposals for their capstone projects. For less experienced students, this can be a challenge to articulate and plan a proper problem. Although this is an option, it should be considered carefully. The benefits of having a customer-led project are quite prominent.

**Table 1: Summary of Project Customer Types**

| Customer | Collection | Benefit |
|---|---|---|
| Industry | Build relationship to create engagement | Collaboration opportunity |
| Internal | Simple, especially within own department | Develop learning resources |
| Entrepreneur | Connect with start-up community | Build broader community |
| Student | Simple, but size and scope require more development | Solution for personal passion |

## Requirements

The three main project requirements to focus on are criticality, timeline, and flexibility. By aligning these three aspects, the project should be on track to be successful. Criticality is by far the most important. As mentioned, the students are not professional engineers and therefore the output should not be placed directly into use for critical function or safety. This can apply to retrofitting or designing manufacturing equipment. Aesthetic prototypes or small-scale simulations to help solve the problem but reduce the end-user compliance is more appropriate.

The project timeline is also something to consider in understanding what is appropriate in terms of scale, scope, and complexity. If the customer has a critical path item, this is not a good requirement. The customer may see that students need to accomplish 150 or 300 hours of work, but this is at a learning level not a professional level. Starting with a smaller scope and expectation allows for both the learning and the development of the project. Other student time requirements must also be identified to the customer. The course documentation for the project, other courseload from the student as well as the learning curve all add into the project hours. Making the customer aware of all the facets of the project and student also helps everyone align for success.

Customers need to be flexible. Not only on the outcome but allowing the student to work, learn and achieve with guidance not directions. This flexibility might mean that the project does not make it all the way to the desired finish line. The outcome should still be able to provide useful knowledge, ideas, and prototypes for the customer to use after the student's deadline. This can lead to multiple projects over several semesters or years. Being able to develop a project brief

 

that can expand to this longer scope aids continued engagement and demonstrates how projects might evolve.

# Discussion

Each capstone project is unique, and every student brings different things to the table. For learners, this may be the first time they are applying their skills and learnings to an applied problem that does not have a singular correct solution. One benefit of the project having an authentic customer is that it helps the student to act on their feet. As students develop the project and customers learn of the progress, the customer will inevitably change their mind about some part of the outcome. Whether a minor tweak or a complete redirection, this may be the first-time students are dealing with a change of scope. Classroom problems and assignments have correct answers and do not evolve like a project can. Dealing with ambiguity and uncertainty in a safe learning environment can help build confidence. The project can also be a major talking point for job interviews. Showing how they were able to collaborate with a team and a customer and communicate and overcome challenges in addition to showing the engineering process and project output are all skills to articulate to a future employer.

For industry, especially in a tight labour market, engaging with the education system can allow a first look at soon-to-be-graduates. The project can be regarded as a long interview process where the company can learn about not only the technical skills of the students but also see the graduate attributes in action. It is a firsthand look at how the students carry themselves and how they might fit into various roles the business might have.

For the educator, the project course offers a wide array of complex problems the students are solving. Providing consistent marking across all the solutions provided is a challenge. Projects can vary both on complexity and breadth creating an endless possibility of scope.

## Future Development

Although obtaining a list of interesting customer lead projects is a resource-heavy endeavour, the bigger challenge is marking the projects in an equitable manner and as transparently as possible for the students. Because each project brings its own levels of complexity and breadth, there is a lot to consider when assessing the result. On top of this, some courses combine disciplines (civil, mechanical, and electrical) into the same course requiring multi-disciplinary collaboration.

A system describer concept is in development to help answer this. This system allows the educator to rate the complexity and the breadth of the project. Both factors are dependent on multiple aspects including what level and number of credits the course achieves. Guidelines are focused on the NZ polytechnic system. As can be seen in Table 2, the project courses the author teaches require adjustment to the complexity and breadth depending on the course. The Project Rating Score is to be the same no matter what level the course is. A level 5 project with a Complexity of 5 has different requirements as a level 7 Complexity of 5. These values should align with course requirements which can include different size, length, scope, and group number.

**Table 2: Breakdown of program and project requirements (*The New Zealand Qualifications Authority: NZQA*, 2023)**

| Certification | Level | Project Hours | Size | Area of Focus |
|---|---|---|---|---|
| Bachelor of Engineering Technology | 7 | 300 | Individual | Civil, Electrical, Mechanical |
| New Zealand Diploma in Engineering | 6 | 150 | 1-4 person groups | Civil, Electrical, Mechanical |
| NZQF Certificate in English for Engineering | 5 | 300 | 1-4 person groups | Information Technology, Mechanical |

The system in development provides a rating for both project complexity and breadth on a scale of 1 to 5. The numbering is arbitrary but allows adequate resolution. By multiplying the Complexity and the Breadth together, a Project Rating Score is achieved. Taking some inspiration from the Risk Assessment Matrix (*Risk Control*, 2023), these scores can equate to an acceptance level. As can be seen in Table 3, project ratings are like the low, moderate, high, and extreme ratings.

**Table 3: Breakdown of Project Rating**

| Project Rating Score | Project Size | Action |
|---|---|---|
| 0-5 | Too small | Increase complexity and/or breadth |
| 6-9 | Acceptable | Proceed. Output as stated in proposal |
| 10-15 | Ambitious but acceptable | Proceed. Results may be reduced from proposal |
| 16-25 | Too large | Reduce complexity and/or breadth |

Visualizing the Project Rating concept can be seen in the Figure 1, where three examples are shown. One project (orange) has an elevated level of complexity (rating of 5) and a low level of breadth (rating of 1) for a Project Rating Score of 5. The second project (grey) has a low level of complexity (rating of 1) and an elevated level of breadth (rating of 5) for a Project Rating Score of 5. Neither of these reach an acceptable project size. The third project (blue) has an elevated level of complexity (rating of 5) and an elevated level of breadth (rating of 5) for a Project Rating Score of 25. This project is too large and needs to be reconsidered or reduced.

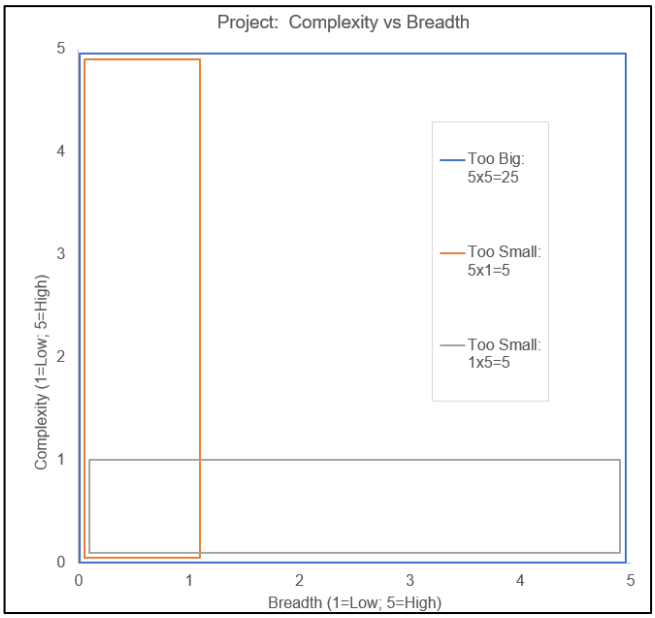


**Figure 1: Project: Complexity vs Breadth**

Three acceptable projects can be seen in Figure 2. Acceptable Balanced is seen in green and has average complexity (rating of 3) and average breadth (rating of 3) for a Project Rating of 9. Acceptable Complex is seen in yellow and has more complexity (rating of 4) than breadth (rating of 2) for a Project Rating of 8. Acceptable Wide is seen in blue and has low complexity (rating of 2) and average breadth (rating of 3) for a Project Rating of 6. Each are acceptable projects, however the Acceptable Wide has the lowest overall rating and therefore has less room for error.

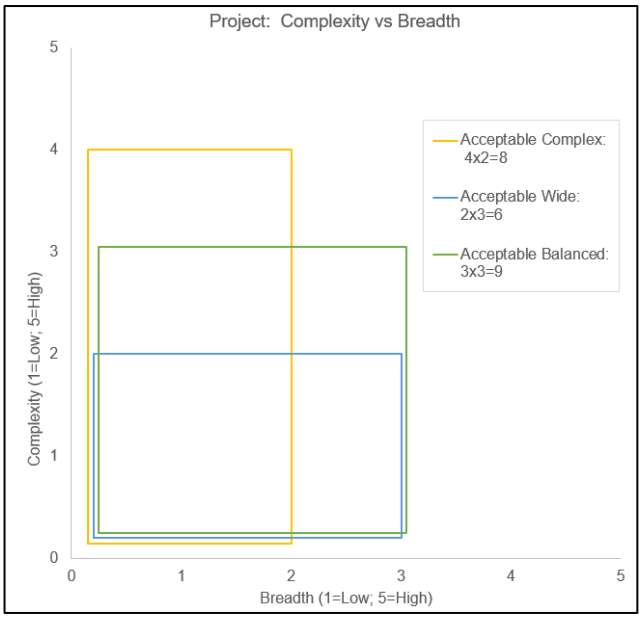


**Figure 2: Various Size Projects**

By including a Project Rating Score for each project, the students have a better idea of the type of projects they are embarking on. This transparency would give the student a better insight into the overall challenge of the task and what needs to be accomplished for success.

Table 4 shows a listing of different components that contribute to the Complexity and Breadth score. This is an abbreviated list. Complexity focuses on main course concepts and first principles. Breadth focuses on application or documentation of these topics that support the final output. It can be considered as what would be handed over at the end of a project.

**Table 4: Example of possible areas of Complexity and Breadth**

| Complexity | Breadth |
|---|---|
| Materials | CAD Parts/Assembly |
| Manufacturing | Simulation |
| Mechanics | Prototype Development: Functional |
| Automation | Design Standards Compliance |
| Structures | Computer Modelling |
| Sustainability | Code (Developed and Commented) |

A value can be award between 0 and 1 for each component identified for the project. Summing both the Complexity and Breadth column gives each a value that is then multiplied to obtain the Project Rating Score. The value main drivers, initially, are the expected time/effort applied to each area as well as the level of thinking. If there is a large portion of effort, then the area gets a value of 1. If there is some portion or a required level, a 0.5 value is assigned.

The Project Rating Score could be used throughout the life of the project. At major milestones, assessments or reassessments of the Project Rating would be conducted. As shown in Figure 3, there are four assessments during the life of the project. Before projects are selected, these rankings are an effective talking point with the customer. Showing a target project range and then assessing the customer's project can show whether the size is appropriate and/or outline the steps needed to achieve an acceptable size.

In the beginning of the project, the student is estimating areas and what level the project may be. At the midpoint, students can reflect and adjust the project requirements as well as the Project Rating Score. If the project has pivoted, the areas can be amended. It is also a good point of reflection for the student to adjust and add time for neglected areas. Upon the conclusion of the project, students need to demonstrate not only the final solution but also show how the Complexity and Breadth areas have been accomplished. This can improve consistency between academics on assessment panel by highlighting areas of knowledge the students should have focused on. This is another point of reflection the students can make before communicating the results. A formal write up requiring reflection and documentation can make this more effective. Final marking from the lecturer will involve a reflection from the beginning score and assessing if they have demonstrated their proposed levels. Both the lecturer and student reflections will culminate in the final Project Rating Score and result in a corresponding Project Adjustment Rating.

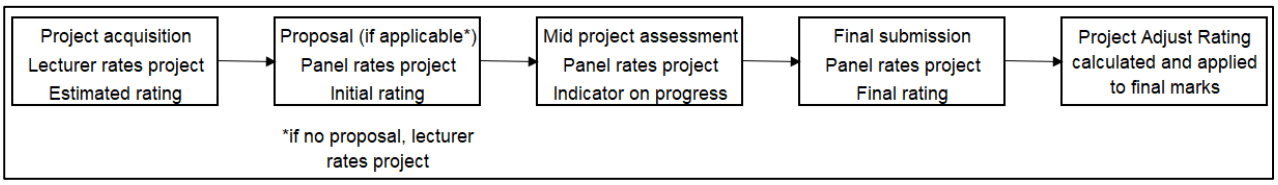


**Figure 3: Flow chart of the process**

The last step in the process would be a grade adjustment based on the difference or movement between the initial and final Project Rating Score. This adjustment could provide projects that achieved above their initial rating an upward adjustment. Similarly, if the project achieved below the initial rating a decrease in overall marks may be needed. A summary can be found in Table 5. The overall marks are adjusted at a predefined value based on the level of movement. This could be a coarse movement as seen in the examples below or could be standardized to ~3% for each decrease in complexity or breadth.

**Table 5: Example of Project Adjust Rating**

| Initial Rating | Final Rating | Comment | Suggested Grade Adjustment (Percent of total marks) |
|---|---|---|---|
| 8 | 9 | No/minimal adjustment, still falls within acceptable range | 100% |
| 12 | 9 | No/minimal adjustment, still falls within acceptable range | 100% |
| 10 | 12 | Upward adjustment, project improved considerably | 101-110% |
| 8 | 4 | Downward adjustment, project did not meet requirements | 80-100% |

# Conclusion

Capstone projects are a critical last step for an engineering student's education. By providing customer-led problems to solve, the students learn invaluable skills. The scope of these projects is always changing and providing consistently scoped projects, although challenging, can be a rewarding education experience. By instituting a Project Rating Score, improved consistency and transparency can be achieved for the project. From the initial conversation with the customer through each stage of a project, having this common language will improve consistency of marking between students and lecturers as well as from year to year.

The Project Rating Score is being applied starting Semester 2 2023. Initial concept and ratings have been completed. Students have completed this step as another part of the project proposal. The student rankings are a good starting point for discussion on the scope and timeline of the project. Further student, customer, and lecturer feedback are the next phase.

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