A FRAMEWORK TO ADD DEPTH, CAREER RELEVANCE, AND SKILLS DEVELOPMENT INTO ASSESSMENT IN A 2ND YEAR DESIGN COURSE

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Abstract: *In a typical engineering classroom, there are many skills that students are expected to learn, develop and apply. Educators struggle on a regular basis to find meaningful ways to get students to develop skills. While it is possible to make large educational reforms in a program, sometimes change can be found in small and meaningful modifications to assessments. This paper focuses on simple, knowledge-based assessments used in accredited programs. An example is provided of a framework used in a second-year design course to transform simple assessments into opportunities for the development of deep skills, while at the same time managing educational resources and maintaining a focus on outcome-based assessment. The primary components of the framework are to tie in long term skills development, aspects of STEAM (specifically the arts elements), as well as aspects of career development and engineering identity into assignments, to allow students to contextualize their skill development into the broader understanding of their own career and identity development as an engineer.*

Keywords: Engineering Design, Paradigms in Design, Engineering Education, Career Development, Engineering Portfolio.

1. INTRODUCTION

In engineering education, there is a major struggle that takes place in nearly every classroom, where instructors are challenged to ensure they are creating assessments that are: applied, reflective of practice or practical skills, and also meet specific assessment criteria for accreditation. Each of these requirements are in some conflict with each other as there are typical educational approaches to account for each one but there isn't necessarily a simple approach that can account for all of them. In many engineering programs, the simplest solution is to divide each of these approaches into discrete ideas, leading to specific assessments (such as basic assignments) where students are easily assessed on their learning outcomes (sometimes via simple summative feedback from a teaching assistant), and more complex

assessments to capture some of these other aspects. This approach, while somewhat effective, has systematic problems that are not necessarily all that easy to solve. One example is that students often delineate skills as "textbook" or "assignment" skills from those that are more applied, due to the nature of splitting up assessments that way [1]. Students also tend to be more engaged when they are cognitively challenged, showcasing a willingness to go beyond basic assignment requirements on challenging projects as compared to simpler assessments [2] [3]. This is also exacerbated by the lack of educational resources that most instructors face, which typically results in educators focusing on the more complex assessments and in exchange needing to occasionally rely on some basic assessments.

This same struggle is, to some extent, also mirrored in industry and the professional skills engineers are expected to have when transitioning into the workplace [4]. Practicing engineers are often expected to be able to solve a diversity of problems, which itself is a dichotomy: students need the skills required to solve the problems, but also the situational ability to apply the knowledge they have learned in an applied setting, and also to be able to synthesize and create that same knowledge in the workplace. Educational literature speaks significantly about this, from looking at how education should move up Bloom's taxonomy [5], which is also mirrored in the CEAB's 12 graduate attributes in their "level of competence" required [6]. This often leads to students focusing on developing a basic understanding of skills in lower year courses and applying these skills more as they go through their degree program before reaching their "capstone" or equivalent upper year course. There have been many efforts to pull some of the application down to lower years [7] [8], however the efficacy of this approach relies on students retaining the knowledge they learn and being able to apply it in a progressively more applied manner. Much of educational literature however would typically indicate that unless a program is carefully sculpted this is, by nature, not the way students learn. Students require very specific scaffolding to support their

learning processes to achieve this [9]. In the most specific case, developing skills at one level and relying on students to maintain and develop them is a fairly optimistic educational goal. To achieve that, an educational program would need to carefully scaffold those skills and ensure continual development is somehow maintained.

A further layer of this problem is finding the connection between what is being studied in school to the skills required by industry. There is debate about whether or not students are equipped for career success, with opinion pieces on one end of the spectrum claiming students do not have the basic skills required to succeed in the workforce upon graduation, while others argue that the issue is students simply do not understand how to effectively articulate the skills they do possess [10]. Research has shown that students do struggle to connect the skills they build in school to the skills required in the world of work [11]. One way students might learn to better articulate their skills is through opportunities to reflect on and connect their studies to employability skills [12]. This can in turn provide opportunities for meaningful career development. Reflection is a major component of the career development process, where individuals connect their experiences, skills, and other self-knowledge to their career goals [13]. By creating explicit connections between what is being studied in the classroom to the skills needed in the world of work, students might be better equipped to market themselves to employers in the future.

From all of these three problems, it can be seen that there is a commonality of elements, and a possible solution is to look at ways to inject elements of practicality, industry relevant engineering skills, and career development into assignment work, without creating extra educational overhead in the process. A way to address this is to look at an assignment (or assignment set) in a portion of a course that typically relies heavily on fairly basic outcome-based assessment, and transform the assessment into something that can capture more of these elements, but still use the same (or similar) evaluative framework. By tying in elements of lifelong learning associated with tasks that also develop awareness of employability skills and engineering identity, value can be given to work that students might not necessarily see as valuable.

1.1. Background

At the University of Manitoba, a pair of courses that draw heavily on practical and applied skills are the graphics derived second-year design courses offered in both the Mechanical and Biosystems Engineering programs. Both courses originally were conceived as introductory graphics courses, but both were transformed over years of development based on a simple idea: in order for students to learn computer aided design effectively, there has to be a mix of knowledge learning and experiential learning. As a result, the graphics content in both courses was reduced, while increasing the design

content, but the end result was that students gained more mastery of the graphics content by needing to apply it regularly. Both courses involve heavy project work blended with a 15-hour graphics portion where students learn the basics of Computer Aided Design (CAD). Students learn design skills, while learning the CAD skills separately. Through project work and deliverables, they are tasked to apply those skills and get some exposure to the complexity of computer aided design in an applied setting. From an accreditation standpoint, both courses originally had a large amount of content related to the CEAB *Engineering Tools* graduate attribute, and shifting this work into design projects can prove to be challenging to some extent [7]. The approach for the course has been to always allocate some portion of the course assessment to purely graphics assignments to ensure students individually understood the content and were assessed on it. However, as many of the problems with this approach mirror those in the introduction to this paper, it leads to a simple idea: can these assignments be transformed into something that is more aligned with the course structure and in doing so can there be a benefit to student learning in a way that addresses some of these problems?

This paper will outline a case study of a framework that was developed to address these problems in context, with the eventual goal of being able to study the results more closely in a research study and also be able to inform new educational approaches for graphics education/assessment. The paper also covers the application of this framework in two courses to implement open ended design portfolios as assignments for students to help them develop needed skills, and apply them in an open-ended setting.

2. METHODOLOGY

One of the core tenants of the presented methodology is to look at the nature of the work that students do and how it develops their skills. In the case of outcome-based learning (as you would see in an accredited program), the principle of assessing students on specific ideas might not shift the focus of assessing students towards simpler assignments, but the assessment difficulty increases as educators drift away from simple assessments. This comes down to a simple notion: what minimum level of skill does a student need to exhibit in order to be deemed competent in that skill and also the related outcome? Likewise, how does one assess a student to ensure that skill is met? An illustrative example from a graphics perspective of this might be in blending in graphics with design. In a typical graphics assignment, a student might be given a tutorial on how to design a simple part, and be tasked to design a different or more challenging version once they finish. This assesses specific skills and the assessment process to ensure the student has developed the skills required is fairly basic. In a more applied assessment however, you might

task the student to design a part to solve a problem or task, and then have them produce a CAD output of the same part. This now opens up the assignment, by incorporating a design aspect to it, but adds a level of complexity to the assessment from an educational standpoint: how do you ensure that the design is complex enough to use the skills you want, yet not scaffolded enough to be minimally different from the previous example? One solution to this is to perhaps come up with a set of carefully scaffolded assignments that let students engage in the content in a more applied sense, however this is not always easy to do in every course, and in the specific example of a graphics course takes a lot of careful scaffolding to do. This goes back to one of the basic points from the introduction that this can be seen as a somewhat trivial problem if educational resources are not finite, however if they are (as is most often the case) this is not a problem that is trivial to solve. This argument can also apply to more complex approaches such as those described in [7] and [8] that rely on blending skills into the design process to selectively evaluate them, however the additional resources required would also be quite challenging to justify for the outcome of a simple graphics skill assessment. Other solutions that rely purely on assessment alone, such as exams or more complex assignments, can also achieve a portion of the desired outcome (the evaluative end), but the application, and practical placement of these skills is critical, and these elements do not touch on those aspects of the skill development process necessarily.

Instead, a simple solution that can be used and that forms one of the two backbones of this framework is to get students to first develop skills and assess their competence in a fairly binary manner, but then allow them to demonstrate the skills in a more rich setting that allows for summative and formative feedback to be given at a point where it can be valued and developed by a student. To do this, students could be given a set of very simple assignments that might not even need to be given summative feedback, but are focused on formative feedback to develop the skills students need. After developing skills, students can work on more complex assignments like a portfolio (multi entry submission of one or more assignments to show competence and skill) or similar that showcases students' ability to apply skills while still allowing their learning to be tracked and allowing for the potential to have deeper meaning be developed by practicing skills in an applied context. Obviously, there are issues with this concept that need to be carefully addressed, but if it could be implemented it would present a viable solution to the situation given above.

While the form of this assessment is basic, a major component that is missing is a technique to motivate and engage students. Educational research tells us that students who are motivated to learn (from either external or internal stimuli) are more engaged and more prepared to learn. This

forms the second backbone to the framework: connecting the assessment to tangible outcomes valued by the student, thereby increasing students' perception of the value of the work they are doing. One way this can be done is to integrate the identity that students develop in the process of becoming engineers, into the assessments. This can be done by tying the skills they are learning into that identity and linking their learning to their skill development as a professional. Both of these are aspects strongly tied into motivation to learn [14]. By activating students' emerging engineering identity and the value they place in the development of skills for their career futures, we might be able to make students feel their assignments are more valuable.

2.1. Articulation of engineering skills

2.1.1. Engineering identity and engineering skills

Engineering identity is the personal and professional qualities defining who an engineer is and what they are capable of [15]. One component of engineering identity is the skills required for success in the profession [16]. Engineering students are engaged in a process of rapid skill expansion as they take the courses required to graduate from an accredited engineering program. But it is not always clear to students how these skills connect to their developing engineering identities or to their overall career goals. At times, educators might notice that students are not engaged in their assignments in a way that suggests they are attempting to grow their skills for their future, but rather they are trying to meet the minimum requirements amidst competing priorities. By positioning the skills developed in the class as relevant, meaningful skills required for career success, students have additional motivation to engage in skill-development beyond simply attempting to meet the minimum academic requirements of their course. Through this approach, the assignment is injected with further meaning in the context of their broader engineering skill development and can even be understood as a marketable example of their skills when searching for work [10].

2.1.2. Reflecting on and articulating skills through portfolio development

Portfolios are already being used as job search tools and have been integrated into engineering co-op programs and courses [17] [18]. By asking students to generate a portfolio of their work, students are given the opportunity to conceptualize their learning in the context of the labour market, which in turn provides the foundation for future communication of their skills to employers through resumes, cover letters, interviews, and during networking opportunities. Further, a portfolio can be referenced during the job search, providing tangible proof of a student's capabilities. By turning a basic assessment in a design heavy course into an opportunity for career development,

students are given a chance to take learning into their own hands and also develop their skills in an applied setting.

2.2. Course Implementation

To try out this approach in a classroom setting, two core courses at the University of Manitoba were used, one in Biosystems Engineering and one in Mechanical Engineering. Both are at a second-year level and are intensive project-based courses that apply design and engineering tools in a practical setting. Instead of focusing on the core content itself, the framework was targeted at the graphics assessment part of the course, which typically has a value of 10% of the course's final mark. Since the graphics portion primarily consists of basic assessments, the framework can be applied to these assessments to provide more depth of learning for students.

In past offerings of the course, the content had been set up so that: students attended graphics tutorials, did basic assignments on which they were given formative and summative feedback, and were given the option to redo the assignments based on feedback. By the end of the course, students were expected to have developed the skills they needed and the majority of students scored well because there was ample opportunity for development and feedback over the course. Students who received lower marks were not in this case typically students with lower abilities but those that did not for a variety of reasons want to rework or redo the assignments. Students were also asked to set up portfolios of their assignment work, with the intent of having them develop more unique work to put into the portfolios as their careers and degrees progressed. Unfortunately, it was informally noted that many students did not pick up their portfolios after submission, as many students informally viewed them as simple assessments that they typically had done well on. Over the years, the career and skill development aspect of a portfolio were also emphasized in class, but this was seen to make little difference in the performance of the students or their general view of the assignments.

To apply this approach to these courses a simple framework was developed and applied to the graphics assignment portion of the course alone. The hope was to see if some improvement could be seen by informing the approach used to assess students. The first step was looking at the typical errors students made in their course work. It was found that approximately 50% of the errors were made on minor details that involved adjusting minor elements to match what was required in the rubrics, and about 50% of the errors were from students who didn't understand how to perform specific skills being taught to a level required by the assessment. To address this, the framework utilized a similar assignment set as before, however the assignments were treated as skill development and converted from assignments that were given scale summative feedback to primarily formative feedback with a pass/fail grade. This greatly reduces the time required for

teaching assistants to mark the assessments, which let them focus on the formative feedback and also allowed them to clearly identify students who needed help to bring them up to the required standard of skill. The deadlines for the assignments was shortened drastically, but students who needed help were also given more educational support.

These assessments were then set up as a gateway (i.e. a pass is required on each assignment to proceed) to the graphics assignment that was given to the students for both formative/summative assessment that was worth the full 10% of the grade. This assignment took the form of an open-ended design portfolio, which was a set of three entries that tied several aspects of design and engineering tools together. Students were expected to make three entries (approximately 4 pages each) that showcased a design that the student was responsible for, using the skills taught in the graphics portion. The entries were meant to be open ended, with students using graphics skills (CAD, renders, drawings) as well as communication skills and design skills to show how they made a specific part and what design processes and skills went into the process of making the part itself. The design and part also had to be a part the students themselves designed, which puts the onus on the student to make sure they at least have the experience of designing a few of the parts for their course projects.

There was also an emphasis placed on designs created for extra or co-curricular work. Of these entries (in the first iteration of the course) one could be something that the students designed on student teams or in other engagement beyond the classroom. This was based on tying in the identity development that students embed in work they do themselves and the perceived value in providing some credit for that work [14]. In later iterations of the framework this was increased to allow a student to submit all three entries based on content not directly designed for the course.

The assessment of the entries was done partially based on students' ability to use the skills required, but as these had been tested beforehand there was not a significant need to ensure that each skill is retested, but also partially on the: presentation, merit and nature of the designs and use of tools by the students. This allowed students to present designs that were very typical of the course (shafts, mechanisms, couplings they made to solve a problem) and also allowed students to present applications of the skills well outside of the realm of the course content (art displays, personal projects, co-curricular work, and work done during a work placement). All of these entries were marked by both the instructor and teaching assistants for the course with an emphasis from the teaching assistant side to ensure that the entries were using the desired graphics and communications skills, all of which had well established rubrics from the assignment portion.

The portfolio portion of the assignment allows students to explore more than what's covered in the course,

with some minor incentive to also positively engage with student's co-curricular and extra-curricular work that uses similar skills. This has been shown in the literature to bring value to the educational process [19] [20], however comes at the price of the potential for extra workload. As the framework was implemented, students had the option to treat the portfolio as another assignment, using the skills and tools used in class to describe parts they made in their projects for the same class with the extra potential learning being something that students could take on if they wished. This is commented on later, but typically students strongly preferred to do independent designs for at least a portion of their own portfolio.

The generalized version of the framework that can be applied in a variety of settings is two-fold. Step one is to take a specific set of assignments, and decrease the level of overall assessment directly tied to them (while still keeping an incentive for students to complete them). Step two is to create another assessment that mirrors the skills developed in the assignments and at its most basic can represent something that is as simple as the assessed content, but is broad and open enough to allow students to apply content beyond what is covered in the course. In doing this, students have the opportunity to create a unique portfolio of their own skills both within and beyond the course. The function of this is to apply the skills developed within the course to areas personally relevant to students and therefore more personally important to their own interests, goals, and engineering identity.

3. OUTCOMES AND RESPONSE

As of writing, three iterations of the discussed design courses have used the framework to have semi-open design portfolios. The overall results from an educational perspective have been very positive, with the course consuming the same resources needed from TA's to provide student feedback, while at the same time allowing focus to be put on developing skills where students need them. Students engaged in portfolio work have also been able to engage with a number of industries, other members of the faculty and have had the opportunity to expand their learning in a very meaningful manner. Multiple employers and other stakeholders have provided informal feedback indicating the appreciation for the design portfolios as a tool used to express a student's personal design accomplishments.

3.1. Student Perspectives

Students who were given the new open portfolio assignment seemed to have positive reactions overall. It was viewed as a chance to bring a more personalized touch to their education, but in a manner that is still optional to engage in. While there were students who used only in-class parts, some found that the in-class designed parts were not necessarily complex enough to easily do a

portfolio entry about without going into significant technical detail. In many cases, students embarked on entirely independent small designs, devices like mechanical pencil bodies, phone mounts and similar practical designs with some personal resonance, while still meeting the requirements of the portfolio. This is to some extent heavily supported in the product development and design portion of the course, but also shows that students are willing to sometimes put in more than the bare minimum effort on what is replacing a simple assignment. In other cases, students were able to get credit for their co-curricular work, such as work on student design teams that goes well above and beyond the graphics requirements in the course. Overall, the perspective given from students was that the openness of the assessment was seen as a positive item.

In terms of career development and engineering identity, students leaving the class now had an artifact of their own personal skills. This artifact in turn could be utilized in future engagement in the labour market, informing skill articulation in resumes and cover letters and generating relevant stories for interviews. These portfolios can even be shared in conversation with potential employers, allowing the students to showcase their unique engineering designs and achievements.

One of the notable outcomes is actually reflected in the title to the paper, where the original framework doesn't necessarily heavily rely on Science Technology Engineering Arts and Math (STEAM) education. In a very simple sense however, the framework presented reflects applying these aspects to a basic assignment, developing something more diverse for students to explore and learn with. A major response from students was the positive engagement with the arts aspects of design and graphical communication, where the open nature of the artistic portion of this type of assessment brought value to the other elements that are typically part of technical engineering identity (the STEM portion of STEAM). The informal feedback given strongly indicated that the artistic side of design is something that many students resonate with but is not typically something that forms a backbone of what people view as traditional engineering identity [15].

4. FUTURE WORK AND SUGGESTIONS

As this is meant to be a work to inform practice, and the informal feedback has indicated that the application of the framework in the courses discussed is fairly successful, a follow-up qualitative study is suggested. This study would look at the experiences of students in second year courses and how alternate assessment frameworks influence students' motivation and understanding of their skill development.

As the portfolio aspect and career development portion of the framework are largely based on informal feedback and theory, a longitudinal study is being planned to explore

some of the potential career and identity outcomes of the frameworks used in courses. The design portfolio developed by students can be a key entryway into building a student's engineering identity, since it allows students to bring their personal interests into the context of their engineering education. Further, this portfolio also provides a record of tangible employability skills useful to the student's broader career, with the hope that students can begin to better connect their education to their longer term career goals in engineering.

4.1. Suggestions and Plans for Expansion

This framework, while in this context is primarily developed for a specific design course, has many applications in other courses where specific skills are taught that students are expected to develop over time on their own. In one example, this framework was also used to inform changes to a professional practice course at the University of Manitoba to create an applied project in a course that typically relies entirely on traditionally simple assessments.

Similar expansion could easily be done into courses in areas like writing, programming, and design, which are all skillsets we want students to develop but often have to also assess and evaluate in fairly specific ways. While these are all topics that could be easily developed with more educational resources, they are all also topics that typically have small assessments tied to them that the framework can be applied to.

Beyond this, educators could also introduce career language into their classrooms, naming the employable skills being developed. This could also highlight opportunities for Faculty to collaborate with Career Services and Co-Op staff to support students in understanding how their assignments can be translated into marketable skills. Overall, by introducing assessments which feel applicable to the real world, students can more easily attach their learning to their career goals.

5. CONCLUSIONS

Based on the outcomes of the framework being applied to a design course, it is clear that there are many opportunities to look at transforming aspects of courses and assessments to be more than just basic assessments and turn them instead into opportunities for students to express some of their deeper learning. While it is often the case in engineering programs that there is a lot of emphasis placed on the more practical skills, there is a need for many of the more basic skills in students to be developed. It is in those cases that frameworks like this or other pedagogical approaches may provide a better learning experience for students. When this framework was applied in a design course, the outcome not only managed to keep the form of the course relatively consistent, but also kept the overall amount of teaching capital required relatively similar as

well. While it is not the most overwhelming finding, the nature of the approach was able to make a noticeable change with only a minor rework to the course layout/content itself, which on its own holds merit.

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