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REFLECTIVE PRACTICES IN ENGINEERING EDUCATION: A PERSONAL ACCOUNT OF A UNIQUE EXPERIENCE IMPLEMENTING A DUAL PROGRAM

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Abstract

The prevalent mindset in engineering education rests on a perception that the practice of engineering consists of acts of pragmatic and rational problem solving. Therefore, a positivist and knowledge centric paradigm to teaching guides many engineering educators. Nevertheless, many aspects of engineering can be viewed as subjective creative acts. This subjectivity implies that professional and personal culture will impact the practice of an engineer. Identifying and accounting for these subjective biases is therefore a responsibility of the engineer. Properly doing so is a skill that must be taught, learned and honed. Reflective practice is one of the many ways that can promote the development of this skill. In view of Dee Fink's taxonomy of the Significant Learning, the reflective practice, implemented in conjunction with experiential learning opportunities, appears to be a powerful tool for learning to happen in engineering education. Reflective exercises have thus been introduced in several courses along the curriculum and a reflective journal is made as the backbone of the DUAL pathway of the Mechanical Engineering undergraduate degree at Université du Québec à Trois-Rivières's Drummondville Campus. This paper describes the use of the Significant Learning Taxonomy and the reflective practice of engineering on the design of the experiential learning focused DUAL approach in a Mechanical Engineering undergraduate program and presents key insights about the exercise.

Keywords: Engineering Education, Reflective Practice, Significant Learning, DUAL, Engineering Design

1. INTRODUCTION

Canadian engineers training enjoys a relatively good international reputation. Among the ways of measuring this reputation are international universities and program rankings. While admitting the great limitation of such ranking methodologies, they are still used a lot by different populations as indicators of reputations. The fact that Canadian engineering programs rate mostly among the top quartile of the Times Higher Education University Ranking 2025 in General Engineering [1] is an example of this favourable perception about Canadian engineering training.

This is likely in part attributable to the accreditation standards for Canadian engineering programs. First, this accreditation requires the leaders of engineering degrees to implement a program wide application of a standard set of Graduate Attributes (GA), which cover a broad set of traits to be acquired by students throughout their curriculum. Second, it mandates the program's leaders to review their performance in fostering the development of this GA set within the student community.

Also helping in the good ranking of Canadian engineering degrees is the fact that in many Canadian Engineering programs, diverse experiential learning opportunities are provided through Co-op internships (CI) within industrial or research environments and capstone projects (CP). These experiential learning opportunities are often very consequential for students.

However, despite the stringent accreditation requirements, many peculiarities and diverse "personalities" still exists across Canadian engineering degrees. Among those peculiarities, in the Province of Quebec, admission to engineering undergraduate degrees is typically granted on the condition that students have successfully completed either a two-year pre-university science training or a three-year technical program. While there was a time, up to the early 1990s, where the majority of students came from the science track, nowadays, there is much greater diversity in that regard. Most undergraduate engineering program admission requirements are for a two years natural science college degree. However, in the early 1990s, the *École de technologie supérieure* developed undergraduate engineering degrees specifically for students coming in with a three-year technical college degree (*techniques physique*s) [2]. Since then, more and more universities

started to offer pathways for students coming in with three years technical degrees. In some program, these students now represent an important fraction, or even the majority of the student population. It is the author's opinion that oftentimes, students from these two pathways have different skill sets and expectations based on their previous experience of higher education. These differences may come both as a challenge for students and educators, but also as a diversity of experiences that can be leveraged. It is therefore important to address these differences while thinking about engineering program development.

It is in this context of engineering education, specific to the province of Quebec, that a new program was launched in 2016 at Université du Québec à Trois-Rivières's Drummondville Campus (UQTR-DR). As a way to differentiate itself while (1) addressing some fundamental challenge of engineering education in general, (2) accounting for the issues related to the diverse academic backgrounds of students and (3) dealing with the specific issues of starting a new program in a regional campus, the UQTR decided to offer an adaptation of Co-op program inspired by the German dual study program [3]. Dee Fink's taxonomy of Significant Learning (SL) was used as a conceptual framework for the development of some key aspects of the program. Promoting SL within the program is achieved through providing numerous Experiential Learning Opportunities (ELO) through expanding the more conventional Co-op approach and by accompanying the students in appropriating the tools of the reflexive practices.

This paper first provides a quick glance at the structure of the DUAL approach, unique to UQTR-DR's Mechanical Engineering (ME) undergraduate degree, around which we anchor the student's reflective journey within the program. The rationale behind this structure is provided. Finally, takeaways of the experience as lived by the small teaching team and the students, as gathered through program development meetings and program assessment exercises are provided.

2. THE DUAL APPROACH TO ENGINEERING EDUCATION AT UQTR-DR

2.1. The DUAL: a different take on Co-op programs

The ME undergraduate degree at UQTR-DR was launched in the fall semester of the year 2016 as a response to a regional shortage of professional engineers. This shortage was associated to an exodus of brains, where candidates moved away from the region to get their degrees, but never come back. However, it was evident that given the great offer of established engineering degrees at other institutions, the new program needed to differentiate itself to attract interested candidates.

One part of the differentiation strategy was to integrate, within a common multifunctional building, a Technical College degree in ME, an undergraduate ME program and graduate programs, sharing a modern high quality infrastructure. The idea behind this was to promote exchanges between employees and students at all levels and provide an academic experience where technicians, engineers and researchers in training and their tutors could meet, building a more cohesive and shared sense of each other's reality, expectations, challenges and opportunities.

The other, and perhaps most significant, part of the offer is the optional DUAL pathway. The design of this DUAL pathway addresses four specific objectives, some of which are local and some of which are common to all undergraduate programs. These objectives are

1. Improving the presence of the university and students in the (regional) industrial network.
2. Helping in bridging the gap between the needs and skills offering of the engineering students workforce to the (regional) industrial network's needs and offerings.
3. Guiding students in the development of broader soft skills set
4. Promoting diverse (creative, analytical, critical, organizational, …) thinking schemes.

As will be demonstrated, the DUAL approach in itself is well suited to address objectives 1–3 by providing the students with more frequent and significant ELO. However, objective 4 requires additional efforts. At UQTR-DR, these efforts were oriented towards favouring a Reflexive Practice (RP) in both the Learning Experience (LE) and the Professional Practice (PP). More details on the integration of RP within the program will be given in section 2.2.

Figure 1 presents the structure of the optional DUAL pathway. The backbone of the DUAL pathway is a standard Co-op program with three full-time summer work terms starting from the third term (year 1, term 3: Y1T3). Students are allowed to opt for the option of this standard Co-op program if they wish so. The alternative optional DUAL program is structured around a continued presence of the students within a host industrial partner over the last 24 months of their studies (Y2T3–Y4T2). For these last two years, where common Co-op program would feature course terms, the DUAL pathway features a course load over three weekdays and on the job (OTJ) training for the remaining two weekdays.

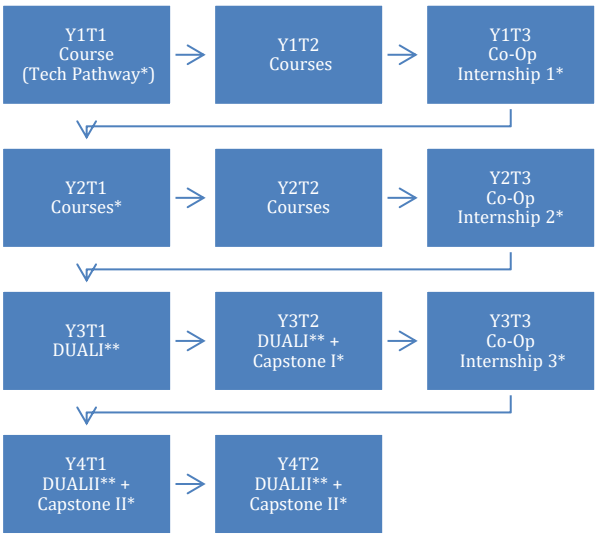

Fig. 1. DUAL pathway program structure. The (*) denotes structured reflective activities and (**) denotes reflective journalling activities and coaching.

This OTJ training consists of four main activities: the two DUAL courses (DUAL I and DUAL II) themselves and the two activities related to the Capstone Projects (CPI and CPII).

The DUAL courses are substituted to two of the complementary courses in the standard curriculum. Each course, carrying over two terms, consists of an individualized syllabus for 45 hours of non-technical training on topics related to:

- Human/Social Sciences
- Communications
- Professionalism, ethics, deontology, equity, law
- Social impacts of technology
- Health and safety
- Sustainable Development and Environmental Governance
- Economy and management

These syllabi consist in three-way agreements between the host industrial partner, the student and the university. The industrial partner acts as a facilitator or provider for the student learning experience and a university professor accompanies both in the process and assessment. In these agreements, the university always retains the responsibility for the global assessment of the students' learning outcomes. This assessment will be detailed in the next section.

In the conventional Co-op program, the capstone project (CP) is designed around a team of students who find an industrial partner to sponsor a design project that will mainly be realized at the university. The CP for the DUAL pathway differs significantly because each student will, under the watchful eyes of a practising engineer from the host partner and of a university professor acting as a methodological advisor, be ‘’accountable“ for an actual major design project for the industrial partner. This nine credit CP spans from the third year's second term (Y3T2) to the final term (Y4T2), excluding the third summer term (Y3T3) which is a full-work term where work on the CP is advised, but not mandatory. Along the four terms of the CP, the student is encouraged to have regular meetings with his academic advisor and some activities may overlap between the work terms, DUAL courses and CP activities. More details about the CP evaluation process are given in the next section.

Although the conventional Co-op program offers several Reflexive Learning opportunities, the DUAL pathway is specially designed to foster a growth mindset and the appropriation of a reflexive professional practice. Efforts have also been put forward to address some concerns about biases (e.g., action bias, positivist bias, confirmation bias, economic bias,…) that may surface due to the strong industry presence early in the student's study and work experiences.

2.2. Mise en Abime: Reflecting on the Integration of the Reflective Practice Along the Way

The prevalent approach to engineering education still appears to be mostly based on a perception that engineering consists of acts of pragmatic and rational problem solving. Therefore, a positivist and knowledge—mostly scientific and engineering knowledge—centric paradigm to teaching guides many if not most engineering educators.

Nevertheless, many aspects of engineering practice can, and probably should, be viewed as subjective creative acts. Whether it be in the acts of engineering design, in the process of devising efficient solutions to everyday problems, in overcoming challenges of the professional practice, in learning or transferring knowledge gained from experiences or even in performing personal activities, subjectivity and creativity are integral parts of an engineer's life.

These biases are numerous and often go unnoticed, may it be in student teams or within the program themselves [4]. For example, a recent study by Agyemang et al. [5] compares biases in the study, research and practice of the medical and engineering trades. In this study, the medical and engineering practices are compared since the study of biases in the former has received much more attention and several parallels can be made between the medical diagnostic process and the engineering design process. The authors conclude that several similar biases likely exist in both disciplines. Among these biases are interpersonal

biases (racial, age, gender, etc.), cognitive biases (confirmation, availability, etc.) and other biases (funding, participation, information, etc.).

This subjectivity implies that professional and personal culture will impact the practice of an engineer. It is then inevitable that biases are present in engineering designs and these biases may either benefit or hinder the outcome of the creative act. Identifying and accounting for these subjective biases is therefore a responsibility of the engineer. Properly doing so is a skill that must be taught, learned and honed. Reflective practice, defined as reflecting on the nature, the constraints, and the validity of one's actions, is one of the many ways that can promote the development of this skill in engineering students.

Dee Fink's taxonomy of the Significant Learning (TSL), identifies six main categories of learning experiences. The more categories that a learning experience relates to, the more significant and transformational it is for the learning person. These six categories are

1. Foundational Knowledge–Threshold concepts, ideas, perspectives required by the learning person
2. Application–Modes of thinking required (practical, critical, creative, …) and procedural skills required by the learning person
3. Integration–Links that can be made between the LE and prior/future learning, personal and professional experiences
4. Human Dimension–knowledge gained on oneself and one's interpersonal relationships
5. Caring–changes on one's values, perceptions, interests or beliefs
6. Learning how to learn–methods to improve one's capacity to access or develop new knowledge.

In view of Dee Fink's TSL, which states that "For learning to occur, there has to be some kind of change in the learner. No change, no learning. And significant learning requires that there be some kind of lasting change that is important in terms of the learner's life" [6], the reflective practice appears to be a powerful tool for learning to happen in any curriculum. Yet, as demonstrated by the following discussion, the reflective practice, when paired with extensive experiential learning experiences (ELE), might be particularly appropriate for engineering education.

Engineering often requires a deep understanding of complex ideas, as well as an understanding of the behaviours of complex systems and of interactions between those complex systems. Gaining such an understanding is conceptually similar to DeeFink's significant learning experience. It is also worth noting that significant experiences build over each other in a positive way. Fostering significant learning experiences (SLE) through extensive access to ELO and active application of the RP was therefore the guideline for developing the DUAL program at UQTR-DR.

In order to multiply the possibilities for students to live SLEs and to gain insights on the multiple biases to which they may be exposed, reflective exercises are gradually integrated in courses and activities. The RP brings a personal dimension to the learning situations that favours caring (5), integration of knowledge (3), learning how to learn (6), and adds a human scale (4) to the technical learning. Thus, the RP touches to many of the components of Dee Fink's TSL. In the context of the DUAL, this is further reinforced by the opportunities for relating the learning experience to the dimensions of application (2), integration (3), human dimension (4) and caring (5). It is therefore expected that more transformative learning experience will be offered to the students.

This approach of provoking ELO and promoting reflection to identify specific learning and challenge initial preconceptions about an engineering problem or experience appears to be coherent with Loughran's view [7] that

"*Effective reflective practice is drawn from the ability to frame and reframe the practice setting, to develop and respond to this framing through action so that the practitioner's wisdom-in action is enhanced and, as a particular outcome, articulation of professional knowledge is encouraged. What is learned as a result of reflection is, to me, at least equally as valuable as reflection itself. It is through the development of knowledge and understanding of the practice setting and the ability to recognize and respond to such knowledge that the reflective practitioner becomes truly responsive to the needs, issues, and concerns that are so important in shaping practice*" (Loughan 2002, p. 42)

The combination of the DUAL's ELO focused approach and of the integration of the RP are the continuation of the ongoing work described in [8].

2.3. The Method: Resetting the Baseline

Although prior exposure to the reflective practice is more common than it used to be for new engineering students, it is seldom integrated in their baseline approach to learning. Therefore, specific efforts are deployed all along the curriculum to provide positive experience of the process. This section provides a more detailed view of the most significant efforts to coopt students into approaching their studies reflectively.

In order to provide multiple and progressive exposure to reflective learning experience for students, several standalone and continuous activities are introduced in various courses. The in-course (in-class and on

assignments) reflective exercises range from end-of-term team work and self-evaluation, research on societal/technological challenges related to the course's topics and identification of further learning that is required to fully understand the problem, to a critical review of former students' projects. These exercises are gradually focusing more on the open-ended nature of engineering problems as opposed to the closed nature of school problems and projects. At the end of the students' journey, reflective journalling about the DUAL experiences bridges the gap between reflective learning and the reflective practice of engineering. Table 1 provides a list of reflective learning experiences integrated within the DUAL pathway,

Table 1: Description and timing of reflective activities.

Timeline	Reflective exercise
Year 1	(for 1st year students coming in with three years technical college degrees) a) Argumentative essay where the bulk of the argument must be built around a scientific analysis using key concepts from the course b) Teamwork and personal learning experience assessment
Year 2	Thermodynamics a) Opinion Essay where teams defend their position on a polemic through key concepts from the course and links to other prior knowledge b) Industrial visit critical review report
Year 3	Machine design and Mechanics of machines courses integrated activities a) Industrial visit critical review report b) Critical review of a machine design project report. c) Reversed classroom workshop on the Engineering Design Methodology d) Engineering design project (one project overlapping two courses: Machine design and Mechanics of machines) e) Teamwork and learning self-assessment
Years 3 and 4	Continuous reflective practice exercises DUAL I and II (4 semesters) part-time work terms. a) Year 3 workplace non-technical skill development planning b) Year 3 reflective journal (biweekly). c) Year 3 Significant Learning Experience report d) Year 4 workplace non-technical skill development planning e) Year 4 reflective journal (biweekly) f) Year 4 Significant Learning Experience report. Workplace Engineering Design Capstone Project

Some of these mandatory exercises are not graded. Instead, direct feedback is provided to students about the exercise process and outcome. The intent being to focus on the students' evolution, fostering autonomy and supporting their growth as future engineering professionals. This being said, essays, critical reviews and projects are both graded and annotated.

For the reflective journalling exercise, each student is provided with an academic advisor among the department professors. The student and professor agree on a meeting schedule to discuss the students' journal entries. The students are expected to lead these meetings. The reflective journal contains prompts that the students are expected to respond to, but they are free to add any information or cues that they feel is useful for them.

Examples of prompts from the reflective journal include:

1. Describe your main technical/non-technical challenge of the current period. What were the main resources mobilized to overcome that challenge? (Note that a discussion on the difference between identifying a difficult task and an understanding of an actual challenge is part of the expected discussion.)
2. What is your most significant learning from the last period? Does it relate to your learning plan?
3. What is your principal learning goal or other expected outcomes/realization for the next two-week period and what are the most relevant resources that you will need to mobilize to succeed?
4. Looking back at the last two-week period and your most significant challenge, what is one of your own or your workplace practises that could be modified to prevent or reduce the occurrence of such challenges?
5. If you look back at your objectives from the last period, how would you rate your success at reaching them? What factors contributed most to this outcome?

The students are encouraged to discuss the content of their entries with their workplace supervisor when appropriate. The journal is also used as a log of the students' progression on their individualized learning plan. It is the students' responsibility to convince their advisor of their proper progression. A small portion of the terms grades are associated with the reflective journal. However, the grades only reflect the progression of the student's capacity to support its claims by examples and arguments.

The students are encouraged to integrate the discussions on their reflective journals within the mentoring sessions associated to their CP as this favours the integration of the

reflective practice within the actual practice of engineering design.

Assessment of the DUALI and DUALII courses also rely on the student's synthesis of SLE report in which each person details its most SLE, describes how and why it matters for her and provides examples of the way this will effect on her personal and professional life. The reflective journal is a useful tool for the student person to review her experience.

2.4. The Research Method

Initially, the ME program at UQTR-DR was expected to be a simple extension of the program available on the main campus in Trois-Rivières. Therefore, it was not devised as a research exercise and resources were only available for the launch, accreditation and continuous evaluation of the program.

However, for reasons described earlier and in [8], many significant changes were effectively implemented to the original programming and a distinct ME undergraduate program emerged at UQTR-DR. Yet, until now, most evaluation of the impact of the DUAL and reflective approaches are the result of ongoing program assessment and evaluation gathered through department meetings, university review procedures, accreditation and direct interaction with the students and professors. There is an ongoing research project that is currently analyzing the results of directed interviews with students, professors and administrators.

Therefore, the results presented in this paper are mainly taken out from the continuous program evaluation efforts, although some preliminary results from the directed interviews will be provided.

3. RESULTS

3.1. Teacher and Advisor Takeaways

As the team responsible for accompanying the students in their reflective practice journey is relatively small, it was possible to reflect collectively on the exercise during several work meetings.

The integration of formative and summative assignments based on reflective practice within specific courses is mostly seen as positive. The workload is not significantly altered, but preparing the students for the assignments takes some time in class that would otherwise have been devoted to teaching more course specific contents. There is therefore a bit of a tradeoff that needs to be carefully navigated by individual teachers.

Globally, the whole team shares a feeling that being allowed to work individually on a regular basis with the students provides a unique learning experience for both the student and the advisor and also foster possibilities for an exceptional professional relationship with the industrial partner. Therefore, some of the objectives of implementing the DUAL approach and the reflexive journalling are definitely approached (objectives 1 and 2 from section 2.1). Industrial hosts also provide a very positive feedback about the soft skills of the DUAL students from UQTR-DR, generally pointing towards some positive effects of the program's reflective tools.

Most advisors appear to agree that the first few periods and the feedback that is provided to the student within this period is very important in order for the student to grasp the importance of the exercise for itself, rather than simply seeing this as a simple assignment.

Even in the current context of small cohorts for the first few years of the program, most advisors do find that the time requirement for properly reviewing and providing feedback on the reflective journal is already quite intensive. Therefore, concerns over the scaleability of the approach are surfacing. Changes to the means of providing feedback and to allow for expanding the roles of the students themselves in the process as they gain experience is being considered. Reviewing the way this supervision is accounted for within the normal workload of professors is also desirable. Effectively, both the DUAL and CP move broad parts of the teaching activities outside the classroom, thus outside of the usual professor's official teaching workload.

In the last two years, concerns about the use of generative artificial intelligence by the students in ways that would be incompatible with the objectives of the reflective practice have also surfaced. Until this matter is thoroughly addressed, some professors have asked students to provide a statement regarding their use of generative artificial intelligence in accordance with institutional guidelines [9], which provides general requirements for the acceptable use of the technology in school work. The face to face meeting with the students also allows for quick understanding of the actual involvement of the student in the reflective exercise.

Some suggestions by faculties on ways to improve the journal's impact on students' outcome is to include explicit reflection on the GA set that they are expected to develop and including the journal in a broader student's portfolio.

3.2. Student Takeaways

As part of program assessment, directed students interviews were conducted on the first cohorts of the program. Results of these interviews and direct feedback from students allow for some preliminary takeaways from the student's perspective.

For the students, the progressive addition of reflective exercise as part of coursework is generally well received and is seen as providing variety in the ways they are assessed. Direct feedback from students demonstrate that they particularly appreciate assignments where they are free to choose the topic and to find ways to relate course contents to personal interests or preoccupations.

Open-ended assignments are also perceived as closer to actual engineering problems. In direct feedback to the professors, many students report finding such projects very challenging, but also very gratifying since they get the feeling of tackling genuine engineering challenges and they feel like they can provide a solution that is their own rather than simply what is expected as the right solution. The possibility to exercise creativity also seems to be appreciated by students.

As for the reflective journal exercise, very diverse perceptions were reported. There is a consensus that, at least early in the process, the objective of the journal is not well understood by the students. Despite the fact that the journal is presented as a tool to help themselves overcome the challenges of the engineering practice through reflecting on their own experiences, many report being uneasy filing the journal because they don't feel like they can provide the expected "answers ". At the beginning of the journalling exercise, and despite previous exposure to the reflective practice, most students have the perception that the journal is "just another school assignment that is not relevant to the practising engineer ".

The consensus among students is that the work/study terms are quite challenging from a time management perspective and the journal exercise is hard to fit in the schedule. Most students believe that it is not right to work on the journal while working at their host industry, but also find it difficult to fit in with all the other schoolwork.

Several of the comments reflected that the feedback and expectation from different academic advisors are not homogenous. This brings a perception of injustice where some students can just rubberstamp their way through the exercise while others are expected to show greater commitment.

However, the more seriously the student person takes the exercise, the more likely she appears to find that it actually helps them manage their objectives and expectations. Some also commented that the journalling experience was a good tool to improve recall and was very useful when done properly.

Many students also appreciate the one-on-one, in person access to their advisor that the reflective journal allows. Some even stress that it is this discussion that is the most valuable.

3.3. Discussion

The overall impression of the effects of integrating the reflective practice and experiential learning within the ME undergraduate program at UQTR-DR is generally more positive for the academic advisors than for the students.

While both students and professors signal the significant workload associated with the addition of integrated reflective exercises and ELO, the perceived benefits are higher from the educators' viewpoint than from the student's.

However, it appears that the reasons why the students' perceptions are not as positive may have more to do with the maturity of the program, rather than fundamental flaws.

For example, the perception of injustice and uncertainty about the expectations around the reflective journal can be addressed by improved guidelines for both the students and advisors. Among those guidelines, the fact that the reflective practice is driven by the student person and that the advisors' role is mainly to offer different perspectives on the students inquiries may help resolve the tension between the professors' and students' expectations.

Implementation of more collective discussions on the reflective journalling experience may also promote more peer interaction and validation, reducing the top-down, academic, impression that some students dislike about the exercise.

After gradually implementing the RP within the DUAL program at UQTR-DR, it is becoming apparent that the current tools for program evaluation do not provide sufficient information on the direct impact of the approach on the actual students' outcome. Therefore, such tools should be developed before further major changes are implemented.

4. CONCLUSION

An innovative DUAL approach, integrating structured reflective practices and experiential learning opportunities, has been implemented in the DUAL mechanical engineering undergraduate degree at the Drummondville Campus of the Université du Québec à Trois-Rivières. Implementing this practice addresses several concerns that are both general to engineering education and specific to this new program offered in a regional campus, but also generates interesting new challenges. It is expected that this transformative learning experience may improve the ability of future engineers to deal with the subjectivity of their practice and appreciate more deeply the impact of their work. However, challenges of scaleability remains and a need for continually assessing the impact of the DUAL program on actual students outcome still needs to be addressed.

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