

A Methodological Evaluation of an Integrative Pedagogy for Engineering Education

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Abstract— This paper is an evaluation of the pedagogy of a five-day co-curricular course, called the “*Lead by Design Institute on Leadership, Diversity and Dialogue For Graduate Students in Engineering*.” The intentions in the design of the pedagogy were: to include elements that align with the motivations and values that engineering students bring to their work and study; and to enhance the retention of women and other diversities in engineering, and their long-term sustainability in the practice of engineering. The *Lead by Design Institute* was offered to an initial group of engineering graduate students within a qualitative research project on diversity-attracting integrative pedagogies for engineering education. The purpose of this paper is to evaluate the design and implementation of the pedagogy of the *Lead by Design Institute* so that we can understand how to improve or alter the pedagogy for future offerings and to more effectively meet the goal of integrative engineering education. To perform the evaluation, a process of key questions based on Lonergan’s basic definition of method is used, with the answers to the questions grounded in the qualitative research data collected during the Institute.

Keywords—women; diversity; graduate education; reflective practice; leadership; identity

I. INTRODUCTION

This paper outlines a pedagogy, and then evaluates it methodologically to understand if and to what extent it can be considered to have met the goal of enabling integrative education in engineering. The pedagogy was developed by the authors as part of a qualitative research project to propose, implement and evaluate integrative pedagogies to attract and retain greater diversity within students of engineering. A key goal underpinning the project was to promote women in engineering; however, in keeping with the perspective that a broader diversity is important in engineering, we considered inclusivity and a wide definition of diversity as important components for our research design.

The research questions that we were interested to address are: 1) What motivates engineering (graduate) students in their career and life choices in engineering? 2) How can we develop innovative pedagogies to enhance the retention of women (and other diverse groups) in engineering and their long-term sustainability in the practice of engineering? Towards providing evidence-based answers to these questions, we developed a five-day co-curricular course, called the “*Lead by*

Design Institute on Leadership, Diversity and Dialogue For Graduate Students in Engineering.” A pilot offering of this program was facilitated by the researchers in April 2014 for graduate students in engineering at Memorial University. The intention of the methodological evaluation in this paper is to understand the extent to which the pilot offering met its goals, so that the results of the evaluation can be factored into the design of similar pedagogies and subsequent programs for other students including undergraduate engineering students.

In this paper, we ask two specific questions related to our research questions above. We want to examine broadly what we did in designing and running the pilot of the *Lead by Design Institute*, and to answer the questions: Did the approach we took tend towards the goal of integrative pedagogy for engineering? How might the pedagogy be altered or improved to make progress towards integrative pedagogy more effective?

Relevant background on integrative pedagogies is summarized in Section 2. The *Lead by Design Institute* is described in Section 3, along with an outline of the research data that were collected during the Institute. Section 4 develops the evaluative criteria, and Section 5 follows with a methodological evaluation of the pedagogy for its potential to enable integrative engineering education. The paper concludes with Conclusions and Future Work in Section 6.

II. INTEGRATIVE PEDAGOGIES IN ENGINEERING

A significant literature exists on pedagogical approaches aimed at enhancing the relevance of engineering education for the 21st century, for the benefit of students studying engineering as well as for all groups and communities who use the products of engineering. There is also a large literature on strategies and best practices to enhance the long-term retention in the profession of engineering. Our research aims to contribute to both bodies of literature. We are chiefly motivated to explore integrative pedagogies, by which we mean specifically pedagogies that can help students to connect who they are with what they are learning and with the wider context of their study and practice of engineering. We posit that such an approach will enhance the learning experience for

engineering students as well as their longer-term retention as engineering professionals [1].

Various researchers and institutions argue that current engineering programs require upgrading to allow engineering to respond to the challenges that engineering will be called to solve in the immediate and longer-term future [2-5]. Accreditation boards agree with this perspective and have mandated new graduate attributes to be met for the accreditation of undergraduate engineering programs, e.g. [6]. The reasons for these changes of perspectives are that the 21st century context of engineering requires innovative engineers who are both problem-definers as well as problem-solvers [5], and who can work intelligently and responsibly in collaboration with other professions and communities [7].

Despite the ongoing transformation underway in engineering education, there remain many unanswered questions about the pedagogies to fully enable the transformation. What appears to be needed are pedagogies and curricula that will foster integration across the disciplines as well as greater emphasis on: building teams and teamwork; the development of more effective communications skills [6]; cross-disciplinary dialogue [3], and dialogue between humans and their objects of study [8]; increased awareness of the social, political, environmental, commercial and government contexts of engineering and science [5], and methods to heighten awareness of self [1,12].

Elements of integrative engineering education have been included in various programs in Canada and the US [2,4,5,9]. In addition, programs in other disciplines have integrative elements; in particular, the Undergraduate Semester in Dialogue at Simon Fraser University in Vancouver, Canada [10] has influenced the development of the *Lead by Design* Institute pedagogy.

While most of the emphasis for the transformation in engineering education is at the undergraduate level, there are also calls for changes in graduate studies. The graduate student experience in engineering is marked by a deeper and more focused engagement with the technical aspects of an area of engineering, as well as the need for greater self-motivation. The latter points to a heightened need for self-understanding and for leadership by graduate students [11]. Because the graduate student experience can be of solo work, or team work under a supervisor's direction, graduate students may not view themselves as leaders, or as needing leadership skills. However, professional development for leadership is important for graduate students, as they need a strong sense of intellectual agency. Moreover, graduate students do lead one another in their lab groups from time to time, and may be expected to lead in the jobs they obtain after graduation [12].

In addition to the foregoing, for all students, and in a special way for women graduate students and others in under-represented groups, it is important to develop a strong sense of

autonomy and self-direction; this important form of leadership points not so much to leadership in the sense of having power over others, but rather in having the power to do something [13,14].

III. LEAD BY DESIGN INSTITUTE

A. Description of the Institute

The *Lead by Design* Institute pilot program was held in April 2014 as a co-curricular program. It was completed by 14 graduate students from the Faculty of Engineering and Applied Science at Memorial University. Eight participants were women, and six were men. One participant was a Canadian student, while the rest were international students from countries that included Bangladesh, China, Pakistan, Sri Lanka and Vietnam. Four participants were Ph.D. students, and ten were master's students. Their disciplines spanned the engineering programs offered at Memorial University, including Civil, Electrical, Environmental Systems, Mechanical, Ocean and Naval Architectural, and Oil and Gas Engineering.

Over a period of one-week, participants were invited to engage in a variety of leadership, communication, reflective-practice and skill-building workshops, and explored questions such as "What is engineering?," "What attracts you to engineering?," "What does empathy have to do with engineering?," etc. The Institute ran from Wednesday, April 23 to Tuesday, April 29, 2014, with daily sessions from 9am to 3pm, and no weekend sessions. Since the *Lead by Design* Institute was aimed at exploring engineering pedagogies within the co-educational university context, we did not limit our programming to women, although we ensured approximate gender parity in our admissions of participants. Spill-over benefits to other diverse groups were anticipated based on past evidence that what works well for women tends to work well for everyone [15].

More details on the Institute format, curriculum and activities are found below in Section 5B.

B. Research Methodology

The research project was a basic qualitative study, as is often found in applied fields of practice where data are collected through interviews, observations and document analysis. An assumption in such research is that individuals construct reality as they engage with their social world. Our purpose in the *Lead by Design* Institute was to explore this engagement by examining how participants interpret their experiences, and what these experiences mean to them. The key point is to understand how people make sense of their experiences [16]. Specifically, we were interested to foster participants' deeper understanding of their own motivations and experiences as students and engineers.

Items of research data collected throughout the *Lead by Design* Institute, included: (i) narratives and reflective

writings, (ii) photographs of sessions, (iii) a pre- and post-Institute survey, (iv) a video of the challenge presentations, and (v) the written observations of the researchers.

One key set of data for the methodological evaluation in this paper are the collected narratives on identity, values and choices, notably the free-writings in response to specific questions throughout the 5-days of the Institute. Another key set of data are the observer-participant notes made throughout each session when at least one (or more) of the researchers recorded observations of the participants and how they were reacting to the activities of the Institute. Thus, our observations as participant-observers (per [15]) form an important part of the research data for the methodological evaluation.

IV. CRITERIA FOR A METHODOLOGICAL EVALUATION

In order to conduct a methodological evaluation of the *Lead by Design* Institute, it is important to first define the criteria for the evaluation. We adopt a basic definition of method, and proceed to evaluate our work against its key stages and questions.

A. Evaluation Criteria

The Canadian philosopher and methodologist, Bernard Lonergan wrote extensively about method, both in general terms and in its specialized forms in a wide range of fields, including philosophy, theology, economics, the natural sciences, etc. [17]. Indeed, one of Lonergan's key contributions to methodology is his articulation and detailed study of the method that is "more general and more fundamental, namely, the procedures of the human mind." [18, p. 4] on which are grounded all "other, more special methods appropriate to particular fields" [18, p. 4] such as scientific method [19], engineering design [20], etc.

As a general definition of method, Lonergan writes, "A method is a set of directives that serve to guide a process towards a result." [18, p. 421]. In his work on method, Lonergan distinguishes the dynamic nature of method from the more static nature of technique for which the outcome is known; for example, Lonergan notes, "Method is not a set of rules to be followed meticulously ... It is a framework for collaborative creativity." [18, p. xi]. Thus, within the Lonerganian understanding of method, method can be found (among many other examples) in parenting, or engineering design, or teaching, notably when the practitioner engages in a "deliberate and responsible exercise of intelligence and reasonableness" [17, p. 21].

We find Lonergan's definition of method to be pertinent to our evaluation of the *Lead by Design* Institute since it is both qualitative and precise. Because it is qualitative, and grounded in the operations of the human person, it is relevant to any educational process, including engineering education [20]. It can guide assessments that are qualitative, and as a methodical

process, also suits a precise examination of endeavours that extend over a longer time frame and that are heuristic in their progress towards goals.

In addition, we are familiar with Lonergan's method and have used it as a framework in our past research [11,21].

For these reasons, we adopt Lonergan's perspective on method for the evaluation in this paper. We start from his classic basic definition of method as "a set of related and recurrent operations cumulatively advancing towards an ideal goal" [18, p. 125]. We will evaluate the *Lead by Design* Institute (i.e. what we did, and its results) against the key terms and notions in this definition. As such, we need to answer the following key questions:

- What were the goal(s) of the *Lead by Design* Institute?
- What operations did we engage in, and what operations did we invite participants to engage in?
- What relationships were there amongst these operations, and were these operations repeated?
- Did the operations and their repetition enable a tendency of progress towards the goal(s)?

We will next answer these questions, citing evidence from the research data of the *Lead by Design* Institute.

V. ANSWERING THE KEY EVALUATIVE QUESTIONS

A. Goals of the *Lead by Design* Institute

The goals for the Institute are embedded in the second research question listed in Section 1, i.e.: How can we develop innovative pedagogies to enhance the retention of women (and other diverse groups) in engineering and their long-term sustainability in the practice of engineering? Thus, the proximate goals we aimed methodically to reach, or to move towards, were:

- To attract more women and other diversities within engineering
- To enhance longer-term retention within the practice of engineering.

In addition, we can situate these goals within the prior goals we had in seeking to conduct this research project—namely to contribute to the ongoing transformation of engineering education for the needs of the 21st century.

B. Operations of the *Lead by Design* Institute

In the year prior to the Institute in April 2014, we developed the overall approach, pedagogy, curriculum and detailed activity plans for the *Lead by Design* Institute. We also developed the research methodology and obtained ethics clearance for research with human subjects. The key operations of importance in tending towards the goals were those of the development of the curriculum and activity plans.

Our design of the *Lead by Design* Spring Institute was oriented in the first instance towards benefiting women in

engineering, while also fostering other diversities in engineering in addition to gender. From the objective of developing an “ideal” pedagogy that would attract women and other diverse groups to engineering, the curriculum was developed through an iterative process with weekly working sessions attended by all the researchers followed by “homework” through the week when each individual worked on self-assigned tasks. After an early stage of brainstorming, we narrowed to focus on three threads to weave through the entire Institute: 1) reflective practice; 2) dialogue to heighten personal, ethical and social awareness; 3) self-awareness, leadership and including yourself in the technical aspects of engineering. From these three threads, the curriculum plan unfolded for the 5 days around a thematic arc of “Understanding how we got where we are, designing (engineering) a new future,” with a focal point on Day 4 of “Re-engineering the foundations of my career.” The per-day themes were: Day 1: “What is Engineering?”; Day 2: “What attracts you to engineering?”; Day 3 “What is the empathic engineer?”; Day 4 “How can I re-engineer the foundations of my career?”; and Day 5 “Now, what is engineering?”

Based on synergies within drafts for each thread, the general themes listed above were developed for each day, followed by particular research questions suited to each day. Specific activities were then identified for each day, from a list that included: skills building; dialogues and reflections; case studies in leadership and diversity; and a team-project on an engineering “challenge” from which the outputs were both a technical solution and an explication in a non-standard form presented at a public Engineering Salon.

Specific sessions and activities were worked out to make best use of the time available while providing participants with a balance of activities and exposure to themes each day. We opted to facilitate the bulk of the Institute ourselves (with two guest speakers to extend the range of expertise beyond the core team). We used Powerpoint sparingly, and instead planned for most of the days to be spent in activities such as free-writing, discussion, working on the group challenge. We also planned activities that required participants to move around the room, to re-arrange the furniture, etc.

C. Relationships and Repetition of Operations

We designed the curriculum so that the three threads, despite being different, would have points of overlap and connection. The key connections between the threads, themes and activities were that all fostered advertence to oneself and one’s context and story, one’s life and experience, and the understanding of patterns in one’s life and choices, as well as the increased possibility for self-realization and choice in the future.

We explicitly included repeating activities, not only in the curriculum development phase (i.e. the weekly iterations and refinements of the curriculum and evolving schedules and activity plans) but also in the participants’ activities. In particular, the participants were invited to free-write regularly

(a total of 24 over 5 days), and to write and revise a personal narrative three times over the Institute. Also, there were regular times for the Engineering challenge work in teams or discussion with the facilitators. And finally, throughout the entire Institute there were repeated occasions when the participants could advert to themselves, including for each, their story, their sense of identity, and their future.

D. Evidence for Progress Towards Goals

Feedback from the participants was generally quite positive. From the post-Institute survey, in response to “I think that engineering graduate students would benefit from the addition of tools/concepts/content from the Spring Institute into the general graduate curriculum,” all Agreed, 7.1%, or Strongly agreed, 92.9% (N= 14). Moreover in response to a post-Institute survey question on what activities were most helpful or insightful for their professional development, participants wrote (with participant names anonymized):

- I think they were all helpful in the combination that they were presented to us. It’s hard to pick just one. [Amy]
- I think it’s a strong requirement to add this program to the general graduate curriculum. Because we got to know each other well and this is the only chance I had to open up at Memorial University. [Lilly]

During the week of the Institute, we collected significant amounts of data that we have analyzed from various perspectives. We have extracted evidence for the Institute’s capability to foster career sustainability, self-awareness and subjectivity [1,21], and to introduce a new engineering literacy of critical reflective-writing practice [22].

Despite the short time span of the Institute (i.e. one week as a co-curricular course during the inter-semester break), we can find evidence for qualitative differences from before the Institute to after the Institute. For example, the post-Institute survey contained the following question, “What main difference have you noticed between how you thought of your professional identity before the Institute and after the Institute? Tell us about a key turning point for you, or something that surprised you about your experience.” Respondents wrote, in free-form:

- Before the Institute I did not think I could handle a position as a leader. I became aware of the different aspects of the leadership and I exerted them during the Institute. This helped and equipped me to further think about the roles I can take my future career. [Sheri]
- Especially after the leadership workshop I understood how I have the ability to be a leader of even my own thoughts and also with the challenge that was given to us I learned more about system thinking. [Melisa]

Personal development can also be perceived from the data of the 24 free-writes in the Institute. At the start of Day 2, participants were asked to free-write on, “What did you learn (or was significant) about yesterday?” One participant

indicated greater clarity and concreteness from using reflection tools:

- Reflective thinking. It makes things more specific. ... The gap between the ideal and the practical was visualized. [Charlotte]

By Day 4, participants tackled the question, “Re-engineering the foundation of my career?” Responses indicated significant insight and even growth over the short period of the Institute, as well as the acknowledgment of further work or growth to come:

- Also the job must fit my personal interest. So what I am doing is trying to achieve this goal. [Tara]
- I still need to get to know more about my foundation, my value, my motivation and vision. Curiosity is a good drive to study engineering, which is my value. [Stephen]
- Foundations: skills + curiosity + management, leadership + known others + balance work and life [Charlotte]

Finally, on Day 5, in response to “How will you contribute to re-designing engineering?” one answer integrated many other responses:

- Redesigning engineering, maybe in the way work together in a project. We are from different backgrounds, cultures, languages, levels. If we work effective in a group, the quality of results will be better. [T. Smith]

Another set of evidence of progress, especially in terms of the goal of diversity comes from the responses to a free-write on Day 2, “Free-write on diversity.” The answers from the majority of the participants indicated increased levels of awareness about diversity following a diversity workshop by a guest facilitator. The comments indicated that they planned in the future to view diversity as a benefit, rather than, as previously, somewhat of a disadvantage, or as just a fact. For example, two responses are:

- My stereotype thinking of “diversity” mainly focuses on the conflict it causes. On some level I neglected the fact that diversity can also help with bottom lines and improving creativity. I was thinking about “how to handle diversity” than “how to take advantage of it.” To me it is a big turn. [Kelly]
- Diversity is not gathering different people to say the same thing but to let different people to speak out their ideas. All of ideas are unique. [Tara]

These responses seem to bode well for the future of the participants to continue to grow, in part because they attended the *Lead by Design* Institute.

Finally, consider one more response from the post-Institute survey question on what activities were most helpful or insightful for their professional development. This response indicates the value of the intense workshop format in creating a

community among all involved, the participants and facilitators together:

- “Actually before attending this program, I thought it might be a boring program with presentation. But I was surprised at the end, because I made many friends. I learnt new perspectives in engineering ... I didn’t know that this program will be educating and at the same time it was really fun. [Lilly]

To the evidence of the collected data, we add the data from our notes as observer-participant (per [16]). As noted above, during each session of the Institute one (or more) of the researchers recorded observations of the participants and how they were reacting to the activities of the Institute. From these notes (as well as from the participant data), we have evidence that the participants were very engaged in what was an intense and time-consuming Institute.

Nonetheless, we observed flaws in our design. The main design flaw was in the Engineering challenge activity. We asked participants (in teams) to solve an engineering problem from a technical perspective, and then present it in a non-traditional format (e.g. a video, a skit, a marketing campaign, a mayoral debate), all within the week’s time of the Institute. Despite initial trepidation, participants engaged with enthusiasm in the non-traditional format presentations; but this reduced the time available for the technical solutions. We need to re-think how to make an integrative engineering challenge more workable in the context of a short course.

We also need to find a way to make the offering less labour intensive for the facilitators. All the researchers were already skilled and comfortable with the type of person-centric facilitation needed to make the Institute work, but we think that for wider offering, we would need to develop a mechanism to “train the trainers”.

VI. CONCLUSIONS AND FUTURE WORK

A method, in the Lonergan sense of a “deliberate and responsible exercise of intelligence and reasonableness” [17, p. 21] is difficult to realize. The process of education fits the Lonergan definition of method, which is one reason why making progress in a methodical way towards a goal of change in education can be challenging.

Through careful analysis of the qualitative data collected during our pilot offering of the *Lead by Design* Institute, we have explored the pedagogy of the *Lead by Design* Institute. The research data show evidence of progress, at least for the participants of the Institute in April 2014. By examining the data we can glean increased satisfaction by many with their chosen careers, while some of them renewed resolves to make personal changes, e.g. to finish a thesis, or increase efforts to find a position matching their personal interests. As well, from many of the participants we find a greater sense of belonging and identity after the Institute compared to before. As such, we can say that the Institute served both the facilitators and the participants “to guide a process towards a result.”

This is progress, measured one person at a time; if it were to be multiplied by many persons, it could be significant, even on quantitative measures. Nonetheless, we admit that the participants in the *Lead by Design* Institute self-selected to attend, and may thereby have been more ready for personal progress than would be typical in a course-based offering. We also would need a longer study to obtain longitudinal evidence for sustained change or progress.

Much work still remains to be done for the pedagogy of the Institute to reach a wider range of students. In particular, we need to find an appropriate way to adapt the pedagogy and content to undergraduate engineering students, while finding a format for delivery in their already full schedules. These remain as future work.

As indicated in the Abstract and Introduction, the purpose of this present paper was to examine what we did in the *Lead by Design* Institute and how participants reacted, so that we can understand how to improve or alter the pedagogy in future offerings to more effectively and efficiently meet the goals of integrative engineering education. By the reactions of participants, we find that the mixed-activity format was successful, as was the emphasis on leadership, diversity and dialogue in the three threads. We need to re-think how to make an integrative engineering challenge more workable in the context of a short course, and to think through the need to “train the trainers” in such integrative and person-centric facilitation in engineering education.

This evaluation has been a useful exercise in understanding what we did in the *Lead by Design* Institute and what we might do to improve subsequent offerings. There is enough evidence from our data to claim that the *Lead by Design* Institute made methodical progress towards its goals—certainly enough evidence to justify continuing this line of inquiry and activity in integrative engineering education.

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