Development of Industry Modules for Engineers Pursuing Advanced Degrees

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Graduate engineering programs largely aim to prepare students for careers in academia. Programs emphasize research, academic publishing, and leadership in relevant national organizations. As a result, engineering students tend to develop professional skills relevant to academia regardless of their career interests outside of academia. Engineering industry employers recognize this gap, which may impact their perceptions when interviewing applicants with advanced engineering degrees. Graduate students with interest in industry careers need alternate resources to learn necessary skills. In this paper, online learning modules are designed for the engineering graduate student population with special emphases on industry-specific skills. The objectives of this paper are to translate empirical findings about students' professional skills into the modules framed into a LEADER framework, which will guide students as they complete mini lessons that align with their knowledge of various professional topics. At the conclusion of each module, students will be able to *locate* their existing perceptions and experiences; *evaluate* and informally assess their views; *absorb* formal, preexisting knowledge about a topic; *demonstrate* ways to apply content in actionable ways; *evolve* in their career and professional development, and *reflect* on ways to process and summarize their thoughts. This paper presents an overview of the development of modules that will guide students as they prepare for their professional positions. Future studies will discuss the findings from piloted learning modules.

Introduction

Graduate engineering programs largely aim to prepare students for careers in academia. Programs emphasize research, academic publishing, and leadership in relevant national organizations. As a result, engineering students tend to develop professional skills relevant to academia regardless of their career interests outside of academia. Engineering industry employers recognize this gap, which may impact their perceptions when interviewing applicants with advanced engineering degrees.

Graduate students with interests in industry careers need alternate resources to learn necessary skills[1]. In this paper, online learning modules are designed for the engineering graduate student population with special emphases on industry-specific skills[2].

The objectives of this paper are to translate empirical findings from engineering professionals in academia and industry about desired students' professional skills into the modules that are represented within a LEADER framework, which will guide students as they complete modules that align with their knowledge of specific professional topics. The LEADER framework is proposed by the authors for the purposes of this and related research, which requires users of the modules to *locate* their existing perceptions and experiences; *evaluate* and informally assess their views; *absorb* formal, preexisting knowledge about a topic; *demonstrate* ways to apply content in actionable ways; *evolve* in their career and professional development, and *reflect* on ways to process and summarize their thoughts. This learning processes was informed through tenets of the

How People Learn framework, which shows that effective learning in any environment should be user-centered, knowledge-centered, community-centered, and assessment-centered[3].

The module topics were informed from the findings of forty interviews with engineering professionals working in academia and industry conducted through previous research by the authors. The design and structure of the modules was also informed by a survey of current graduate students at a large Midwestern university, as presented in this work. The development of these modules provides a foundation for future online professional development curricula supporting engineers pursuing advanced degrees that may supplement traditional engineering courses[4,5].

Literature Review

Professional development is a key component of higher education. Programs such as Preparing Future Faculty[6] and CIRTL[7] offer graduate students opportunities to learn about skills such as teaching, educational research, diversity, and community-building (www.cirtl.net). Although a few programs focus on students' preparations for industry careers, the majority of such programs focus upon the preparation of students for academic positions, since one of the purposes of doctoral programs is to socialize students into future academic roles[8]. At the graduate level, several changes have been suggested to engage students in activities that promote students' professional skills, focusing on the inclusion of non-technical skills such as communication, management, leadership and multidisciplinary teamwork [2,4,5,9,10,11,12] . Since the majority of graduate programs allow students to acquire depth in technical areas but not necessarily breadth, a national push has been made toward the development of "T-trained" students who are technically competent *and* professionally proficient[13,14]. Among the suggestions for obtaining depth and breadth include students' engagement in formal, nontraditional models of development mirroring professional school training (e.g., medical and nursing)[16], exposure to academic skills such as teaching, communication, identity development, and teamwork [7,9,16,17].

Methods

The methods behind the creation of the LEADER framework pull from commonly used constructivist learning frameworks in engineering education learning research, such as the How People Learn framework[3] and the Backward Design framework for curriculum design[18]. Although these frameworks give instructors quality guidance on designing a course, for the development of the professional development modules, the researchers in this paper were interested in developing a more concise framework that could employ best practices in How People Learn and Backward Design for short (~60 minute) modules. It also seeks to extend these two popular frameworks into the online (and blended) learning space, which is becoming more popular in an online society.
The How People Learn framework[3] posits that meaningful learning environments are composed of four interconnected elements: Learner-centered, content-centered, assessment-centered, and community-centered. The LEADER framework takes

advantage of these components in the creation of a series of guiding questions for the learner as they progress through the online module.

> Locate→ The learner is asked about previous experience with a given topic (learner-centered)
>
> Evaluate→ The learner is asked to informally evaluate her or his previous views (learner-centered)
>
> Absorb→ The learner progresses through the online module on an engineering-specific professional development topic, tailored for a graduate student engineer (content-centered)
>
> Demonstrate→ The learner is asked to demonstrate that she or he has learned the content that was presented in the module (assessment-centered)
>
> Evolve→ The learner is asked to describe how her or his views have shifted based on the content presented in the module, and how she or he will use the content in future applications in the engineering community (community-centered)
>
> Reflect→The learner is given time to personally reflect on the content and learning that has transpired in the module (learner-centered.) Stemming from early constructivist theorists like John Dewey and Jean Piaget, structured time for reflection in learning is becoming a well-recognized component in meaningful engineering learning environments.

The LEADER modules were designed and structured to advance particular professionals skills as identified: (1) via empirical findings of a qualitative research study and (2) via a brief survey presented to students in a graduate professional development course at a large Midwestern University. Researchers interviewed 40 engineering professionals concerning the characteristics and expectations of engineering Ph.D. holders. From the qualitative responses, researchers identified the most frequently occurring knowledge, skills, and attitudes. These were coupled with topics created for professional development efforts for underrepresented minorities doctoral students in the graduate student at a Midwestern University. Ten of the most frequently occurring topics were translated into topics for the modules.

The interview questions from the empirical study were mapped according to the following codes; demographic, motivation, transitions, engineering education, added value, expectations, stewardship, characteristics and recommendations. The frequency of which SKAs, such as develop technical writing skills, appeared in the answers to the questions was calculated and used to inform the module topics. These topics were later modified to fit the expectations of graduate students for taking an online learning module, according to the survey results.

After identifying the topics and learning contexts, the researchers sought to investigate the most appropriate means for implementing the modules. Sixty-four Ph.D. graduate students (42 males and 22 females) in engineering disciplines were asked to respond to the following 8 questions via an online survey to gain insight into their needs and expectations concerning taking an online learning module. These open-ended questions were used to determine the general format of the online modules.

1. "*Which skills and abilities do you think would be well-suited for a professionals online training program?"*
2. *"How much time would you be willing to put into an online training module for each skill (e.g., a module on developing presentation skills)?"*
3. *"What would motivate you to log on regularly and partake in online professional development modules?"*
4. *"What would be your biggest concerns about partaking in online professional development modules?"*
5. *"What are two major benefits that would encourage you to partake in online modules?"*
6. *"What would make these modules be more valuable than LinkedIn or career fair in helping you secure a job?"*
7. *"On a scale of 1 (extremely unlikely) to 6 extremely likely), how likely would you be to complete an online professional development module?"*
8. *"On a scale of 1 (extremely unsupportive) to 6 (extremely supportive), how supportive do you think your academic advisor would be of you completing an online professional development module?"*

The investigators are currently piloting the "communication" online module with a graduate engineering fellowship group. This group will help inform any modifications necessary for that particular module and feedback that is generalize able may be applied to other module topics. The modules are to be placed on a website and students have the ability to access the first online module, "communication". In the future, the modules will be offered to the various STEM scholar groups, engineering schools, and overarching graduate professional development workshops.

Results

Delivery of Modules

Initial survey results from authors decided that the modules would be 35-40 minutes long and would consist of pre-tests and post-tests. Formative assessments will be embedded within the modules, and users' responses to questions within each module will be stored in a database and will be accessible at the conclusion of each session. Summaries of students' responses for each question are found below.

(1) When asked "*Which skills and abilities do you think would be well-suited for a professionals online training program?"* 41% of the responses recommended oral and written communication, 29% listed management, project budgeting and team

development, 11% of the responses concerned interaction with industry professionals, and 19% related to possible linkages of research to industry.

(2) Students reported that they be willing to devote approximately 1.5 hours per week to each module.

(3) Students' possible motivations for completing the modules related to their obtaining skills to improve weaknesses or to develop skills in new areas.

(4) The major concerns that students had about completing online professional development modules included having no direct interactions with others and wasting time on material they already knew.

(5) Possible benefits that would encourage students to partake *in online modules* involve skills improvement and ease of use of the modules.

(6) In assessing *What would make these modules be more valuable than LinkedIn or Career Fairs within their job searchers, researchers found that* having the ability to interact with someone who would provide immediate feedback would help differentiate our proposed models from other services along with the ability of students to enhance practical skills and share via LinkedIn or on a Resume/CV work completed within the module.

(7) Seventy-one percent of the students stated they would be at least somewhat likely to complete an online professional development module.

(8) Twelve percent of the students thought their advisors would be extremely supportive of them taking an online professional development module, and 73% thought their advisors would be somewhat supportive or supportive of them taking an online professional development module.

Content of Modules

The research team used an exploratory method to analyze the module development process. This was guided by the aforementioned research and survey results, which guided the development of modules. The answers to the questions of the empirical study gave additional insight into the content of the modules. For example, if a respondent stated that graduate students should develop communication skills for all audiences, they would elaborate on the statement and explain why communication skills are necessary and what students should anticipate in the industry work environment. Thirteen modules were developed and each module was developed within the LEADER framework, a six part framework that identifies users' pre-existing knowledge, incorporates effective educational practices and learning theories, and assesses users' skill development through a standard process of discovery and reflection online[19].

From the data gathered through interviews of engineering professionals, perceived gaps in KSAs by engineering Ph.D. holders were analyzed. The top codes of KSAs were identified and used to develop module themes that would provide Ph.D. students practice and experience developing targeted KSAs. The following topics have already been translated into learning modules for doctoral students preparing for positions in industry as well as academia- communication skills, mentoring skills, professional writing, project management, leadership, and transformation of knowledge from experts to diverse audiences.

Given the empirical findings and students' feedback, the LEADER framework was developed. Revised from earlier work[19], the LEADER Framework was formalized to ensure that the needs of the students were met consistently and to allow the modules to stand out effective STEM-focused tools that would guide graduate students as they encounter content for the first time and apply a variety of professional skills to their graduate student lives. The LEADER framework is demonstrated in Table 1, using content from the "Communication" module as an example. Pre-assessment and Post-assessment evaluations are included with each module, the scoring remains the same through all modules as noted in Table 2.

Table 1. LEADER Framework with Example from Communication Module

LEADER Framework	Description	Example – Communication Module
Pre-assessment	Students are evaluated to determine their present knowledge of the learning objectives that will be presented in each module.	
Locate	Students identify their existing perceptions and experiences	Users write a statement presenting their research to a middle school student, a Nobel prize winner and the First Lady of the United States.
Evaluate	Students informally assess their views	Users are asked what communication strategies would be similar and different across the three individuals encountered in the LOCATE exercise.
Absorb	Students learn formal, preexisting knowledge	Users are shown how to bridge gaps between their communication styles and the technical or non-technical audiences.
Demonstrate	Students apply content in actionable ways	Users review a natural disaster and explain how, as a technical expert, they will communicate formally and informally to a variety of audiences.
Evolve	Students communicate how they will apply content in their career and professional development	Users are asked to discuss possible consequences of ineffective communication one may encounter during their graduate education experience.
Reflect	Students process and summarize their thoughts	Users identify communication strengths and weaknesses along with strategies and necessary resources to overcome their weaknesses.
Post-Assessment	Students are evaluated to determine how much they obtained from the module, according to their knowledge of the learning objectives that were presented in each module	

Formative assessments will be embedded within the modules, and users' responses to questions within each module will be stored in a database and will be accessible at the conclusion of each session. Modules may also be supplemented with a real-time feedback component so that users may connect with members of the research team regarding scheduled topics (e.g., live feedback as part of module completion).

A pre- and post-test also will be added to each module to track user progress through each module. Development for the pre- and post-tests will be informed from the framework in past literature[20], which focuses on learner-centered, content-centered, assessment-centered, and community-centered facets of the learning process.

Table 2. Scoring guide for module learning assessment

Score (points)	Pre & Post Assessment Evaluation
16 - Above	Excellent skills and knowledge in the module theme
11 - 15	Adequate skills and knowledge in the module theme
Below 10	Insufficient skills and knowledge in the module theme

The results from the assessment will allow the student to better understand if they have mastered the KSAs presented in that module topic. Once a student becomes excellent or proficient they are given the opportunity to move on to another topic area.

Based on student feedback, the findings from previous work by the authors, and the revision of the LEADER framework to meet student learning needs and objectives, the final topics which were developed are as follows:

1. Communication
2. Professional Writing
3. Generation
4. Project Management
5. Mentoring
6. Transformation

The authors anticipate creating many more modules based on other necessary attributes for graduate students pursuing careers in academia and industry, in order to meet the national call for broader and better prepared Ph.D. engineers in the workplace.

Based upon all of the KSAs identified within the research interviews, a survey has been developed to explore the skills necessary for STEM career success[21]. This survey will serve as the initial assessment presented to the graduate students who are given the modules. Although users are welcome to engage in all the content, the initial survey developed by the research team will be used to recommend specific modules that users should complete.

Discussion

Although the modules were developed to support all engineering Ph.D. students, there are limitations to the study. First, the engineering modules are meant to represent general professional development topics, not in-depth technical ones. For this reason, users will have to determine explicitly ways that their technical content connects to the ones offered by the LEADER framework. Nevertheless, we believe that the modules will assist students as they develop valuable KSAs. These skills were based on a previous research studies that interviewing professional engineers from a major engineering disciplines (i.e., chemical, electrical, and mechanical). However, the modules do not incorporate discipline specific industry modules (e.g., chemical engineers in pharmaceutical drug development). In the future, the investigators may consider developing discipline specific

engineering industry modules as a supplemental feature. Finally, the module assessment measures rely heavily on the engagement levels of module users. If someone is not invested in his/her learning, learning outcomes may not be achieved at the level explored by module developers.

The principles of Backward Design[18] were also used in the formation of this practical application for online module learning frameworks. Wiggins and McTighe propose that the best way to design a course that aligns the course objectives, content, and assessment elements necessary for student success is to work *backward*, first, designing the overall learning objectives, then aligning those goals with appropriate and aligned formative and summative assessment strategies, *then* filling in the content of the desired course[18]. In the design of the LEADER framework, and in its application in the professional development modules, the learning objectives of the course are presented at the beginning of the module, and by planning the questions and responses (which are formative feedback sources for the researchers), the instructor is forced to think about the alignment of the Demonstrate (summative assessment) component with the other aspects. After the questions are formed, content is easily distributed within the framework to help students achieve the desired learning objectives of the module.

The objective of this work was to develop an online learning tool that provides industry learning experiences for highly trained technical people (engineering Ph.D. students) and format the modules such that they complement the working culture of engineers in graduate study. The LEADER framework is applied to ensure each student has a unique learning experience that adds value to their current technical knowledge. Within this framework, the *Locate and Evaluate* steps are aligned with previous research findings that advocate for a learner cognitive inventory, in other words, accounting for the learner's current knowledge[22, 23] and assisting the learning in reflecting on their current knowledge[23]. *Absorb*, *Demonstrate*, and *Evolve* steps actively engage the learner such that new knowledge and previous knowledge can be aligned and connected to the professional engineering context described in the module activity. These three steps were designed based on research that discusses the importance of domain knowledge and knowledge found within particular communities of practice[25]. In the last step, *Reflect*, participants reflect on their actions, similar to Schon's reflection on practice[26], to manage the new content they have just learned. Based on the preliminary questionnaire, graduate students invest their time wisely in activities that add great value to their development and are interested in gaining knowledge that they do not currently know and cannot learn in their current academic setting.

Some of the content of the modules is proprietary; therefore, further descriptions of the modules will be reserved for future reporting. Future studies will discuss the findings from piloted learning modules. Assessment of users' KSAs would be evaluated through pre and post module quizzes. Users will be asked 20-25 questions which will give insight into what they knew beforehand and what was retained from the modules. The assessment questions will focus on topics similar to those suggested by Crewsell[21].

Conclusions

In conclusion, the LEADER framework offers a unique, learner-centered approach to develop online modules that support the professional development of engineers pursuing Ph.Ds. We anticipate LEADER-framed modules will help graduate students develop knowledge, skills, and attributes to prepare them for their professional positions. In the next steps of this research, the investigators aim to complete additional modules and pilot them with a variety of audiences. There are currently thirteen modules included in the online learning module series, of which eight modules have been developed. The LEADER framework may be a valuable tool for other engineering education researchers designing educational tools for engineering graduate students.

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