Development of online training modules for critical reflection and global engineering competency

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Development of Online Training Modules for Critical Reflection and Global Engineering Competency (Work in Progress)

Introduction

As the field of engineering becomes increasingly connected, today's engineering graduates need intercultural skills to participate in the global workforce. Working on a cross-cultural team requires understanding different approaches to problem solving, communication, and collaboration [1], [2]. Although prior research shows that studying abroad helps students develop global skills [3], [4], [5], not every student has the means to study abroad. Nevertheless, an engineering student can learn significant global skills without ever leaving the country if global competencies are addressed in the curriculum [1]. Several authors have discussed the development of global courses that can help students develop these skills [1], [6], [7], but not every engineering student has access to such courses. To provide global learning to the broadest range of students, this content would need to be integrated into regular engineering coursework. However, many engineering educators may not feel equipped to incorporate global content into their classrooms.

The purpose of our project is to develop two online training modules that teach students to critically reflect on their educational experiences and identify global components of their future engineering work. We have developed these online modules so that they can be used in a variety of settings to help students learn skills related to critical reflection and Global Engineering Competency (GEC). This paper presents our motivation in creating these modules, the frameworks that have guided their development, and an outline of the module content. We conclude with a description of our planned pilot study for the modules and a discussion about the potential applications of these modules in engineering education.

Motivation for Developing Online Modules

The field of engineering increasingly involves working on projects and problems that span international borders and impact people around the world, from aviation to climate change. To prepare students for working in a globalized world, engineering educators must intentionally create opportunities to develop global skills [8]. One traditional avenue for global skill development is study abroad. Although engineering programs have expanded the number of study abroad opportunities in recent years [9], students may not be able to afford such programs due to financial constraints or difficulty fitting the program into their curriculum [5], [10]. As a result, it is important that engineering educators address global skills in the core curriculum and not rely on study abroad or related programs to teach these skills [1]. However, given the complexity of engineering curricula [11], it can be tricky to introduce additional topics. Similarly, engineering educators may not feel qualified to introduce such topics in their classrooms, even though there is external pressure to emphasize non-technical outcomes within engineering degrees. ABET assesses professional skills as part of its accreditation criteria for undergraduate engineering programs, including communication with a range of audiences and the ability to recognize the impact of engineering solutions in global environments [12]. However, engineering faculty may struggle to teach or assess these professional skills as part of traditional, technical courses [13]. Some educators create specialized courses to teach these skills

[14], [15] while other institutions have shifted their curriculum to include more non-engineering coursework [16]. There is no unified theory on how to integrate professional skills into engineering curricula.

One approach that has been used to introduce ethics content into technical courses is "micro-insertion." Micro-insertion is a strategy where small units of content are introduced over an entire course rather than replacing significant sections of the technical content. Davis [17] describes this approach as a "pervasive method," and presents several ways that ethics content can be integrated into homework problems and class discussions with minimal effort from instructors. Others have implemented micro-insertion for content on entrepreneurship [18], corporate social responsibility [19], and energy justice [20]. Micro-insertion can help students see the connection between technical courses and professional skills, though some educators find that the impact of micro-insertion for ethics instruction can be limited if not intentionally scaffolded across the curriculum [21], [22]. In summary, micro-insertion offers an approach to integrating professional skills into engineering courses that can raise students' awareness of the importance of these skills in the engineering profession while also reducing barriers to faculty implementation.

Our project aims to support micro-insertion of global competence development in engineering courses through the development of two online training modules. We have designed these modules to be asynchronous, online, and applicable in a range of educational settings. The modules are intended to be useable on their own or can be integrated with in-class activities and discussion. The modules will be available free online to encourage broad use, alongside resources to support instructors in thinking about how to integrate them into engineering courses, extracurricular activities, or other educational contexts. We hope these modules will reduce burden on instructors by providing clear guidance and materials to support the integration of global topics into technical classes. These types of resources can help instructors align their courses with ABET requirements and better prepare students for real work environments.

Guiding Frameworks

Each of our modules is guided by a central framework that has informed our design of content. In this section, we explain each of these frameworks and why we chose them for this purpose.

Module 1: Critical Reflection

Our first module is grounded in the concept of critical reflection. Critical reflection is a tool used to deepen learning from any experience. At its core, critical reflection requires a person to remember an experience, determine how it impacted them, and develop a plan for moving forward based on the new knowledge, skills, or behavior. It has been used as a learning aid for content such as teacher preparation [23], engineering ethics [24], and workplace competencies learned from study abroad [25]. We draw here from the DEAL model of critical reflection, designed to strengthen learning when used in experiential learning programs [26]. This model breaks critical reflection into three steps: Describe, Examine, and Articulate Learning, steps

which are easy to remember and allow students to experience the learning benefits of critical reflection. These steps are defined as follows:

Describe. This step is focused on providing a detailed description of a situation, including observations of what happened and how different people responded. Students are asked to provide statements of observable facts, not interpretations, and try to be as objective as possible.

Examine. This step is when students are asked to consider possible interpretations of the situation through different lenses. For example, students may be asked to consider potential motivations, feelings, or prior experiences that may be informing different people in the situation. They could also be asked to consider the situation using frameworks such as power and privilege or cultural dimensions. The goal of this step is to help students move beyond summarizing the event to making meaning from it.

Articulate Learning. This step asks students to clearly state specific lessons learned they have from reflecting on the experience and to discuss future actions they might take based on this learning.

The DEAL model is widely used in applied learning situations like nursing because it allows the student to deepen their learning when analyzing case studies [27]. We chose to focus our first module around critical reflection, because it is a central skill in the development of global competency [28] but can also be applicable across a wide range of educational outcomes and contexts.

Module 2: Global Engineering Competency

Our second module is grounded in the model of Global Engineering Competency (GEC) developed by Jesiek et al. [29]. GEC is defined as "those attributes uniquely relevant for cross-cultural engineering practice" [2, p. 660]. We chose this focus for our module based on our prior research, which suggests that even when students demonstrate intercultural competence, they often struggle to integrate this learning into engineering [30], [31]. The GEC model was developed through research on engineering workplaces, which makes it well-aligned for use with micro-insertion into engineering courses. The framework identifies three dimensions of GEC: Technical Coordination, Engineering Cultures, and Ethics, Standards, and Regulations [29]. *Technical Coordination* describes the informal management tasks that engineers complete when working to complete a project on a team. *Engineering Cultures* are differences in work practices between different engineers which arise from both cultural and national differences. *Ethics, Standards, and Regulations* encompass ethical and regulatory differences, again due to both cultural and national differences. One method of teaching this framework is to provide students with case studies and ask them to reflect upon cultural differences and the potential actions they might take. A series of these scenarios is housed in the Global Engineering Competency Scenario Index [32]. Reflecting upon these scenarios allows students to imagine themselves in a real situation where cultural differences may cause tension on an engineering project, performing *critical reflection* which can deepen their learning.

Module Development Process

The purpose of this project is to develop two online training modules that teach students to critically reflect on their educational experiences and identify global components of their future engineering work. We used a Backwards Design approach to create the two modules [33], starting by defining the learning outcomes for each module. These learning outcomes are shown in Tables 1 and 4 in the following sections. We designed activities for students to practice the target skills such that each module can be completed in less than an hour. Our modules focus on introducing the topics and having students complete short analysis or reflection activities. While developing the modules, we sought input from project advisory board members who had prior experience developing activities focused on critical reflection or GEC. These advisors also reviewed draft versions of our modules and provided feedback on content and structure. We adapted content from both the Intercultural Learning Hub [34] and the Global Engineering Competency Scenario Index [32]. To keep students engaged, we developed several 2–3-minute videos to introduce content for each module, using an artificial intelligence tool called Synesthesia. These videos are interspersed with written content. We developed the modules using Qualtrics as a platform for ease of distribution. Qualtrics is widely used to distribute surveys and has a variety of response options. Our modules allow students to choose between writing their responses or recording video or audio files. The next two sections provide an overview for each of the two modules.

Overview of Module 1: Critical Reflection

We developed three learning outcomes for this module, using Bloom's taxonomy verbs [35] in order of increasing complexity. These learning outcomes are presented in Table 1.

Table 1: Learning Outcomes for Critical Reflection Module

Learning Outcomes
Students will be able to explain the DEAL model of critical reflection
Students will be able to critique their own written reflections using criteria for critical reflection
Students will reflect on their personal perspective and identity and how this can influence their experiences

To develop these outcomes, students are asked to work through a series of activities, which are described below.

The student will begin by watching a short (3 minute) video introducing the importance of reflection in learning, the experiential learning cycle [36], and the DEAL model of critical reflection. They will then write or record an introductory reflection about a situation in their own life, responding to the following prompt. This prompt was developed in alignment with the Critical Incident Technique (CIT), which is an interview/survey question format often used to understand how individuals respond to specific situations [37].

> *Take three to five minutes to write about an experience you had this week. This could be about anything (classes, social life, extracurriculars, work, family) as long as it is meaningful to you. Consider the following:*
>
> *1) What happened?*

2) How did you respond?
3) What was the outcome?
4) What did you learn?

After drafting their personal reflection, the student will learn more about each phase of the DEAL model. We include a scenario written from the perspective of a fictional student, Britney, for the student to reflect and expand upon, providing increasing detail with every activity the student completes (see Table 2). The student will intentionally *Describe* the scenario by filling in gaps in the initial description, *Examine* the scenario by considering different interpretations, and *Articulate Learning* by considering how the response to the situation might impact the student's life moving forward.

Table 2: Example Scenarios and Activities for Critical Reflection Module

Describe	Scenario	My friend Anna really ticked me off last week. At the student government meeting, she embarrassed me. I wanted to be on the assessment committee, but after what she said I withdrew from running. When Professor Roberts had us split into pairs for group work later, I ignored her and paired up with Ian instead.
	Activity Prompt	What other types of details would be helpful for Britney to think about or include when following the Describe step of the DEAL model? Don't worry, this situation is imaginary and there are no wrong answers!
Examine	Scenario	My friend Anna really ticked me off last week. We are both in student government, and we are in several of the same classes. We typically sit together in Hydraulics to work on problems. At the student government meeting, she embarrassed me. I wanted to be on the assessment committee. I believe that given my experience using and applying for testing accommodations, I have a lot to contribute compared to someone who has never struggled on an exam. When I raised my hand to volunteer, Anna said out loud, "Are you sure, Britney? You really bombed that last Hydraulics exam." I really wanted this opportunity but after what she said I withdrew from running. Considering how much money Anna's parents spend on private tutoring, it's unfair of her to call out someone like me who doesn't have as much help. When Professor Roberts had us split into pairs for group work later, I ignored her and paired up with Ian instead. I think I let my anger cloud my vision, because Anna left class pretty quickly after that and I was unable to focus.
	Activity Prompt	What are some possible interpretations of this scenario? Consider different lenses, like emotions or power and privilege.
Articulate Learning	Scenario	Same as for *Examine*
	Activity Prompt	What might Britney learn from the situation and how might this learning influence her in the future?

After analyzing the fictional scenario, the student will return to analyze the situation from their original reflection. They will reflect on what factors, assumptions, emotions, or perspectives influenced their action, what insights they gained from their experience, and what actions they

want to experiment with moving forward. They will score their original reflection using the DEAL rubric (see Table 3) and re-write the reflection to better align with the content they have reviewed throughout the module. Finally, the student will write or record a short response to the question, "How can critical reflection help you in your current program of education or your current job?"

Table 3: DEAL Critical Reflection Rubric (based on [26])

Criteria	Level 1	Level 2	Level 3
Describe	Describes experience with almost no detail. Doesn't refer to self as a participant but only an observer. Doesn't refer to other people involved meaningfully.	Uses some detail but the full situation may not be clearly described. Refers to self as a participant but may not acknowledge how their actions contribute to the situation. Mentions other people and interactions with them, but not all relevant parties.	Describes experience clearly and in detail without asserting personal interpretations. Frequently refers to self as a participant in the event and acknowledges how their actions contribute to the situation. Describes other people involved in the situation and interactions between them.
Examine	Does not consider their own response to the scenario. Does not consider perspectives other than own. Does not consider multiple potential interpretations of the situation.	Briefly considers their response to the scenario. Describes some aspect of either cause or effect. Considers at least two potential interpretations of the situation.	Examines their response to the scenario. Articulates cause and effect – what led to the situation, and where can it go from here. Considers three or more potential interpretations of the situation.
Articulate Learning	Does not describe anything learned from the experience or how the experience will impact life moving forward.	Describes some learning but may not clearly connect this learning to particular aspects of the experience. Does not consider the impact of this learning on future life.	Clearly describes what has been learned from the experience. Connects learning to particular aspects of experience. Considers how this learning will impact life moving forward. BONUS: Proposes future actions or behaviors.

Overview for Module 2: Global Engineering Competency

Similar to the Critical Reflection module, we began this work by defining three essential learning outcomes in order of complexity. Shown in Table 4, these learning outcomes guided the activity design for this module.

Table 4: Learning Outcomes for Global Engineering Competency Module

Learning Outcomes
Students will be able to explain the GEC model components
Students will be able to identify GEC model components in example scenarios
Students will be able to articulate their areas of strength and growth on the GEC components

This module is divided into two parts. The first introduces GEC through a video. Students will then consider GEC scenarios which each focus on a specific dimension of the GEC framework (see Table 5 for examples). For each scenario, the student will be asked to write or record a response to the following questions:

1) Which dimension is represented here?
2) How do you see that connection?
3) What information would you want to have to make a response to the situation?
4) Based on the information you have now, how would you respond to the situation?

In question 4, students are given a list of options to select from, which they identify as "Best Options," "Acceptable Options," or "Unacceptable Options."

Table 5: GEC Dimension Scenarios [32]

GEC Dimension	GEC Scenario
Technical Coordination	You are a mechanical design engineer working for a U.S.-based company that builds and services specialized manufacturing equipment. Your firm has a multi-million-dollar contract with a large Chinese company that is building a new factory on the outskirts of Beijing. During a recent meeting at the new plant, a high-ranking Chinese engineering manager requests several minor modifications to one of the machines they ordered from you. You remind him that the contract imposes fees for each modification, likely amounting to tens of thousands of dollars. The Chinese manager is angry and dismayed, asking how you could make such a silly demand when a multi-million-dollar contract is on the line.
Engineering Cultures	You work in a small production engineering team in a large multinational firm. Your group has been asked to recommend process improvements for one of your company's manufacturing lines in Germany. During a recent site visit, you present some of your team's preliminary findings. After the meeting, one of the German plant managers pulls you aside and questions your team's qualifications. You and your colleagues have an impressive array of degrees and a range of prior experiences.
Ethics, Standards, and Regulations	As a sales engineer working for a U.S.-based company, you receive a large order from an intermediate distributor located in Tianjin, China. Upon receiving the order, you check to make sure that both your product and the intended end product are not banned in China or restricted by export trade policies. When you look up information about the end user online, you find that the website for the end user's company looks suspicious and may have been created to appease you.

In the second part of the module, students will learn about the six dimensions of Hofstede's model of national culture [38] and reflect on the advantages and disadvantages of using this framework to understand cultural interactions. They will choose two countries to compare using the Country Comparison Bar Charts on the Hofstede research website [38] and

discuss their observations about how the countries are similar or different for at least three of the dimensions shown. The next activity asks students to read scenarios from the GEC Scenarios Index [32] and interpret them through both lenses of GEC and Hofstede's Cultural Dimensions (see Table 6 for an example of one scenario with its interpretation).

Table 6: GEC Scenario Example Activity [32]

Scenario
As a petroleum engineer employed by a multinational oilfield services firm, you are planning a trip to Mexico City with one of your company's sales teams. You will be visiting the headquarters of Petroleos Mexicanos (PEMEX), Mexico's state-owned petroleum company, where your team is pitching a major business proposal. Your supervisor asks you to recruit a "native expert" to travel with and support the team, and gives you contact information for three engineers in your firm who are originally from Mexico. While these individuals are of comparable rank and expertise, you learn that one was educated at Instituto Politécnico Nacional (IPN), another at Universidad Nacional Autónoma de Mexico (UNAM), and a third at Tecnológico de Monterrey (Monterrey Tech). Which engineer would you take with you?
Interpretation
Considering Hofstede's dimensions: Mexico has higher Power Distance compared to U.S. This indicates that there is more acceptance of unequal distribution of resources and wealth, and an emphasis on prestige and hierarchy. You should research the educational institutions and take a native expert from the most highly ranked institution, as this could help your firm's chance of winning the proposal. Considering Engineering Cultures specifically: We know that different institutions have different approaches to teaching engineering. It can be invigorating to run into an alum from your alma mater, and you may trust that they are competent because you received the same education. You could investigate how many PEMEX engineers graduated from each of the three institutions. UNAM is the largest engineering institution in Mexico City, where PEMEX is based, and one of the most prestigious engineering schools in the country. All other things being equal, you should consider choosing the engineer who graduated from UNAM.

After students have analyzed the above scenarios, we ask them to reflect upon their own life. They will write or record a reflection identifying an area of strength within the GEC framework, an area for potential growth, and the relevance of global engineering competency to their future profession.

Piloting the Modules

We are currently piloting the draft modules during the Spring 2026 semester. We recruited pilot participants through the Purdue Office of Professional Practice, which oversees internships, co-ops, and some international experiences for engineers. We also recruited students from a class on Humanities Informed Engineering. In this way, we recruited student participants who were completing study abroad programs, internships, and engineering elective coursework. We asked each participant to complete both the GEC and Critical Reflection modules. To evaluate the modules, we are considering two factors: ease of use of the modules and student learning from the modules.

To evaluate ease of use for our modules, we considered both time data and student feedback. Qualtrics automatically collected data about the time each student spent completing

each module. Additionally, we asked pilot participants to complete an open-ended survey upon completing each module, which included six questions:

- What was the most valuable part of this module?
- Were there any parts of the module that were confusing?
- Were there any parts of the module that were boring/not engaging?
- Is there anything you would change about the module's content or format?
- What was your biggest takeaway from the module, and how will you carry it forward?
- You opted to complete this module using [written OR recorded] responses. How easy did you find it to complete the module in this mode?

We compared responses to each of these questions and highlighted feedback that was common among students. We did not compare modalities using the final question, because all students in the pilot chose to write their responses. To evaluate student learning through the modules, we analyzed students' responses in the module activities to determine if students were meeting the learning objectives. For the critical reflection module, we compared the reflection students submitted at the start and end of the module for differences in length and evidence of students applying the DEAL model of reflection. We scored each reflection using the rubric shown in Table 3, which can also be used by instructors to evaluate student reflections. We also included the score students gave themselves on the initial reflection. To evaluate the GEC module, we reviewed how students responded to each example scenario to determine if they are correctly applying both the GEC framework and Hofstede's Cultural Dimensions model. We used a rubric that both evaluated students' understanding of the main dimension shown in each scenario and allowed them to earn points by identifying other related dimensions (shown in Table 7).

Table 7: GEC Module Scenario Scoring Rubric

Criteria	Level 1	Level 2	Level 3
GEC Scenarios 1-3	Does not identify a single GEC dimension that relates to the scenario	Identifies a GEC dimension or two which are related to the scenario, but fails to identify the primary dimension. Alternatively, identifies the primary dimension but connection to the scenario is weak.	Correctly identifies the primary GEC dimension associated with the scenario. May identify other related dimensions and correctly connects them to the scenario
Hofstede Scenarios 1-3	Does not identify a single Hofstede cultural dimension which can be used to interpret the scenario	Identifies one Hofstede dimension which is used to correctly interpret the scenario, but fails to recognize other related dimensions or incorrectly applies them to the scenario	Correctly identifies and applies multiple Hofstede dimensions

Preliminary Findings from the Module Pilot

At the time of writing this paper, a total of five students have completed the Critical Reflection module, and three students have completed the Global Engineering Competency module. All students chose to complete the module in the written format. We evaluated each response based on the rubrics presented above and averaged the scores for all responses. In Table 8, we present the quantitative results for the Critical Reflection module and in Table 9 we present

the quantitative results for the GEC module. Following each table is a short summary of students' feedback on each module.

The Critical Reflection module took less than one hour to complete, on average, though in completing the module students met the learning objectives. After working through the module activities, student reflections more than doubled in length and the average rubric score increased from 2.00 to 2.73 out of three points (as evaluated by the research team). Final responses showed a marked increase in detail, interpretations through multiple lenses, and articulation of distinct lessons to carry forward. These results are shown in Table 8.

Table 8: Evaluation of the Critical Reflection Module Pilot Responses (n=5)

Metric	Average Across Responses
Completion Time (minutes)	39
Initial reflection length (words)	213
Final reflection length (words)	464
Initial reflection rubric score (researcher)	2.00
Initial reflection rubric score (student self-rating)	2.20
Final reflection rubric score (researcher)	2.73

Note: Reflection rubric is out of 3 possible points

In their comments, students so far have reported that they appreciate several aspects of the Critical Reflection module and provided important points of feedback. Students appreciated being shown how to objectively describe a situation before applying interpretive lenses. They also liked applying the DEAL model to their own situation and being given clear criteria to evaluate their responses. Students overall did not find this module confusing, but several remarked that it is difficult to apply the steps of the DEAL model without first knowing what a "good" example looked like. They also reported that analyzing the same scenario several times felt repetitive. To address this concern, students suggested including an alternative scenario and using different question formats to break up the writing. Students commented that written responses were easy to complete, though one student noted that the text boxes in the program were small and that it was helpful to type responses on another document before pasting them into the module. Based on this feedback, we are incorporating a second example scenario which focuses on a workplace situation. We are also incorporating different question types. Rather than just writing about the scenario, students will rank this reflection based on the DEAL rubric, and match key phrases in the scenario to elements of both the DEAL model and Kolb's cycle.

The Global Engineering Competency module took roughly one hour for each student to complete. Overall, students correctly interpreted the example scenarios using both GEC dimensions and Hofstede's Cultural Dimensions framework. These results are shown in Table 9.

Table 9: Evaluation of the GEC Module Pilot Responses (n = 3)

Metric	Average Across Responses
Completion Time (minutes)	63
GEC Scenarios Rubric Score (out of 3)	2.33
Hofstede Scenarios Rubric Score (out of 3)	2.56

In their comments, students so far have reported that they appreciate several aspects of the Global Engineering Competency module and provided important points of feedback. Students found both the GEC model and Hofstede's framework to be beneficial, and they enjoyed applying their knowledge to different scenarios. One student commented that the videos introducing the frameworks were confusing because they did not include example scenarios, though there was an example scenario in the GEC introduction video. One student requested more explanation in the videos introducing the frameworks, but others did not have any suggestions for improvement. Students found applying frameworks of culture to real scenarios allowed them to develop more awareness of how cultural differences impact global engineering work. Based on these responses, we made the example scenario in the GEC introduction video more prominent, but are otherwise not making changes to the GEC module at this time.

Discussion & Future Work

In this paper, we have argued for the need to develop content that can support micro-insertion of global learning into engineering courses. As global skills become more relevant in engineering, it is increasingly important to develop approaches for teaching these skills throughout the engineering curriculum without demanding significant time investment from instructors. To address this need, we developed two online modules which can help students develop reflective skills and global awareness that can support them in becoming more globally competent engineers. The activities in our modules were developed in alignment with the Global Engineering Competency framework and the DEAL model of critical reflection to provide structure in student learning and evaluation. The modules are designed such that they could be integrated into technical coursework or used to support student learning through other experiential education activities (e.g., internships or community-engaged learning). The content introduces engineering students to skills needed for global careers without relying on study abroad or dedicated global engineering courses, which many students cannot access.

Although we have not yet completed the pilot study, we are actively updating the modules based on the feedback from the students who have completed the pilot so far as well as feedback from the project advisory board. We will use the results from our pilot study to further improve the modules before sharing the modules publicly for broad use. Once we have finalized versions of the modules, we will share them on our project website and through relevant distribution lists. We will also develop lesson plans and supporting content to help instructors integrate the modules into their classrooms or other educational programs. We will additionally integrate these modules into a larger research study on the development of global engineering competency in engineering students, which will provide additional evidence to inform future updates to the modules.

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