Integrating Soft Skills into Technical Curriculum

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Abstract

This paper focuses on development and delivery of soft skill (more recently referred to as professional skills) modules to be integrated into technical curriculum at the high school level. We also discuss possible implementation at the engineering department including its manufacturing program. Funded by a local foundation, a cross-disciplinary team encompassing social sciences and engineering professors coordinated with high school teachers to create technical and soft skills modules. One of the technical areas selected was advanced/digital manufacturing. Materials were developed for upper-level high school students. Alongside the technical modules, a set of essential soft skills was developed to be integrated with the technical modules to help students excel in the workplace. The instruction and practice of the soft skills was designed as several discrete modules contributing to three distinct themes. Each module contained explanations, examples, exercises and instructions for teachers to use the module. The activities and learning opportunities were tied directly with the technical content to make them repeatable in different classes and to help reinforce the skills. In total, nine team/teamwork modules including teamwork, problem solving, decision making, leadership (with the sub-contents of team organization, influence and motivation, conflict management, peer and team evaluation as well as reporting and presentation) were prepared, in addition to six individual skill modules covering skills such as dependability, responsibility, independence, persistence, integrity, and ethics. The main goal is to create multiple opportunities to teach and reinforce soft skills within the regular technical curriculum in the high schools. This paper discusses the integration of the soft skills modules into the technical curriculum developed via examples, and outlines its potential uses in this engineering department's curriculum including its manufacturing engineering program. The paper concludes with a discussion of the implementation of this project and provides some preliminary feedback from the participating high schools and reflections of the authors. It also includes future work opportunities such as incorporating additional skills like self-reflection and emotional intelligence into the engineering curriculum.

Introduction

It is generally known that soft skills are necessary to support a successful career. Employers have continually voiced concerns about college students not being ready for the demands of the workplace in terms of their personal and team-based soft skills. As a result, we focused our efforts to design and implement a set of soft skills modules that can be seamlessly integrated into the technical curriculum. This paper focuses on development and delivery of such soft skill modules at the high school level to help prepare students for college and careers.

After receiving grant funding from the Claude Worthington Benedum Foundation, the cross-disciplinary team encompassing social sciences and engineering professors (from Robert Morris University) identified local school district partners, and took charge of the technical and soft skills development efforts. One of the technical areas selected was advanced/digital manufacturing, with content in 3D scanning, 3D printing and additive manufacturing (AM), multiple realities (MR), industrial Internet of Things (IIoT) and robotics. Materials developed

were intended for upper level high school students. While equipping these students with the relevant technical skills, the proposed program included the development of several essential soft skills to help students excel in the workplace. The main goal was to design these soft skills modules in a way that make them easy to integrate into technical content such as those we introduced in the technical part of the project or within already existing technical courses at the schools. The target is to provide the teachers with well-designed and documented sets of activities for each of the soft skill that they can pick from and use in their classrooms. This aims to help teach the students the soft skills and reinforces this learning through repeated use of the activities in different courses and contexts. These soft skills were considered to cover three distinct exemplar themes and were to be integrated into the proposed technical curriculum for greater effectiveness. These themes were labeled as defining/knowing one's self, being a professional, and practicing with ethics. The instruction and practice of the specified soft skills, which we further refined based on needs assessment activities was designed as several discrete modules. Each module covers a soft skill that contributes to one or more of the themes and contains instructions for teachers to use. Each module included several activities and learning opportunities that can be tied directly with the technical content being delivered. The main objective was to make these activities repeatable in different classes to help reinforce the skills. Further, supported by the outcomes of the needs' assessment, the delivery of these modules was to be integrated within the proposed technical modules or leveraged as components of existing STEM curricula. Modules included the requisite instructional content and activities (e.g. deliverables) along with insights and guidance on module integration (e.g. mappings between soft skills activities and technical activities) and assessment at the student (learner), teacher (instructor), and overall programmatic levels.

In this paper we will first offer a brief background about soft skills and their importance in preparing students to meet employers' demand in that regard. In addition, we review some examples where teaching soft skills is integrated with technical skills. Then we outline the technical content development efforts and the areas covered. After that we will describe the development of the soft skills modules and demonstrate examples of how these can become part of the general high school curriculum. In the final sections, we discuss the integration aspects and conclude the paper and offer some prospects for future work.

Background and Related Work

Workforce development requires providing relevant and up-to-date knowledge to students to prepare them to take on the various roles in the workforce. In STEM fields, this requires rigorous curriculum and in-depth technical coverage in the fields of study. One of the problems colleges facing is the lack of interest in STEM fields among high school students [1]. Another problem is the under preparedness of these students for the rigorous college curriculum required in the STEM fields. The discussion of why students do not go for STEM programs and what factors affect their choices have been researched heavily. In one study [2] the authors determined that high school students who participate in STEM competitions while at school are more likely to go for programs directly related to the competitions and that participating in more competitions further increase these chances. Another study [3] highlights participation in STEM clubs and taking STEM courses have a strong influence on them selecting STEM careers. A third study [4] found that parents and teachers also have a strong influence on students' career choices and that parents and teachers who have good knowledge of STEM careers can be a strong driver for the students because they can provide more information and encouragement.

The three studies given above confirm potential impact of this project as we target high school students and their teachers with our work, in hopes of increasing teachers' and students' knowledge in these fields and consequently influence the students' career choices. In addition, a similar approach was done by another group of researchers [5] who introduced engineering project-based learning to grade school students and determined that the students' interest in STEM careers increased after their exposure.

The second part of career preparedness is soft skills such as interpersonal communications, the ability to work well with others, professionalism, ethics and others similar facets. Employers have, for a long time, voiced concerns about the lack of preparedness of new hires in terms of soft skills. For example, in [6] the authors explore the works discussing the role of soft skills in increasing employability based on the employers' perspective. A Wall Street Journal article [7] echoes a similar concern as they highlight critical thinking as one of the soft skills employers say recent graduates do not have. This trend has continued into our present time as shown in [8], [9] and [10].

ASEE Peer database search indicated 2693 entries based on the keywords "soft skills". It seems like almost every different way has been tested in many different disciplines. When you add the phrase "high schools" to "soft skills", the number falls to 1639. Advanced search conducted by employing the phrase "soft skills in high school" in the papers' titles, yielded no results. It seems like - any of the papers associated with high schools reference mostly to debate teams and communication skills. In Google Scholar, the search construct ""soft skills" + "technology skills" + "integrations" led to around 120 entries, more than half being irrelevant. Using "soft skills in high school" for the search led to 78 results. Some of these are very relevant as in [11] thru [15], while many are not. Outcome of our literature search pointed out that the integration of soft skills with technical skills in high school curriculum is not being investigated a lot.

Technical Content Development

Technical content development efforts are presented in this section. Multiple technical modules were developed and shared with the high school teachers as listed below:

- 3D Printing/Additive Manufacturing (AM)
- Multiple Realities (Augmented/Virtual Reality (AR/VR))
- Computer-Aided Design (CAD)/3D Scanning
- Educational and Industrial Robotics
- Industrial Internet of Things (IIoT)

Each technical module consisted of a slide-deck with background information about the subject (Figure 1), complemented with review questions, research questions, and challenge activities. Students who are studying these modules can easily answer the review questions since they are based on the slide content. On the contrary, research questions require students to carry out additional work for them to be able complete them including literature reviews and processing information learned from them. Finally, the challenge activities channel students towards computer-based and/or physical/hands on assignments and projects.

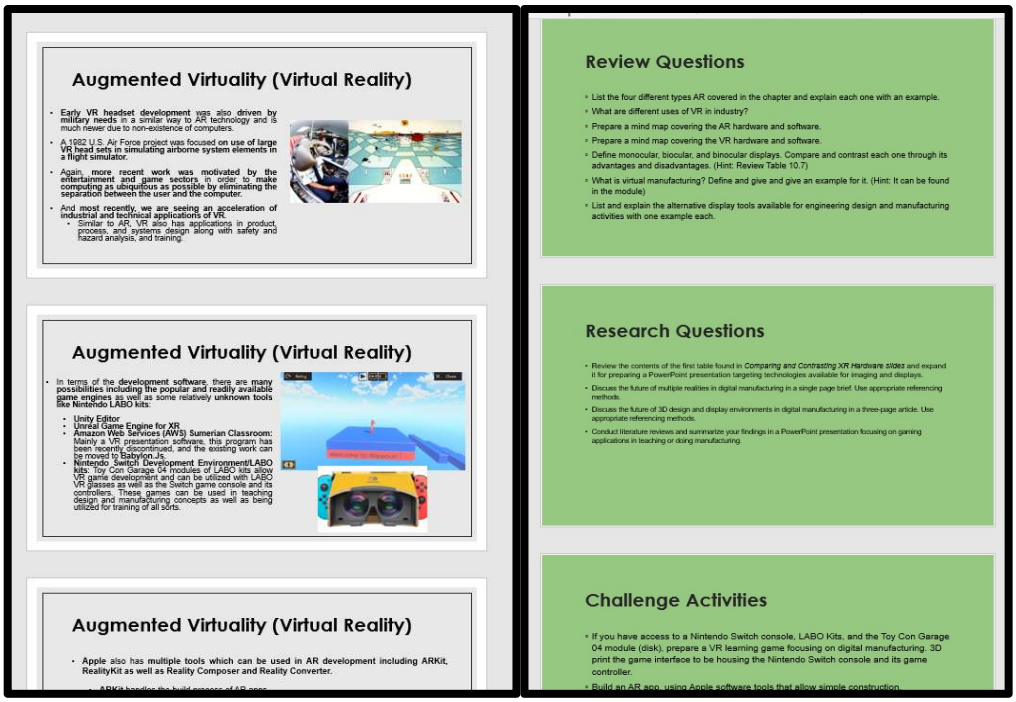

Figure 1. Technical module slide-decks and the question section

In addition to the slide-decks, each module was supplied with a useful Internet links document (this document is to be used as a working document where the project team can modify it or add new components over time) with an intention of supplying additional resources. Other materials attached to the modules included demo videos/tutorials of the equipment and/or software tools (Figure 2) given to the high schools along with other supplemental materials such as educational papers.

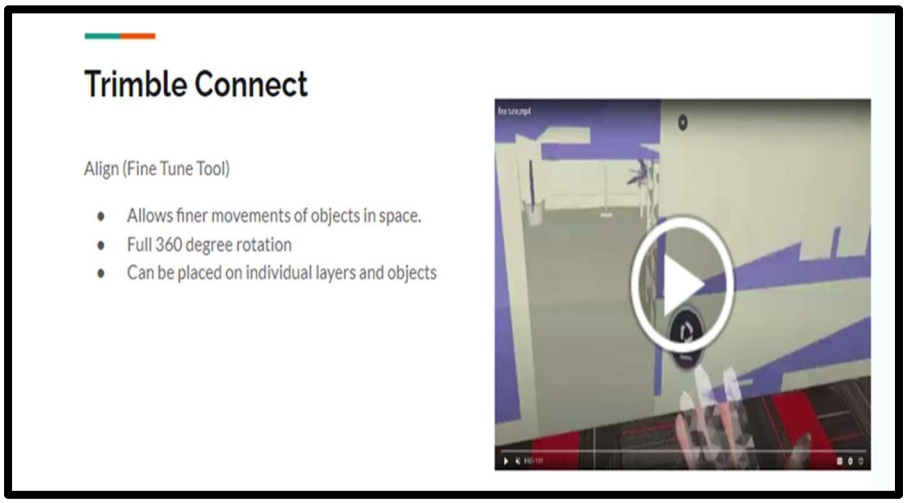

Figure 2. Trimble Connect VR Tutorial for HoloLens 2

Each high school involved in this grant project received the following equipment and their associated software as well as consumables needed for the equipment:

- 24 IoT kits
- 2 Structure Core 3D Scanners and 4 Apple iPads.

- 1 HoloLens 2
- 1 VEX V5 Work cell System
- 10 Creality CR-10 FFF 3D printers
- 1 Elegoo Mars SLA 3D printer

Hopewell High School dedicated one of their classrooms as a digital manufacturing laboratory after working with the project team (Figure 3).

Figure 3. Digital manufacturing laboratory at the Hopewell High School

Multiple training sessions were organized for the high school students and their teachers (Figure 4a and b). Student training took place at the high schools, when the project team arrived at the schools to check on the newly purchased equipment. These trips were also used in fixing the issues associated with the new equipment and supplying consumables. Teachers were also trained at their schools. However, they were also invited to the university for multiple comprehensive training sessions:

- 3D Scanning Training for the Structure Core Scan
- FDM/FFF 3D Printing Training
- VEX V5 Manufacturing Work cell Training
- VEX Code VR Training

Figure 4. a - High school students 3D scanning a trophy under the guidance of project team, b – the outcome of the scan

Soft Skills Development

This section of the paper offers an overview of the modules developed for soft skills. Two sets of soft skills modules were developed. One is the set of individual skills modules (N1- N6) that covered the following subjects:

1. Dependability
2. Responsibility
3. Independence
4. Persistence
5. Integrity
6. Ethics

These modules help build on general personal and social skills developed through curriculum and social interactions. As students learn many important skills like communication (oral, written), cultural awareness (at home, work place, school, etc.), and diversity awareness through formal courses and social interactions, the supplied modules add several more focused elements to them. Teachers can use the PowerPoint slide deck as a guide and build the exercises into their classroom activities.

The second set, with a larger focus, was developed on the team-based skills as these are somewhat harder to teach and require continuous reinforcement. Nine different modules (T1-T9) were included:

1. Teamwork
2. Problem Solving
3. Decision Making
4. Time Management
5. Leadership
    a. Team Organization
    b. Influence and Motivation
    c. Conflict Management
    d. Peer and Team Evaluation
    e. Reporting

The team-based skills modules were designed to allow teachers to weave individual topics and activities through a regular curriculum. A mapping was created to show the relationship amongst all modules (individual and team-based) and guide the teachers through the flow of topics and skills to be covered. The mapping defines what each module in the team-based skills require from the individual skills to be developed first. Table 1 shows these relationships and the prerequisites for each module from the same series.

- Instructors need to decide which modules (or parts of modules) to use during a given course.
- Module 0 is the general introduction to the soft skills topic. It is necessary and must be the first module to go through before any other individual or team-based soft skills modules.
- The individual soft skills modules are relatively independent and may be introduced partially or fully in various orders as instructors see fit within their technical course content.

- In the team-based soft skills, Module T-1 is necessary and needs to be covered before any other module. The rest of the modules are interchangeable and can be introduced in any order that satisfies the modules' prerequisites.

All modules have a set of PowerPoint slides for the instructors. These are not designed for direct delivery to the students. Instructors should use these as a guide to the module content and activities. Some slides can be separated and adapted for sharing with the students. In addition, various samples and templates are prepared for the teachers' use for the different modules. Some of these may be usable as is, while others can be adapted to the appropriate context of the class they are offered in.

The following are team-based soft skills modules descriptions that include basic information about the modules and various items on each module:

- **Module number and title**.
- **Context**. Where it could fit in the technical modules.
- **Material**. Material or resources needed for the activities in the module.
- **Prerequisites**. Other soft skills needed to support learning this skill.
- **Time**. Estimated time needed to go through the module (very tentative and can vary based on instructor's style, class size, level of details, etc.). Most modules can be divided across multiple sessions as needed. Instructors may also choose to include parts of a module only.
- **Learning objectives**. Main learning points the students should learn by going through a module.
- **Delivery**. Discussion points for the delivery methods. Most concepts and activities are described in the notes section of the slides.
- **Assessment**. Examples of assessment components for the students work. Instructors have the freedom to decide on how much weight they will put on the soft skills modules and when and how to assess them for grading purposes. However, instructors are encouraged to continuously assess students' performance and keep track of how well they are learning and retaining these skills.
- **Outcomes**. Overall module outcomes assessment information. Instructors will need to assess the modules and the expected outcomes after completing each module.
- **Next modules**. List of other modules that can logically follow the module being described. This creates a tentative timeline (organization) of the modules. Some modules would possibly fit anywhere, so these will not have information here.
- **Usability**. Identifies other skills modules each of the activities in this module can be used for. Adaptation and different applications of activities are also discussed in the note's sections of the slides.

More general information that applies to all modules for team-based soft skills were added within the slides and as separate documents for the teachers. Various examples of how the activities can be applied in the technical modules were provided. When delivering soft skills modules teachers also have the following guidelines:

Delivery: A module comes with multiple resources to help the teachers deliver the content in their classrooms. These include:

- Slides and activities to be done in class and as homework assignments
- Students will be asked to complete some tasks before starting a module and after completing one

Table 1. The team skills modules and their mappings to individual skills modules.

Individual skills	Build on general skills required through curriculum and social interactions. Examples: communication (oral, written), cultural awareness (Home, work place, School, etc.), and diversity awareness. Each module N-1 thru N-6 covers one of essential skills that an individual need to know and/or master. Many of these forms the basis for other individual skills and for teamwork skills.			
Team Skills	**Main Skills (Module)**	**Sub-Skills (Module)**	**Prerequisites**	**Individual Relevant Skills**
	1. Teamwork (T-1)		Module 0	
	2. Time Management (T-4)		Module T-1 & T-2	N-1, N-2
	3. Problem Solving (T-5)		Module T-1 & T-4	N-3, N-4, N-5 & N-6
	4. Decision Making (T-6)		Module T-1, T-4 & T-5	N-3, N-5, & N-6
	5. Leadership			
		a. Team Organization (T-2)	Module T-1	N-1, N-2 & N-5
		b. Influence and Motivation (T-3)	Module T-1	N-4 & N-5
		c. Conflict Management (T-7)	Module T-3, T-5 & T-6	N1, N2, N-5, & N6
		d. Peer and Team Evaluation (T-8)	Module T-1, T-2 & T-3	N-1, N-2, N-5 & N-6
		e. Reporting (T-9)	Module T-1	N5 & N6

- Students will be encouraged to discuss soft skill topics throughout the course
- Instructors should find different opportunities to mention and reinforce a module's team soft skills throughout the course.

Assignments: Students will be given assignments and activities to work on and complete such as:

- Discussing the topic in class
- Completing activities in class and outside of class
- Writing in their individual learning journal [16] on a regular basis (possibly weekly) and writing in their team learning journals when teamwork/skills are being covered.
    - Journals (individual or team) have certain prompts to help the students in their writing and to focus the ideas and reflections.
    - The following are examples of prompts for the journal entries:
        - Minimum requirements in a weekly journal entry are: the date, topic discussed, what I already knew, what I learned, and what I still want to learn.
        - Free form discussion of the experience, reflection on its benefits/shortcomings, discussion of a specific activity, describing how things went and reflecting on why, etc.
        - Identifying difficulties or challenges and how to work them out.
        - Suggesting ways to make things better.
        - Specific entries relevant to other technical modules/content.
        - Responses to specific instructions or questions from the instructor on some content.
        - Research-based prompts asking students to include external references like articles, blogs, videos, etc. relevant to a given topic along with a discussion of the item included and how it relates to the topic.
    - A team learning journal entry can be used when team-based soft skills modules are being covered. These will be different from the individual entries in some ways:
        - These are completed individually by each student however; the focus is on reflections on the team and the student as a member of the team.
        - Guidelines are similar to those for the individual journal recording, but these are not supposed to be regular entries. Entries are prompted whenever the instructor finds an opportunity to get the students to examine their performance in the team and the overall teamwork experience.
        - Students should be encouraged to discuss their entries within their teams as part of the discussions of their tasks.
        - Teachers can use these to spot issues in team dynamics and address them in a timely manner.
    - The journal entries (individual and team) should be kept private and reviewed only by instructors to confirm completion. However, on some occasions the instructor may ask the students to share some of their reflections in class discussions. Instructors should clearly state that this is optional and students need not reveal any private (or embarrassing) content to the class. This is particularly important to encourage students to be open and honest in their reflections.
    - Teachers are encouraged to read these journals regularly and address the students input and concerns either individually (through comments to the student or private conversations) or as a general discussion in the classroom without alluding to who wrote what.
    - Teachers are also encouraged to adjust how they do certain things in the classroom to accommodate for needs or suggestions expressed in the journals. This point in particular will further enhance the students' individual skills by making them feel empowered and heard, which positively impacts their independence, responsibility and overall interest.

- If the journal entries will be graded as part of the course assessment tools, the grading should be based on completion and meeting minimum requirement only.

Students Assessment: Teachers will assess students work based on the following (these are examples and there may be other methods to use as well):

- Involvement in the discussions
- Completing assigned tasks (keep in mind quality, timeliness, organization, and adherence to an activity's specific requirements).
- Updating the learning journal(s) (In many cases a simple proof of completion is enough. However, the instructor may grade some specific entries more closely, especially those explicitly requested by the instructor)
- Showing improvements in demonstrating and using certain skills.
- Teachers may also create and use additional tools as they see fit.

Outcomes Assessment: Teachers need to evaluate the soft skills modules they use and assess the outcomes achieved by introducing the modules in their classrooms. Some criteria to consider include:

- Success of delivery
- Students' engagement
- Students' grades (average scores, min, max, etc.)
- Solicited students' feedback (polls, surveys, open discussions, etc.)
- Observations of changes in students' behavior and performance in situations requiring the taught soft skills.

Usability: Sample activities and discussion prompts are included for the teachers with each module's slides. In addition, some templates and several articles, videos and other resources are included. These will help the teachers identify when and where to use the components of any module and provide them with examples how to use them:

- Many of the activities and discussion prompts can be incorporated in various parts of a technical course and can be repeated across other modules (soft or technical skills).
- With each module some pointers are given for the teachers on possible reuse of activities and content.
- Teachers may pick what activities to include in their technical sessions and they can mix and match activities from several soft skills modules in the same class (e.g. activities for time management, organization and decision making can be used together as part of the same technical unit.
- In general, activities requiring input from individual students or groups can be used practically for any topic that has multiple points of discussion. For example, when talking about material that can be used in some process (e.g. 3D printing); listing the advantages/disadvantages of something (e.g. personal protective equipment (PPE)); and characteristics or descriptions of something (e.g. how 3D printed parts or traditionally fabricated parts compare based on their builds).
- The individual and team learning journals should be used throughout the course. The entry requirements need to be set by the instructor for each module (e.g. an entry per

class, an entry per week, an entry per topic, and/or by request from the instructor). It is useful to remind the students of this task continuously.
- Instructors may choose to include the reflections on the technical concepts of the course as part of the individual learning journal entries.

Integration

Generally, soft skills are being regularly taught independently. Short workshops, day activities, team building retreats, etc. can raise awareness of such skills. However, it is also important to reinforce these skills on a continuous basis. Teaching these once and moving on will not lead to lifelong use of these skills. Thus, this project included an integrated approach where soft skills are interleaved with technical topics as they are being taught in the regular classrooms. In this project, the design of the soft skills modules was deliberate and geared specifically for reuse. Providing the teachers with discrete bites of teaching components that they can incorporate into their classes and reapply in various contexts. To illustrate this, we offered some examples that show how a certain skill can be taught along a specific task. Something as simple as asking the students to monitor and reflect on team interactions while performing a team-based project like rapid prototyping a potential product with 3D printing will shift the students focus to their team interactions as they do their work. As a result, they will be aware of how they interact and as they discuss them in class, will learn how to become better. Repeating the same activities in a different class, e.g. material science and engineering class where teams work together to do some experiments will help reinforce the materials selection for the prototype. This also requires the teachers to include team performance as part of the project/experiment assessment alongside the technical outcomes.

Another example would be including discussions of certain soft skills as part of a specific technical content module, such as adding discussions of an Individual Skill like Ethics to the 3D Scanning module along with Reverse Engineering and Intellectual Property Law content. This way, the students can see an important application of ethics in reverse engineering others' creations – products or machines as they can judge if it is legal or ethical to behave in certain ways. Similar points can be made for Ethics and 3D Printing, especially in the bioprinting area when the researchers employ stem cells. In this manner, teachers will have a wide range of interchangeable components between the technical modules and soft skills modules to work with. On top of that, they can include their own content and subject matter and integrate the soft skills components into them. The most important thing though is to make sure that these soft skills are reinforced continuously in various contexts and multiple classes to help students truly develop and maintain these skills.

Similar integration effort is applicable to post-secondary education for engineering programs, for example. A very good example is the manufacturing engineering program this department houses. These soft skills modules carry an important role in generating standards for the communication intensive courses (designated by the department) and help with engineering and university-wide accreditation processes. These could also be an ideal supplement to the competencies and learning outcomes development and assessment in the general education curriculum at the university. In addition, applying some of the soft skills modules will help improve the students' career readiness and make them more employable.

Conclusion and Future Work

This paper presents two sets of development modules for high school students to first increase their exposure to current technical concepts like 3D printing and AM and then incorporate material and activities to build their soft skills. The soft skills components offer a flexible set of modules that can be interleaved with the technical content and help cultivate the students abilities in these areas. The paper also demonstrates the integration of the soft skills modules into the technical curriculum developed via examples. The goals here are to increase the high school students' awareness and interest in STEM fields and at the same time improve their soft skills to be better prepared for college and for future employment. We believe that our approach to integrating soft skills with technical learning helps strengthen the skills and reinforces the students' learning of these skills. In addition, as we reviewed the NACE Career Readiness Competencies, we see that our selected soft skills align very well with the list they offer (Career & Self Development; Critical Thinking; Communication; Teamwork; Technology; Leadership; Professionalism; and Equity & Inclusion) [17]. We intend to further use this information to refine the soft skills and technical skills components for future applications of this approach.

The team collected some feedback from the participating schools (from 2 schools, 4 teachers) and in general it was very positive. The team interactions with the teachers indicated good support from the teachers and several teachers indicated the usefulness of this approach when they tried it. As the project focus was on designing and implementing a pilot run, the number of participants and experiments done did not warrant full scale evaluation of the outcomes.

From our perspective we see the project and all the efforts put into it as a rewarding and informative experience that allowed the project team to better understand the importance of the soft skills and place them in the context of technical subject matter, making them more valuable and attached to the technical world, rather than keeping them detached and floating by themselves. The experience of working with the school teachers and soliciting their input on what soft skills are important and what they perceive as their students' needs in this area was valuable to our modules design process. However, the process had its issues and challenges as well. To start, working with multiple schools and teachers from varying backgrounds, led to having too many varying inputs on what soft skills to address and it took some time and lengthy discussions with the teachers to narrow these down. The next issue arose when we started delivering the initial soft skills modules and teachers needed time to go through them to figure out how to incorporate them into their own classrooms. We helped them through the process by providing specific examples using the technical modules in manufacturing and epidemiology we created for them. This gave them solid examples showing how and where soft skills activities can be included. Ultimately seeing these technical and soft skills modules in action at the schools was also an important step that showed the value of this work. Then we also had various issues with follow up tasks and especially getting enough feedback from the teachers. Given the available time for the project and the many objectives that needed to be satisfied, it was hard to get the teachers to give us more time to provide detailed feedback. Through all of this we, the project team, learned several valuable lessons that we hope to apply when we approach similar projects in the future. The most important one is to allow for more time within the project schedule for assessment and measurement. In addition, we need to be more attentive to data collection and creating better ways to have more objective evaluations of the work.

Based on the results and, now, better understanding of this integration, we believe there is a strong potential to use the soft skills modules (possibly with adjustments/adaptation) in our

engineering department's curriculum including its manufacturing engineering program. We see great potential to benefit the students and better prepare them for their careers as engineers. This is one of our near-future goals to achieve. In addition, beyond this, we are considering incorporating additional skills such as self-reflection and emotional intelligence into the engineering curriculum. We believe that a similar integrated approach will help introduce these skills in different engineering courses to teach the students these valuable skills and help them explore their potential. We also believe that these are very important soft skills not only for managers, but also engineers, technologists, technicians, and blue-collar workers as they try to work in harmony with others, making their teams and work environment successful.

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