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Blending the Entrepreneurial Mindset into a Learning Module with a HVAC Design Project: Pilot Implementation

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Abstract

The authors implemented Kern Entrepreneurial Engineering Network (KEEN's) Framework for Entrepreneurial Mindset Learning into a senior level Applied Fluid Mechanics course within a Mechanical Engineering Technology (MET) program. The four-credit senior level course, which has lecture (three credits) and lab (one credit) components, covers topics such as pipeline systems, pump selection, and flow of air in ducts. This collaboration between engineering and education faculty builds upon the knowledge gained from the summer 2020 Integrating Curriculum with Entrepreneurial Mindset (ICE) workshop, and focuses on fusing Curiosity, Connections, and Creating Value (the 3C's) throughout the Flow of Air in Ducts learning module, including an HVAC design project.

New lectures and assignments covering topics related to HVAC industry were added to the learning module curriculum. An existing HVAC design project was revised and updated to incorporate Entrepreneurial Mindset Learning (EML) outcomes. The project required students to complement in-class learning with i) content knowledge learned from previous courses; ii) independent research using credible sources; and iii) a proposed HVAC design. New project deliverables were related to project economics and the environmental and societal impacts of the proposed design. Students authored and delivered a multi-stage written report and presented their proposed solutions to their peers. The classmates reviewed and graded the proposal including the quality of the presentation.

Direct assessments (course assignments) and indirect assessments (pre- and post-project surveys) were used to evaluate the effectiveness of the EML activities learning outcomes. Findings support the use of the updated KEEN's 3C's learning module to facilitate students' understanding of the technical content and development of an entrepreneurial mindset. Results also satisfy the latest ABET student learning outcomes and increase the students' preparedness for the workforce.

Introduction

The National Engineering Education Research Colloquies (EERC) (2006) framed the engineering education (EE) research field within five broad areas, including engineering learning mechanisms, learning systems, and assessment. To identify and offer the best solution for a given problem, engineers must consider the economic and social impact of the proposed solution. (Kant & Kerr, 2019). Educational programs are charged with identifying knowledge progressions and skill development as part of a culture of continuous improvement. Pedagogical practices should use a variety of educational experiences and methods to engage and motivate, and to enable a diverse pool of learners to develop hard and soft skills that are transferable to real-world contexts. Educational systems must challenge and reframe practices so that the engineering profession progresses (Mejia et al., 2020). Hence, pedagogical practices should build an engineering workforce that reflects diverse communities, thinking, and perspectives. There are several well-established pedagogical practices, project-based learning included, that focus on improving content knowledge, communication, and collaboration, for example, but not necessarily focus on improving effectual reasoning. To drive innovations, our engineering graduates should be prepared not only with strong soft and technical skills, but also with an entrepreneurial mind (Zhu, 2021).

Entrepreneurial minded learning (EML) emphasizes seeking opportunities, pursuing innovation, and creating value. For example, Gerhart and Melton (2016) observed that when EML is incorporated into a Problem Based Learning activity done in a Fluid Mechanics course, the student's enthusiasm for the assignment and the subject matter increased and the learning is enhanced. Problem- and project-based learning activities that integrated EML in either a course or a sequence of courses fostered entrepreneurial skills in students (Liu et al., 2017; Mallory, 2015; Gibbons, 2021; Seyed, 2020). Moreover, several higher education institutions have already started to redesign their entire engineering curriculum to incorporate EML at multiple levels (Mynderse et al., 2015, 2019; Gerhard et al., 2014; Seyed, 2021).

Engineering assessment is essential to evidence-based decisions and practice in key areas of EE research, such as learning and assessment frameworks, policies and practices that provide critical feedback throughout the educational system, including pedagogical practice, and of course, student learning. The work of The Kern Entrepreneurial Engineering Network (KEEN) as in-part, influenced the increased implementation of EML activities into EE curricular, namely in online discussions (Bosman, 2019). Hence, the need to evaluate the effectiveness of EML-related curricular enhancements and related student learning outcomes, including the development of direct and indirect assessments, are a priority (Li, et al., 2016).

Both the EERC and KEEN frameworks align with ABET quality assurance goals to prepare qualified engineers who can contribute their expertise in a global workforce (ABET, 2021). Therefore, the five EE research broad areas, the KEEN's mission, and ABET goals together provide a useful framework for considering, designing, implementing, and evaluating innovative engineering curricula and pedagogical best practices.

Research Methods and Procedures

This paper describes the implementation and evaluation of EML activities added to a learning module and to a Project Based Learning (PBL) activity part of that learning module. The pedagogical practices discussed herein focuses on solving a real-world problem by integrating: i) a collaborative model with multiple socio-technological dimensions supported by cooperative learning, peer assessment, and communication (Jordan, 2018; Dym et al., 2003); and ii) a KEEN's 3C's approach incorporated into an existing learning module and project.

Study Site

The site for this Entrepreneurial Mindset (EM) integration study described herein is the Engineering Technology Department (ET) in the College of Engineering (COE) at the University of Toledo. The ET Department offers 5 ABET-accredited Bachelor of Science (BS) in engineering technology programs, one of them being BS in Mechanical Engineering Technology (MET). Due to the COVID pandemic, the enrollment in the program decreased, and as of January 2022, there are 184 students enrolled. This student body is comprised of traditional students (37.0%), transfers (22.3%), internationals (4.3%), and non-traditional students (36.4%). The substantial number of transfer and non-traditional students brings a variety of engineering skills and lifelong learning experiences to the MET program.

The Course

The Applied Fluid Mechanics course (MET 4100) is a senior level core course in the MET program and the second in the sequence of fluid mechanics coursework, following Fluid & Hydraulic Mechanics (MET 2050). This four-credit hour (ch) course consists of a 3ch lecture and a 1ch laboratory. During the Fall 2021 semester, the course was offered face-to-face on campus. To increase the accessibility to the lectures for those students not able to attend them in person due to COVID issues, the authors developed the course more like a "blended" experience, using Blackboard platform to post lectures, course materials, instructional aids, and assignment submissions. Simultaneously, all the lectures were conducted synchronously through Blackboard Collaborate Ultra and recorded for later viewing.

The course focuses on the applications of the basic principles of fluid dynamics, including series pipeline and parallel and branching pipeline systems, open-channel flow, pump selection, flow measurement, drag and lift, flow of air through ducts, etc. A proficient grounding in these concepts is critical for solving a wide range of engineering mechanics problems, and therefore it is essential for success in the engineering profession.

The work described herein is based on a new module that was piloted during the fall 21 semester with 29 students enrolled and covered Flow of Air in Ducts. The learning module was infused with entrepreneurial mindset learning through the addition of three new lectures given by experts in the fields, and an updated one-month long project to design a HVAC system to satisfy a client's requirements.

The Learning Module

The MET 4100 course was designed into 12 Learning Modules, one of them being ***Learning Module #9: Flow of Air in Ducts*** and subject of this work. In general, there was one learning module per week, with few exceptions, including this learning module, for which a two-week period was used to complete all in-class learning activities. Two additional weeks were used to finalize the HVAC project, and the students were asked to work outside the classroom time.

To incorporate EML into the learning module activities, and to increase the students' interest in the topic, three new guest lectures were added to this learning module. The three lectures were related to entrepreneurship and innovation, especially related to heating, ventilation, and air conditioning processes (HVAC).

- <u>Guest speaker #1</u>: The first guest speaker was the Director of the University's Innovations Center. One of his roles is to prove programmatic support and other needed resources to help move faculty ideas and research outcomes from an internal university setting out into the world, and such solving big problems and meeting societal needs. The talk was entitled *Entrepreneurial Minding Thinking and Learning, and Lifelong Learning & Startup of You*. Through many personal stories from his life as an entrepreneur, the guest speaker emphasized the constant need to be curious and to always make connections, to be innovative, and to create value throughout own's career. He continued his lecture talking about Robert Kern's and EML as a new way of thinking and doing, mentioning that it is not just about improving one's skills, but it is about a mindset. The guest speaker finished his lecture talking and encouraging the students to adapt to the future by investing in themselves, by being an intrapreneur, and a lifelong learner. He advised the students to start by identifying what is needed and identifying the gaps in their workplaces. The lecture ended with a Q&A session. The multitude of questions the students asked showed their interest in the topic. The lecture was both livestreamed through the Blackboard Collaborate Ultra and recorded for later viewing.

- Guest speaker #2: The second guest speaker was the Director of Energy Management at the University of Toledo. He is managing the $14 million campus utilities consumptions and procurement, mechanical infrastructure, improvement projects, including LEED projects, provides direction for the steam plants, chilled water plants, building automation controls, and overall campus sustainability. The presentation, titled *Geothermal at the University of Toledo Fetterman Indoor Athletic*, focused on I) innovative methods to increase the University's sustainability through energy efficiency projects in wind, solar, and geothermal, and ii) a cost analysis for the Savage Hall sport arena, comparing the energy consumption from three diverse sources, electricity, steam, and fuel oil., with if using electricity vs. Purchased steam, vs. Fuel oil. The lecture ended with a campus tour to see Fetterman's geothermal plant in action. The after-class discussion with a group of students emphasis the benefits of such activities, and the strong need for students to see real-life applications instead of pictures from textbooks or YouTube videos. As before, the lecture was livestreamed through the Blackboard Collaborate Ultra and recorded for a later viewing.

- Guest speaker #3: The third guest speaker was a LEED Green Associate and Consultant Sales Engineer with a major HVAC company. His talk focused on HVAC systems, especially on innovative chiller solutions and basics, and their applications to building configurations. This talk, done by an expert in HVAC industry, brought a different flavor to the planned in-class activities, and the students had the opportunity to ask questions like what the necessary skills are to get hired and be successful in the HVAC industry. Similarly, the lecture was livestreamed and recorded on Blackboard Collaborate Ultra.

Project Description

In addition to the previously mentioned activities, part of this Learning Module was a one-month long project related to heating, ventilation, and air conditioning (HVAC) systems. The project was introduced / advertised during one of the lectures, and all the submissions were done through Blackboard. The project was not new to the curriculum, but the addition of EML components and learning outcomes was. Overall, the project required the students to complement in-class learning with i) content knowledge learned from previous courses; ii) independent research using credible sources; and iii) a proposed HVAC design. New project deliverables were related to project economics and the environmental and societal impacts of the proposed design.

The students received the following project description, listing the tasks and the due dates.

> "*The ET Department is looking to replace the current HVAC system in two of the laboratories, namely for Material Science and Thermal - Fluids Laboratories. The Department needs your help! The allocated funds are* <u>*$20,000*</u>*. Since the winter is fast approaching, the focus is heating the two labs.*
> *Your job is to design an HVAC system – heating only, and to make recommendations for installation and future maintenance.*
> *To complete the project, six project stages are necessary:*

- *(Nov.7, 2021 – 5%)* ***Stage 1****:* <u>*The Hook*</u>*: List the Stakeholder(s) Requirements; Floor Plan (to be done 2D or 3D); Research the required documentations, including ASHRE Standards applicable.*
- *(Nov. 14, 2021 – 20%)* ***Stage 2****: Using previous knowledge from Applied Thermodynamics and following the ASHRE recommendations, calculate the* <u>*Required Heating Loads*</u> *(identify the cfm necessary per room; show the calculations and draw the cycle on a psychrometric chart).*
- *(Nov. 21, 2021 – 25%)* ***Stage 3****:* <u>*Design the HVAC System*</u>*: dimension the duct system; select the appropriate fan and heater.*
- *(Nov. 28, 2021 – 15%)* ***Stage 4****:* <u>*Project Economics*</u>*: Discuss the costs associated with installation and maintenance (independent search using credible sources). If the costs are too high, make recommendations for improvement and reducing the costs to fit the budget.*
- *(Nov. 28, 2021 – 10%)* ***Stage 5****:* <u>*Environmental and Societal Impact*</u>*: Discuss the potential impact of your proposed (independent search using credible sources).*
- *(Nov 29 and Dec 01 – 25%)* ***Stage 6****:* <u>*Live Presentations*</u>*: Team presentations followed by a Q&A session, peer-to-peer evaluation and grading, self-evaluation, and members' contribution to the project survey*."

Apart from Stage 1, in which the students were asked to measure the labs' spaces, the students were given the freedom to develop and implement the project in alignment with the communicated requirements listed above. Compared to the previous project implementations, Stages 4 and 5 were new, with an assigned budget of $20,000, and with a modified Stage 1 to include the stakeholders.

Each of the first five stages was graded by the teaching faculty who provided immediate formative feedback, enabling improvements, and giving the students the opportunity to improve their previous scores. The final stage, Stage 6, was graded by both the instructor and the students attending the presentations. Their average score represented 50% of Stage 6's final score.

Assessment Instruments

Direct Assessments

The content knowledge gained through this learning module was assessed using: 1) a comprehensive test (Assignment #12, see Appendix 1) at the end of the learning module, in which the students were asked to complete the design of a given HVAC system by specifying the sizes for all duct sections so that the system is balanced when it carries the given flowrates, and 2) the HVAC project.

Regarding the HVAC project assessment, the project's scores at various stages and the final score align with the ABET (2021) Criterion 3 – Student outcomes - for engineering technology programs as follows: (1) "an ability to apply knowledge, techniques, skills and modern tools of mathematics, science, engineering, and technology to solve broadly-defined engineering problems appropriate to the discipline" – as demonstrated by the project final score; (2) "an ability to design systems, components, or processes meeting specified needs for broadly-defined engineering problems appropriate to the discipline" – as demonstrated by the score on Stages 2 and 3; (3) "an ability to apply written, oral, and graphical communication in broadly-defined technical and non-technical environments; and an ability to identify and use appropriate technical literature" – as demonstrated by the scores on Stages 1 to 6; (4) "an ability to conduct standard .... measurements, ...and to analyze and interpret the results to improve processes" – as demonstrated by the score on Stages 1, 4, and 5; (5) "an ability to function effectively as a member as well as a leader on technical teams" – as demonstrated by the final score on the project and through additional indirect assessments to be discussed.

The project's direct assessment also aligns with ABET (2021) Criterion 5 - Curriculum: Outcome (C): "Develop student competency in the discipline" – as demonstrated by the scores on each of the project's stages; Outcome (D) "Include design considerations appropriate to the discipline and degree level such as: industry and engineering standards and codes; public safety and health; and local and global impact of engineering solutions on individuals, organizations and society" – as demonstrated by the scores on stages 2 to 5; and Outcome (E) "Combine technical, professional, and general education components to prepare students for a career, further study, and lifelong professional development" – as demonstrated by the final score.

The entrepreneurial mindset learning can be also assessed throughout this project as follows i) curiosity - as demonstrated at all stages throughout the project, from searching credible sources, looking for documentations, standard and normative not discussed during the lectures, perform an investigative economic analysis to get the project under the budget, etc.; ii) connections –as demonstrated throughout the project. Previously learned content knowledge from technical drawing, Computer Aided Design, SolidWorks, economics, and thermodynamics courses was used throughout to solve and help finalize the project; iii) creating value – as demonstrated not only by the final technical solution presented by each team, but also by stages 4 and 5.
The investigative nature of this project fits perfectly with this KEEN EML framework.

Indirect Assessments

The work presented herein is a collaborative effort of two engineering faculty and one educational faculty with the final goal of improving not only the technical and soft skills, but also to instigate an entrepreneurial mindset learning in our upper-level engineering technology students. Two indirect assessments were implemented to assess this learning module.

Using a combination of prior in-house survey(s) (Cioc et al., 2020, 2021) and influenced by EML assessments developed by the Arizona State University (EM@FSE 2.0 aq Indicators, 2016) and Ohio Northern University (2020), the team developed a comprehensive 76 questions survey covering broad engineering-related skills including entrepreneurial mindset, problem solving, communication, and collaboration. The four entrepreneurial mindset sub-scales focused on the students' ability to: make connections between courses and to real-world contexts (three questions, $\alpha = .74$); create value with new and existing products (four questions, $\alpha = .83$); gather data from multiple sources to inform decisions (six questions, $\alpha = .88$); and consider the consequences of their choices (four questions, $\alpha = .87$). A fifth sub-scale – oral and written communication (seven questions, $\alpha = .79$) – was also assessed. Responses were based on a five-point rating scale: 1=strongly disagree; 2=agree; 3=neither agree nor disagree; 4=agree; 5=strongly agree. Paired two-tailed t tests were performed to assess pre-course and post-course differences.

In addition, the students were asked to evaluate all the teams' final project presentations (what they would present to the client), except their own. The students received before the class a Presentations Grading Guide & Scores file, as shown in Appendix 2. The students were asked to grade their peers' presentations in terms of supporting materials and preparedness. The final score for Stage 6 for each project's was done by taking the average of the scores given by the instructor teaching the course and the average of the students. To encourage the students' participation in this peer review process, extra credit was given for this exercise.

Results and Discussions

Direct Assessments

The technical content knowledge gained through this learning module was assessed using a comprehensive test given at the end of the learning module. An average class of 85% is considered as proficiency in the subject. During the fall 21 semester, the class average for assignment #12 which covers the flow of air through ducts was 86.3 %, stdev.= 6.1 (N=27), similar with the 87.7%, stdev.= 9.0, observed for spring 2021 (N=10), when a similar problem was given as extra credit assignment, and higher than the 76%, stdev. = 14.4, observed for fall 2020 semester (N=34).

Compared with the previous semester, two new stages were added to the final project to cover EML skill development, a limited budget was assigned, and the first stage was updated to include a list of stakeholders. The results were encouraging, and the students were incredibly detailed in their project evaluation, especially with respect to economics, and to societal impact. The class average reached a combined average score of 23.13 out of the maximum of 25 (representing 92.5%). Only one group (4 students) did not submit their work on stages 4 and 5 but that team incorporated the required information into their final presentation. Unfortunately, the class performed poorly on the two stages requiring content knowledge from previous thermodynamics course and air flow calculations, having an average class per stage 2 of only 50%, stdev. = 3.74, and 64% for stage 4, stdev. = 3.47, respectively. These scores are lower than previous implementations of the project without EML, and one of the reasons is that during fall 2021 semester, the students did not have the opportunity to improve their work based on the feedback received from the instructor and to resubmit their work as before. This was an experiment, and a continuous improvement will be added to the next project implementations. Regarding stage 6, presentation to a client, the fall 2021 cohort outperformed the previous cohorts, reaching a class average of 96% compared to 92% received by the spring 2021 cohort. One team of two students decided not to present their work, though they attended the presentation. Their reason was that they both reached the threshold for an A in the course even without earning the points for the final presentation.

Indirect Assessment

Table 1 describes the pre and post course self-reported entrepreneurial mindset of the MET 4100 students. Students reported growth in all areas of curiosity, connections, and creating value.

Growth was strongest in the areas of creating value from new and existing products (significant growth is represented through bolded characters). All post-course responses were significant in terms of suspending judgment on new ideas [$t(23) = -2.064$, $p=.050$], defining potential markets for new products [$t(24) =-3.645$, $p=.001$], defining potential markets for existing products [$t(24) = -4.262$, $p<.001$], and describing how existing products can solve new problems [$t(24) = -3.161$, $p=.004$]. Students also reported significant growth in their ability to recognize the ethical [$t(24) = -3.412$, $p=.002$], professional [$t(24) = -2.326$, $p=.029$], and social [$t(24) = -3.161$, $p=.004$] consequences of their decisions. Finally, students felt significantly more prepared to gather data from multiple sources [$t(24) = -2.598$, $p=.016$] to inform their decision making.

Table 2 describes students' pre- and post-course self-reported ability to communicate with clients. Students reported post-course growth in all dimensions of communication, especially delivering presentations. Students also reported significant growth in their ability to present to an audience [$t(24) = -2.377$, $p=.026$] and to deliver a compelling presentation to a client [$t(24) = -2.681$, $p=.013$].

Table 1
Students' Pre-Course and Post-Course Entrepreneurial Mindset

	Mean	N	Std. Dev	*t*, *p*-value
Connections: Course Work and the Real World				
make connections between classroom and outside	3.88	24	.947	-1.430, .166
	4.17	24	.761	
make connections between courses	4.08	24	.881	-1.430, .166
	4.38	24	.824	
ask probing questions to clarify facts concepts	4.08	24	1.100	-1.187, .247
	4.33	24	.702	
Creating Value: Use New and Existing Products				
suspend judgement on new ideas	4.20	25	.816	**-2.064, .050**
	4.48	25	.770	
define potential markets new & existing products	3.84	25	.987	**-3.645, .001**
	4.40	25	.816	
define potential opportunities new & existing products	3.68	25	.988	**-4.272, <.001**
	4.40	25	.707	
describe how existing products can solve new problems	4.04	25	.841	**-3.161, .004**
	4.56	25	.583	
Curiosity: Gather Data from a Variety of Credible Sources				
identify information to solve problems	4.38	24	.576	-1.661, .110
	4.63	24	.495	
gather data from multiple sources	4.50	24	.590	**-2.598, .016**
	4.79	24	.415	
gather data from multiple stakeholders	4.33	24	.702	-1.415, .170
	4.54	24	.588	
organize information from multiple sources	4.50	24	.511	-1.735, .096
	4.71	24	.550	
critically observe surroundings	4.54	24	.588	-.827, .417
	4.67	24	.565	
think outside of the box	4.46	24	.588	-1.282, .213
	4.63	24	.576	
Connections: Consequences of Decisions				
identify potential ethical issues	4.13	24	1.035	-1.163, .257
	4.29	24	.908	
recognize the ethical considerations solutions	4.04	24	.806	**-3.412, .002**
	4.50	24	.780	
recognize professional considerations solutions	4.21	24	.833	**-2.326, .029**
	4.54	24	.588	
recognize social considerations solutions	4.08	24	.929	**-2.198, .038**
	4.50	24	.590	

Table 2
Students' Pre-Course and Post-Course Communication with Clients

	Mean	N	Std. Dev	*t, p*-value
present information visual (graphs, etc.)	4.24	25	.663	-2.009, .056
	4.48	25	.653	
present information audience	3.92	25	.954	**-2.377, .026**
	4.28	25	.614	
produce effective written reports	4.16	25	.850	-1.365, .185
	4.40	25	.816	
deliver effective oral reports	3.96	25	.935	-.440, .664
	4.04	25	.790	
draft compelling proposal for client	3.70	25	.791	-1.405, .173
	3.96	25	.889	
deliver compelling presentation to client	3.96	25	.889	**-2.681, .013**
	4.40	25	.707	

Conclusion

This was an initial implementation of EML in this learning module, part of an advanced fluid mechanics course. At this stage, seniors should be considering connections beyond their academic coursework. A final project, part of this learning module, though exploratory, had mixed results, some of which are promising. Limitations related to sample size and self-report are also noted. However, the students' self-reported gains in EML were encouraging. This is especially in the areas of creating value and considering the consequences of various decisions, which shows their analysis of the consequences of implementing various solutions. This is an important extension of considering real-world factors related to content covered in their coursework. Thus, the results from this exploratory implementation add to the growing body of evidence that supports integrating EML in EE coursework and programs (e.g., Bosman et al., 2019; Liu et al., 2017; Mallory, 2015; Gibbons, 2021; Seyed, 2020) especially at the upper division where students are focused on post-graduate professional opportunities.

The direct assessment results from Assignment #12 and the final project, especially the scores the students received for stages 1, 4, 5, and 6, are in line with the EML skills improvements observed from the survey's responses, especially on questions related to ethical, professional, and social considerations, and delivering compelling presentation to a client, and presenting information to an audience. These skills are for the preparation of qualified engineers and workforce readiness (ABET, 2021; KEEN, n.d.).

Partnering with industry experts continues to be an opportunity to expand the curriculum and students' learning experiences. However, while all self-reported post-project gains were positive, there are areas in the curriculum that need additional attention, namely strengthening connections between courses, courses and the real-world, and gathering and analyzing data. Results from this project will support further curriculum modifications in these areas.

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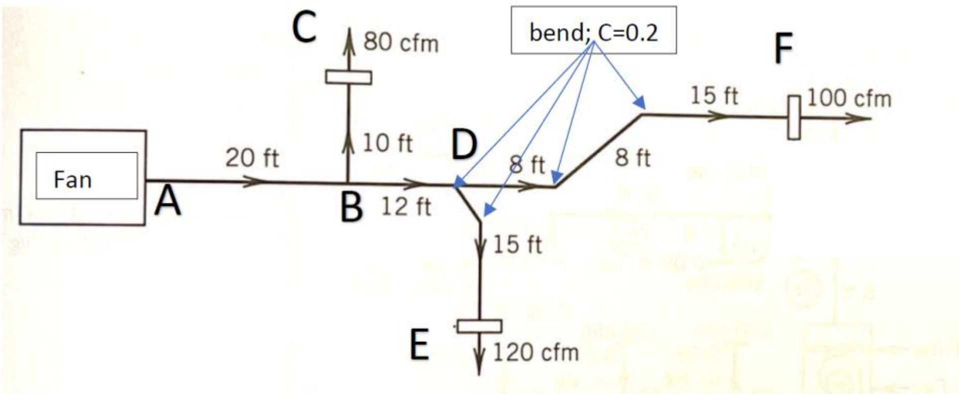
Appendix 1

Assignment # 12

Size the system below using the equal friction method and round pipe. Calculate the total pressure loss per each run and provide recommendations for equalizing the system. Each end has a 90° elbow down and a grille.



Use to attached excel file for submitting your work.

Section	AirFlow, cfm	Length, ft	Friction loss (inH20 per 100ft)	Velocity (ft/min)	Duct Diameter (in)	Energy Loss over Duct length (inH20)	Velocity Pressure (inH20)	Loss in Transition (inH20)	Loss in Elbows and / or bends (inH20)	Grille (inH20)	Size the duct system
A-B		20	0.1								
B-C	80	10	0.1								
B-D		12	0.1								
D-E	120	15	0.1								
D-F	100	31	0.1								
Path A to C											
Path A to E											
Path A to F											

Appendix 2

Presentations Grading Guide and Scores

Presentation Grading Guide.	Needs Improvement	Developmental	Proficient	Advanced
Support Materials (10 points max)	Points Range: 0 - 2 No visual aids used.	Points Range: 3 - 5 Visual aid is used but detracts from the presentation.	Points Range: 6 - 8 Visual aid adds to the presentation.	Points Range: 9 - 10 Visual aid shows considerable work and creativity and adds to the presentation.
Preparedness: Volume / Clarity & Professional Demeanor (15 points max)	Points Range: 0 - 3 Presenter does not seem at all prepared and lacks confidence. Reads directly from presentation or notes. Volume often to soft to be heard by all audience members. Lacks confidence.	Points Range: 4 - 7 Presenter is somewhat prepared, but it is clear that rehearsal was lacking. Reads directly from presentation or notes most of the time. Speaks clearly and distinctly most of the time, but lacks confidence.	Points Range: 8 - 11 Presenter seems pretty prepared, but could have used a couple more rehearsals. Reads directly from presentation or notes some of the time. Speaks clearly and distinctly. Confident; adjust to audience response	Points Range: 12 - 15 Presenter is completely prepared and has obviously rehearsed their presentation. Confident; adjust to audience response. Does not read directly from presentation or notes. Speaks clearly and distinctly.

Scores for Presentations:

Team #	Support Materials	Preparedness	Total
Group 1			
Group 2			
Group 3			
Group 4			
Group 5			

Appendix 3: Samples of Student Work for Project Stages 4 and 5

Stage 4				
Item	**Qty**	**Cost Per**	**Total Cost**	**Reference**
Stright Duct Work (ft)	200	$ 10.00	$ 2,000.00	https://www.fixr.com/costs/d
90 degree Elbow	13	$ 33.00	$ 429.00	https://www.ferguson.com/ca
Cross-Intersection	4	$ 75.00	$ 300.00	https://www.grainger.com/se
Tee	2	$ 60.00	$ 120.00	https://www.ferguson.com/ca
Damper	8	$ 131.00	$ 1,048.00	https://www.grainger.com/se dampers?tv_optin=true&searc
Grille	12	$ 4.30	$ 51.60	https://www.grainger.com/ca
Fan	1	$ 542.43	$ 542.43	Canarm IDBX12 Forward Curve
Heater	1	$ 1,213.00	$ 1,213.00	Goodman 120,000 BTU 80% A
Installation	1	$ 4,000.00	$ 4,000.00	https://homeguide.com/costs
System Total Cost:			$ 9,704.03	Total Sum
Budget:			$ 20,000.00	Given in Assignment

Maintenance costs would be routine tune-ups and occasional filter replacements. With the mater
money could be used to help further make the l

With a new and more efficient HVAC system in place, there should be energy savings with gas and electricity. Not only is this environmentally friendly as it is helping save a natural resource (gas) but will also save the university financially with cost savings as a result of the energy savings. The university would gain several societal advantages by replacing the HVAC system. They would be employing a local business to do the installation. This is a PR positive as many local businesses are struggling to bounce back since the pandemic arrived last March, so employing a local business would be in a way giving back to the community. They would also be able to continue advertising their "green initiative", by being more environmentally friendly with reduced energy use.

Environmental and Societal Impact: When working with a rooftop unit and the systems running off of them, many factors need to be considered during the design phase. Customer needs, state / city requirements, cost, and environmental impact.
For our design of this HVAC system, our 2 main key points that are going to affect the environmental and societal impact will be the Bryant Unit we selected based on its efficiency and the economizer we have chosen to place on the unit. With a brand-new Bryant 6-ton unit, Bryant tells us that based on the average age of the units replaced by this model, our customer (The University of Toledo) could see much better energy efficiency, specifically an electrical efficiency of 22%.
Not only will the school be spending less on electricity because of the unit itself, motors, fans, squirrel cages, etc., we have also opted to save the school money by installing an economizer.

With pairing this economizer with the unit, the thermostat control will consider the outside air temperature and when possible, use outside air rather than creating its own cold or warm air. In Toledo, while these are highly recommended, they are not required. The alternative is a regular fan and motor, which does the same job, but is much less efficient.

Project Economic: The linear length of the ductwork is about 79 feet per room. So total feet per room will come out to around 158 feet total of duct work. We figured that the most efficient material to use would be flexible aluminum. The duct work cost for material, basic labor cost and the installation supplies comes out to about $12.25 per linear foot which comes out to a total cost of $1,931.42 for ductwork. With each room needing around 1000 cfm per minute. Specifically, 1134 cfm for room 1410 and 1062 cfm for room 1430. We had to select the appropriate fan and heater to support this. The heater needed was a total of $2,549 and the fan needed was a total of $1,095. The total labor and installation cost for the fan and heater comes out to about $3,000. From our calculations we found we had to add 2 dampers to each room for 2 diffusers. The cost of these dampers came out to be $179 each so for a total of $716 with an approximate $300 extra dollars for installation for a sum of $1,016. The total cost of the entire system for both labs comes out to be approximately $9,592.