2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #36818

Combining Project-Based Learning with the KEEN Framework in an Advanced Fluid Mechanics Course: A Continued Implementation

Dr. Carmen Cioc, The University of Toledo

Dr. Carmen Cioc is Associate Professor in the Engineering Technology Department, College of Engineering, at the University of Toledo. She received her Master in Aerospace Engineering from The University Politehnica of Bucharest, her Master in Physics - P

Dr. Sorin Cioc

Dr. Sorin Cioc is a clinical associate professor and undergraduate program director in the Department of Mechanical, Industrial, and Manufacturing Engineering (MIME).

Dr. Noela A. Haughton, The University of Toledo

Dr. Noela A. Haughton is an associate professor of Education (Research and Measurement program) in the Judith Herb College of Education at the University of Toledo. She teaches courses in assessment and research methods.

Combining Project Based Learning with the KEEN Framework in an Advanced Fluid Mechanics Course: A Continued Implementation

Abstract

This paper describes a one-year implementation and the results of a Project Based Learning (PBL) pedagogy combined with KEEN Entrepreneurial Mindset (EML) Framework in a core senior level course part of the Mechanical Engineering Technology (MET) program. The work is a close collaboration between engineering and education faculty, and in alignment with all the five Student Learning Outcomes (SLOs) for ABET Criteria for Engineering Technology Programs.

The course selected for this PBL - EML implementation is Applied Fluid Mechanics, a four-credit course with a lab component. It is the second in the fluid mechanics sequence and covers topics like pipeline systems, pump selection, and flow of air in ducts.

During the spring and fall 2022 terms, the authors studied the role of the previously introduced PBL & EML exercises covering the fluid flow through pipeline systems and the flow of air in ducts. For example, one exercise asked the students to design a pump storage hydropower system able to satisfy a list of specific design requirements, including selecting a feasible pump and estimating the costs associated with implementing the proposed design. Another exercise asked the students to design an HVAC system able to provide heating / cooling for the two MET laboratories. In all instances, the students were asked to analyze the economical and societal impact of their designs based on the selection of three materials for their pipeline systems. Students were also asked to complete pre- and post-assignment surveys related to their EML. They also peer-reviewed components of all submitted projects except their own.

Assessment results and available student responses are positive and support the continued use of these PBL EML exercises to develop a better understanding of the technical content, societal and economic impact of the proposed solution, while supporting the students' preparedness and readiness for the workforce.

Introduction

There are numerous recent scholarly works examined the way in which the Kern Entrepreneurial Engineering Network (KEEN)'s mindset is enhancing the students' engagement and skills in various engineering courses, like Material Science [1], or Mechanical Design or Structural Analysis [2, 3, 4], or Fluid Mechanics [5, 6, 7, 8] or across engineering curriculum [9, 10, 11, 12, 13].

In all instances, the authors found that the inclusion of an entrepreneurship education, as promoted by KEEN, and further support the engineering students' readiness for the engineering profession [14, 15] and aligns with ABET criteria and student learning outcomes [11, 16, 17, 18]. EML inclusion in courses and across the curriculum is in support of preparing qualified engineers ready to produce and contribute to a global workforce. Therefore, both the KEEN's mission and the ABET goals provide a useful framework for considering, designing, implementing, and evaluating innovative engineering curricula and pedagogical best practices.

Research Methods and Procedures

This paper, a continuation of a previous work [6], describes the most recent implementations (spring and fall 2022) and evaluation of EML activities added to an advanced fluid mechanics course. The pedagogical practices discussed herein focus on solving a couple of real-world problems by integrating the KEEN's 3Cs: i) curiosity to identify viable sources of information, including standards and codes; ii) making connections between discussed topics and real-life applications, or between discussed topics and topics learned in other courses; iii) creating value by developing excel file to act as computer simulators for similar problems with different input data.

Study Site: The site for yearlong EML integration study is the Mechanical Engineering Technology program, part of the Engineering Technology Department (ET) in the College of Engineering (COE) at the University of Toledo. The MET program is one of the five ABET-accredited Bachelor of Science (BS) in engineering technology programs. Historically, the student body is comprised of relatively equal parts of traditional students, transfer students, and non-traditional students, all bringing a variety of engineering skills and lifelong learning experiences to the MET program.

The Course: The Applied Fluid Mechanics course (MET 4100) is an upper division core course in the MET program and the second in the sequence on the topic of fluid mechanics. It is a 4-credit hour (ch) course, consisting of a 3ch lecture and a 1ch laboratory, offered in person, on campus. To increase the accessibility to the lectures for the students not able to attend some of the lectures in person, either due to COVID or work-related issues, the authors developed the course closer to a blended experience than a traditional course, using the Blackboard platform to post lectures, course materials, instructional aids, and facilitate assignment submissions. During the spring and fall 2022 semesters, 21 and 22 students were enrolled.

The course focuses on applications fluid dynamics, including series and branching pipeline systems, pump selection and flow measurement, drag and lift, and the flow of air through duct systems. Laboratory exercises consist of either hands-on experience in the Fluid Mechanics Laboratory, or computer simulations using the Tahoe Design's HydroFlo Academic software; all simulations can be performed in the ET Department's computer labs or remotely using Virtual Lab (VLab).

To increase the students' interest in the topics and their ability to make connections with real-world applications, three guest speakers were invited. All three were able to participate during the spring 2022 semester, while only one could attend during fall 2022 semester. Their talks were related to entrepreneurship and innovation, ethics, HVAC systems, and economics of heating and cooling.

Examples of Problem-Based and Project-Based Learning Exercises with EML component(s)

<u>Pump Storage Hydropower (Project #1)</u>
The students were asked to design and select a pump, part of a hydropower storage system, able to meet some specific parameters, such as flow rate, elevation differential between the two reservoirs, and configuration, including suction and discharge pipeline, number of fittings, type of valves, etc. [6]. They were asked to either work alone or as part of a group to create either an Excel file able to function as simulator or a HydroFlo simulation; two weeks were assigned for this exercise. The output of the Excel file should provide pressure values at various locations along the pipeline, required pump power, estimated power generated by the turbine (new addition compared to the previous year), and others (see Appendix 1). In addition, the students were asked to evaluate the cost of the proposed design, and to discuss the societal impact of their proposed solution. This exercise included a peer evaluation component, and once all the files were collected and posted anonymously on Blackboard by the instructor, the students were asked to evaluate and grade all projects, except their own, and to provide at least three ways for improvement for each project. To support the students in their evaluation, a grading sheet was provided by the teaching faculty. Peer evaluations were considered as part of the final grade for this exercise.

<u>Series Pipeline Systems (Laboratory Exercise)</u>
This exercise was done during a session of laboratory, in the computer room, and using HydroFlo software. The students were asked to solve an assigned series pipeline problem and to investigate two additional scenarios, by changing the pipeline material from Steel Schedule 40 to copper and PVC, while all other parameters are kept constant. The three scenarios were compared from an economical and societal impact and best option selected (see Appendix 2).

<u>HVAC Design (Project #2)</u>
This one-month long project was part of the Flow of Air through Ducts topic and, as the title indicates, it is related to designing a heating, ventilation, and air conditioning (HVAC) system. The project was introduced during the first HVAC related lecture and asked the students to design a system providing air to the two MET laboratories on campus for a given budget. Depending on the semester in which the project was assigned, the students were asked to focus only on cooling, for the spring assignment, or heating, for the fall assignment, respectively. No additional info about the project was given to the students other than access to the two laboratories for room measurements. To successfully complete this project, the students needed to:

- List the stakeholder(s); draw a floor plan using CAD (Computer Aided Design); and research on their own the required documentation, including ASHRAE standards.

- Calculate the required cooling / or heating loads using previous learned knowledge from a thermodynamics course; this included the cfm per room, and the representation of the cycle on the psychrometric chart.
- Dimension the duct system based on the cfm and room dimensions and select the appropriate cooling or heating unit.
- Discuss the costs associated with installation and maintenance, by independent search using credible sources, and provide recommendations for savings to fit the budget.
- Discuss the societal impact of installing the new system, and
- Present to the class the final solution, including all the design steps. Team presentations were followed by a Q&A session, peer-to-peer evaluation, and grading, as well as a self-evaluation and members' contribution to the project survey.

Assessment Instruments

Direct Assessments: The scores the students received from their peers on all above-mentioned PBLs constitute direct assessments. The investigative nature of these problems and projects fit perfectly with this KEEN's framework. All exercises require the students i) to be curious about the given subject and to investigate it on their own by finding credible sources of information, ii) to make connections between the topics learned during the course and real-life examples, or with topics from other classes, and iii) to create value, by developing simulation tools either in excel or HydroFlo.

Indirect Assessments: Two indirect assessments were implemented to assess the efficacity of the course and the blending of EML into the course. First, a 75-question professional engineering knowledge and skills survey [5, 6] distributed at the beginning and the end of the semester; second, the end of semester university wide and college course evaluations.

The survey incorporated ideas from existing in-house surveys and asked the students to self-assess their professional engineering professional skills, including entrepreneurial mindset, problem solving, communication and collaboration. The EML sub-scales were influenced by similar assessments developed by [18, 19].

Three entrepreneurial mindset sub-scales focused on the students' ability to: make connections between courses and to real-world contexts [three questions (pre $\alpha = .67$ and post $\alpha = .77$); create value with new and existing products [four questions, (pre $\alpha = .79$ and post $\alpha = .71$)]; and consider the consequences of their choices [four questions (pre $\alpha = .86$ and post $\alpha = .83$)]. Two additional sub-scales related to collaboration skills also informed student learning outcomes: interpersonal collaboration [seven questions (pre $\alpha = .84$ and post $\alpha = .83$)]; and the use of ideas and feedback [five questions (pre $\alpha = .78$ and post $\alpha =.84$)]. 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.

The end of course university-driven evaluations included 13 questions plus an additional three engineering college-level questions. The first ten of the thirteen university-level questions focused on the students' effort, performance expectation, motivation, support of learning needs, comfort with expressing own views, receipt of timely feedback, quality of feedback, fairness of grading, quality of the learning experiences, as well as the instructor's engagement with students, the last three are short answers and ask the students to "describe activities or assignments that were most beneficial to your learning", to "suggest way(s) in which the course could be improved, (if any)", and to "briefly describe what you thought was the most important thing you learned". Responses to these questions were based on a 4-point rating scale: 1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree. The college-level statements focused on instructor effectiveness, clear presentation of subject matter, and overall course quality. Responses were based on a 5-point rating scale: from 1=strongly disagree to 5=strongly agree. The university gave summary results from both surveys at the beginning of the next semester.

Results and Discussions

Direct Assessments: The class scores for the three assignments listed above, as shown in Table 1, showed proficiency (class average above 75%) in all the subjects except for Series Pipeline during spring 22, when the class average was borderline at 73.8. Noted here is that the students' performance significantly improved from spring semester to fall on all the assessments, with the larger increase observed for the HydroFlo assessment (78% to 94.8%). This was mainly because the instructor teaching the course spent additional lab time to introduce the HydroFlo software by step-by-step instructions and to provide additional support for learning during the introduction of each assessment. Scores are proof of the students mastering a new software and becoming more familiar with solving real-life scenarios. This would not be possible without the students' ability to be curious and to connect their knowledge with real life examples.

Table 1. *Class Performance on Assessments*

		Class Average	Stdev.
Pump Storage	Spring 2022	75.05	22.03
	Fall 2022	81.71	12.13
Series Pipeline HydroFlo	Spring 2022	73.8	11.64
	Fall 2022	94.8	2.81
HVAC	Spring 2022	85.37	16.02
	Fall 2022	88.61	7.87

Indirect Assessments:

<u>Survey</u>: Responses from the spring 2022 and the fall 2022 MET 4100 cohorts were combined, yielding 24 students who completed both pre- and post-course surveys, representing a response rate of 55%. A chi-square test of independence was performed to examine the relationship between cohort and pre-course self-reported EML and collaboration abilities, while paired *t*-tests examined pre-to-post-self-reported changes in EML and collaboration abilities. Results are shown in Tables 2 and 3.

Table 2. *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**	**.850**	**-2.849, .009**
	4.42	**24**	**1.018**	
make connections between courses	3.96	24	.751	-1.479, .153
	4.38	24	1.013	
ask probing questions to clarify facts concepts	**3.63**	**24**	**.647**	**-3.498, .002**
	4.46	**24**	**.833**	
Creating Value: Use New and Existing Products				
suspend judgement on new ideas	4.17	24	.482	-1.282, .213
	4.33	24	.482	
define potential markets new & existing products	3.79	24	.884	-1.574, .129
	4.08	24	.881	
define potential opportunities new & existing products	**3.63**	**24**	**.711**	**-3.817, <.001**
	3.08	**24**	**.717**	
describe how existing products can solve new problems	3.92	24	.776	-1.556, .133
	4.25	24	.676	
Connections: Consequences of Decisions				
identify potential ethical issues	**3.79**	**24**	**.884**	**-2.933, .007**
	4.38	**24**	**.711**	
recognize the ethical considerations solutions	**3.67**	**24**	**.761**	**-3.762, .001**
	4.33	**24**	**.816**	
recognize professional considerations solutions	4.13	24	.612	-1.781, .088
	4.46	24	.721	
recognize social considerations solutions	**3.88**	**24**	**.680**	**-2.716, .012**
	4.42	**24**	**.776**	

Students on average reported growth in all EML areas. In the area of making connections between the classroom and the real world, their growth was strongest and significant in their ability to ask probing questions to clarify facts and concepts [$t(23) = -3.489$, p=.002 and making connections between course work and the real world [$t(23) = -2.849$, p=.009]. In the area of creating value with new and existing products, growth in recognizing ethical considerations was strongest and significant [*t(*23) = -3.817, *p*<.001]. Growth in considering the consequences of decisions was also significant in the areas of recognizing ethical considerations [*t(*23) = -3.762, *p*<.001], identifying potential ethical issues [*t(*23) = -2.933, *p*=.007], and recognizing social considerations[*t(*23) = -2.716, *p*=.012].

Table 3. *Students' Pre-course and Post-course Communication and Collaboration*

	Mean	N	Std. Dev	*t*, *p*-value
Interpersonal Collaboration				
manage formal communication	4.17	24	.637	-1.772, .090
	4.46	24	.833	
display empathy – peers' ideas and solutions	4.33	24	.761	-2.070, .050
	4.63	24	.576	
use positive communication tone	4.17	24	.702	-1.556, .133
	4.50	24	.722	
recognize peers' strengths: knowledge	**3.96**	**24**	**.624**	**-4.033, <.001**
	4.50	**24**	**.511**	
recognize peers' strengths: communication skills	**4.08**	**24**	**.584**	**-4.033, <.001**
	4.63	**24**	**.495**	
recognize peers' strengths: collaboration skills	**4.00**	**24**	**.590**	**-2.326, .029**
	4.33	**24**	**.637**	
recognize peers' strengths: problem solving	**3.96**	**24**	**.624**	**-2.632, .015**
	4.38	**24**	**.576**	
Use of Ideas and Feedback				
accept critical feedback from peers	**4.28**	**24**	**.464**	**-2.290, .032**
	4.58	**24**	**.504**	
evaluate ideas of peers	4.42	24	.504	-1.310, .203
	4.63	24	.647	
accept critical feedback from instructors	**4.13**	**24**	**.537**	**-4.897, <.001**
	4.71	**24**	**.464**	
integrate feedback from peers	**4.29**	**24**	**.550**	**-2.840, .009**
	4.67	**24**	**.482**	
take ownership of problems	**4.25**	**24**	**.676**	
	4.79	**24**	**.509**	**-3.406, .002**

Students on average reported growth in all areas of interpersonal collaboration and the use of ideas and feedback. In the area of interpersonal collaboration, growth was strongest and significant in the areas of recognizing peers' strength in terms of their knowledge [*t(*23) = -4.033, *p*<.001], communication skills [*t(*23) = -4.033, *p*<.001], collaboration skills [*t(*23) = -2.326, *p*=.029], and problem-solving abilities [*t(*23) = -2.632, *p*=.015]. Finally, regarding the use of ideas and feedback, growth was strongest and significant in the areas of accepting critical feedback from instructor [$t(23) = -4.897$, $p<.001$], taking ownership of problems [$t(23) = -3.406$, $p=.002$], integrating feedback from peers [$t(23) = -2.840$, $p=.009$], and accepting critical feedback from peers [$t(23) = -2.290$, $p=.032$].

A chi-square test of independence was performed to examine the relationship between cohort and post-course self-reported EML and collaboration abilities. The relationship between all but one variable was non-significant, indicating students from each cohort reported similar post-course EML and collaboration abilities. The exception was their ability to understand potential ethical issues. Fall students (n=15) were significantly more likely to agree (60%) versus the spring students (n=12) who strongly agreed (75%), $\chi 2(1, N=27) = 8.125$, $p = .004$. The cohort averages on this question were M=4.00(.625) and M=4.75(.452) for fall and spring, respectively, $t(25) = -3.371$, $p=.002$. The course was similar in all respects except for the number of guest speakers. The spring cohort had three guest speakers, two of whom included the importance of entrepreneurial considerations in workplaces, including ethics. The fall cohort had only one speaker who discussed the economics of heating and cooling systems in general. Hence the spring students benefited from discussions that were more contextualized in real-world situations.

<u>End of course university- and college - driven evaluations:</u> Only seven students (five in spring and two in fall) completed the university and the college end of course evaluations. This represented a response rate of 24% and 9%, respectively. The course evaluations, as seen from Table 4, and the comments posted by the responders under the end of semester's course evaluations were in general positive, and the students listed under activities most beneficial to them: "Project based learning;" "... and group work were the most helpful because they allowed me to test what had been taught in class and collaborate with my peers;" "In class examples."

When the students were asked to suggest ways to improve, one student, part of the spring 2022 cohort, complained about the fact that the HVAC project had a Thermodynamics component but provided two topics for future projects "make the project designing an oil pipeline cross state. Or maybe a sewer system with multiple pump substations," while a student, part of the fall 2022 cohort complained about the time required to search the ASHRAE docs "All of the HVAC review and ASHRE documentation was a waste of time. A third comment, from the spring 2022 cohort, was about the group work, "MUCH less group work, My group was a nightmare to try to get any help from or communication, and I was stuck with them all semester. I usually have absolutely no problem working in a group and understand the value of teamwork, but this group was awful." While some students positively evaluated the group work, this was the only negative comment ever received about group work and supports the authors' effort to provide a platform for collaboration and empowering leadership roles.

The last question, related to the most important thing learned, received positive feedback from both cohorts; the responses from the spring 22 cohort list "Pump selection;" "everything before the final project"; "Losses major and minor", while the responses from fall 2022 emphasize the

"How to solve an HVAC system ....", and "pipeline systems or hvac". From the comments discussed before, the authors concluded that the PBL exercises were, in general, positively received, and the students appreciated such real-life exercises, though sometimes they complained about the amount of work and group collaboration.

Table 4. *End of Semester Course Evaluation Survey*

University-level Statements (1=strongly disagree to 4=strongly agree)	Spring 2022 respondents (n=5)	Fall 2022 respondents (n=2)
I put forth my best effort in this course	3.40	4.00
Expectations for performance were clearly communicated throughout the semester	3.60	3.50
The teaching strategies used to motivate me do my best work	2.80	3.50
The teaching approaches used supported my learning needs	3.00	3.50
The course provided a comfortable environment for expressing views and ideas	3.20	3.50
I received feedback on my work within a reasonable timeframe	3.60	4.00
The quality of the feedback on my work helped my learning	3.40	3.50
The grading in the course fairly reflected the quality of my work	3.20	3.50
Overall, I had a good learning experience on this course	3.00	3.50
The instructor worked to make the course engaging for all students	3.40	3.50
College of Engineering Specific Statements (1=strongly disagree to 5=strongly agree)		
For overall quality, the instructor is an effective instructor	4.33	4.50
I learned a great deal about the subject matter presented in this class	4.33	4.50
The overall quality of this course was excellent	4.33	4.50

Conclusion

Integrating PBL with EML in several activities and assignments was successful. The students enrolled in the course, most of whom were graduating seniors, accepted, and learned from the PBL–EML content, as shown in their performance on the direct assessments and responses on the indirect assessments. Limitations related to self-report and the low-rate student participation in the end of course evaluations were noted. Guest speaker participation, though important, was subject to availability and might be outside the control of the instructor.

Despite the limitations, the direct and indirect assessment results provide support for the continued focus on EML integration and aligns with previous findings [3, 14, 20, 21]. The available student responses were mostly positive and reflected their positive view of the PBL activities and assignments. The professional engineering skills that were the focus on this course are critical to the preparation of qualified engineers and global workforce readiness.

References:

[1] Shen, H., & Gargac, J. (2022, August), *Enhancing Student Engagement in Engineering Materials Science using KEEN Mindset in Laboratory Activities* Paper presented at 2022 ASEE Annual Conference & Exposition, Minneapolis, MN. https://peer.asee.org/40543

[2] Reissman, T., & Vijayan, V., & Fang, S., & Reissman, M., & Miller, S. (2022, August), *Impact of Scaffolding 'Making' Assignments within Mechatronics on the Three Student Learning Outcomes of KEEN's Entrepreneurial Mindset: Curiosity, Connections, and Creating Value* Paper presented at 2022 ASEE Annual Conference & Exposition, Minneapolis, MN. https://peer.asee.org/40850

[3] Ardakani, S. M.S (2022, August), *Jeopardy in Structural Analysis* Paper presented at 2022 ASEE Annual Conference & Exposition, Minneapolis, MN. https://peer.asee.org/40892

[4] Zhu, H. (2021, July), *Fostering Entrepreneurial Mindset through a Hands-on Design Project in a Mechanism Design Course* Paper presented at 2021 ASEE Virtual Annual Conference Content Access, Virtual Conference. https://peer.asee.org/37201

[5] Cioc, C., Haughton, N., Napp, J., & Cioc. S. (2020). *Incorporating Information Literacy in MET Design Project: Pilot Implementation*. Conference Proceedings. ASEE's Virtual Conference. June 22-26. Paper ID #29596.

[6] Cioc, C., Haughton, N., & Cioc, S. (2022). *Combining PBL with KEEN's Framework for Entrepreneurially Minded learning in a Fluid Mechanics Course: Pilot Implementation*. Paper presented at 2022 ASEE Annual Conference & Exposition, Minneapolis, MN. Paper ID #35039.

[7] Liu, L., & Mynderse, J. A., & Fletcher, R. W., & Gerhart, A. L. (2017, June), *Embedding Fluid Power into Fluid Mechanics and Thermodynamics Courses through Problem-Based Learning and Entrepreneurially Minded Learning Modules* Paper presented at 2017 ASEE Annual Conference & Exposition, Columbus, Ohio. 10.18260/1-2—28215

[8] Mynderse, J. A., & Gerhart, A. L., & Liu, L., & Arslan, S. (2015, June), *Multi-course Problem-based Learning Module Spanning Across the Junior and Senior Mechanical Engineering Curriculum: Mechatronics, Fluid Mechanic, and Heat Transfer* Paper presented at 2015 ASEE Annual Conference & Exposition, Seattle, Washington. 10.18260/p.24511

[9] Jayaram, S., & Swartwout, M. A. (2015, June), *Systems Engineering Entrepreneurship Modules Across Aerospace Engineering Curriculum* Paper presented at 2015 ASEE Annual Conference & Exposition, Seattle, Washington. 10.18260/p.24791

[10] Khan, F., & Singh, K. V. (2014, June), *Embedded Learning Modules for the Mechanical Engineering Curriculum* Paper presented at 2014 ASEE Annual Conference & Exposition, Indianapolis, Indiana. 10.18260/1-2--20362

[11] Petersen, O. G., & Jordan, W. M., & Radharamanan, R. (2012, June), *Proposed KEEN Initiative Framework for Entrepreneurial Mindedness in Engineering Education* Paper presented at 2012 ASEE Annual Conference & Exposition, San Antonio, Texas. 10.18260/1-2--21846

[12] Williams, J. M., & Kline, W. A. (2020, June), *KEEN Engineering Skill Set and Competition Teams Success: Creating Value Through the Co-curriculum* Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual Online. 10.18260/1-2—34891

[13] Woolard, C., & Kirkland, C., & Plymesser, K., & Phillips, A., & Gallagher, S., & Miley, M., & Intemann, K., & Lauchnor, E., & Schell, W. (2022, August), *Developing an Integrated Environmental Engineering Curriculum* Paper presented at 2022 ASEE Annual Conference & Exposition, Minneapolis, MN. https://peer.asee.org/40808

[14] Gerhart, A. L., & Melton, D. E. (2016, June), *Entrepreneurially Minded Learning: Incorporating Stakeholders, Discovery, Opportunity Identification, and Value Creation into Problem-Based Learning Modules with Examples and Assessment Specific to Fluid Mechanics* Paper presented at 2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana. 10.18260/p.26724

[15] Thompson, S., & Cheville, A., & Forsyth, J. (2022, August), *Addressing Convergent Problems with Entrepreneurially-Minded Learning* Paper presented at 2022 ASEE Annual Conference & Exposition, Minneapolis, MN. https://peer.asee.org/41579

[16] ABET (2022) retrieved on January 18 from https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2022-2023/

[17] Duval-Couetil, N., & Kisenwether, E. C., & Tranquillo, J., & Wheadon, J. D. (2014, June), *Catalyzing the Adoption of Entrepreneurship Education in Engineering by Aligning Outcomes with ABET* Paper presented at 2014 ASEE Annual Conference & Exposition, Indianapolis, Indiana. 10.18260/1-2—20156

[18] Estell, J. K. (2020, June), *"EMbedding" the KEEN Framework: An Assessment Plan for Measuring ABET Student Outcomes and Entrepreneurial Mindset* Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line . 10.18260/1-2—33968

[19] Arizona State University Kern Project (2016, May). Available: https://engineeringunleashed.com/media/download?secureId=0HSuoS9%2F9sA%3D [Last accessed April 12, 2023]

[20] Barron, B.J.S., Schwartz, D.L., Vye, N. J., Moore, A., Petrosino, A., Zech, L., & Bransford. J.D. (1998). Doing with understanding: Lessons from research on problem and project-based learning. Journal of the Learning Sciences, 7(3-4), 271-311.

[21] Bosman, L., McDonald, W., & Paterson, K., (2019). A collaborative multi-faculty approach to increase engineering competency through on-line discussions, *World Transactions on Engineering and Technology Education*, 17(2)

Appendix 1.

Pump Storage Hydropower

Group Project

Objective:

The objective of this project is to design a pump storage hydropower system able to meet the client's location (California desert) and proposed design as shown in figures 1, 2, and 3, and to identify the required pump power and the expected turbine generated power.

Pump Storage Hydropower:

Pumped storage hydropower is a type of hydroelectric energy storage, consisting of two water reservoirs at different elevations that can generate power as water moves down from one to the other, passing through a turbine. The system also requires power as it pumps water back into the upper reservoir. The two reservoirs act similarly to a giant battery, storing power and then release it when needed.

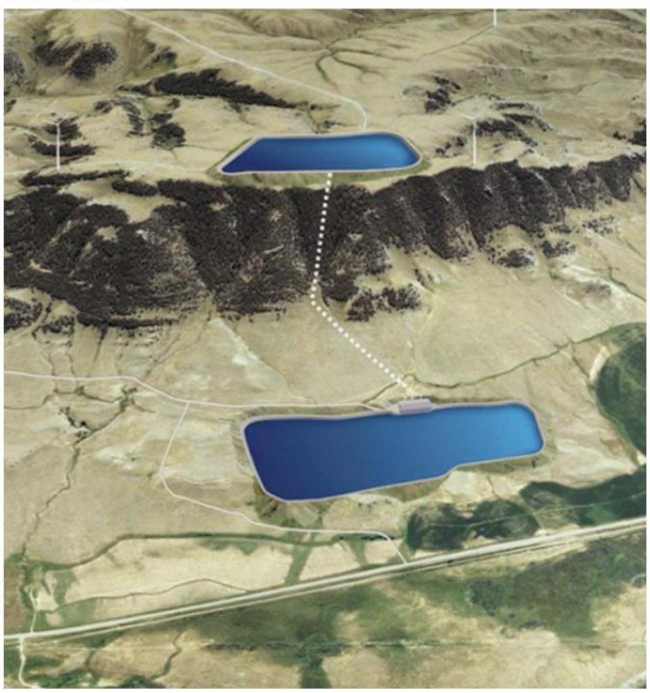


Figure 1: Aerial photo of the proposed location[(1)]

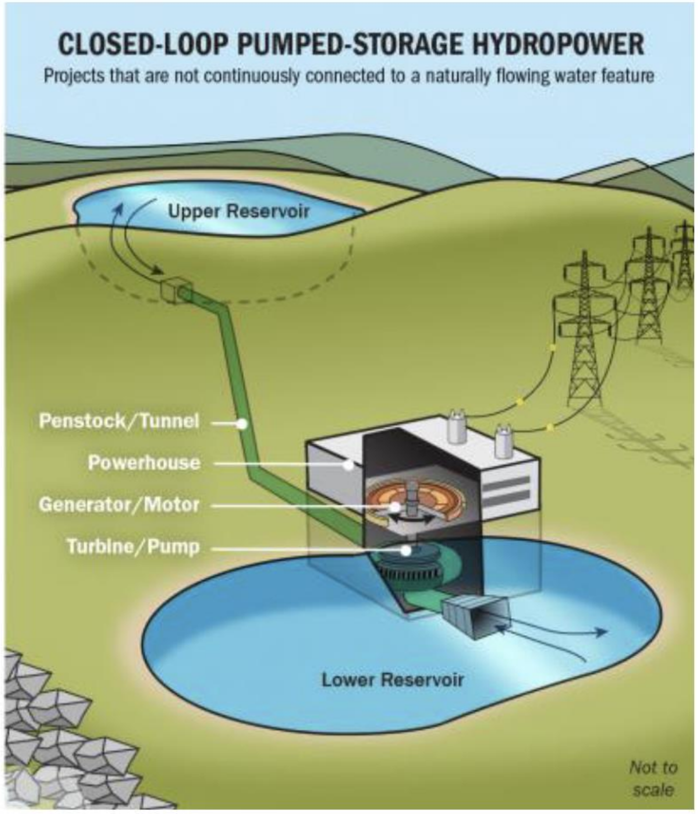


Figure 2: Closed-Loop Pumped Storage Hydropower(2)

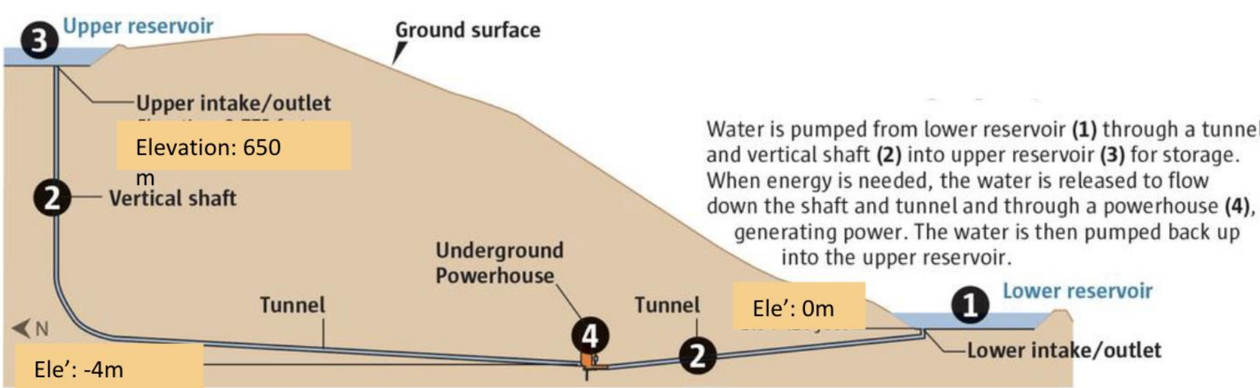


Figure 3: Proposed Design(3)

The following data is provided for the completion of this project:

- The pumping of water from the lower to the upper reservoir is done when outside average temperature is 30°C.
- The flow rate is calculated as $0.25m^3/s$
- The suction pump line is made of DN500 PVC schedule 40 pressure pipe, totaling 250m (take a roughness of $1.524x10^{-6}m$)
- The discharge pump line is made of DN400 PVC schedule 40 pressure pipe, totaling 850m.
- The suction line requires 5 standard 90°elbows.
- The discharge line requires 10 standard 90°elbows.
- The system requires a globe valve in the suction line, and a check valve - ball type in the discharge line.
- Inward projected pipes are considered at the connection with each reservoir.

Results and Discussions:

1. Create an excel file to work as a **fluid flow simulator** (meaning, that if one changes any of the given / input values, the final results update instantaneously), and calculate:
    a) Pressure at the pump inlet, in kPa;
    b) Pressure at the pump outlet, in kPa.
    c) Total head of the pump, in m;
    d) Required pump input power, in hp, for an average pump efficiency of 90%.
    e) Turbine head, in m;
    f) Estimated generated power (MW) by a combined turbine - generator system with an overall efficiency of 70%
2. Estimate the cost associated with this design. Provide solutions for improvements.
3. Discuss the societal impact of your proposed solution.

Notes:

- Keep your fluid flow simulator for future assignments. Submit **one excel file per team**
- Once I collect all your solutions, I will post them on BB (nameless), and you will be asked to peer review / evaluate the competitive solutions presented by all the other teams, by **detailing the pros and cons of the presented work**. At that time, I will also post a grading sheet on BB. **This peer review component will be also included in this assignment grade and should be done by each group**. You will have an additional week to finalize the peer review.

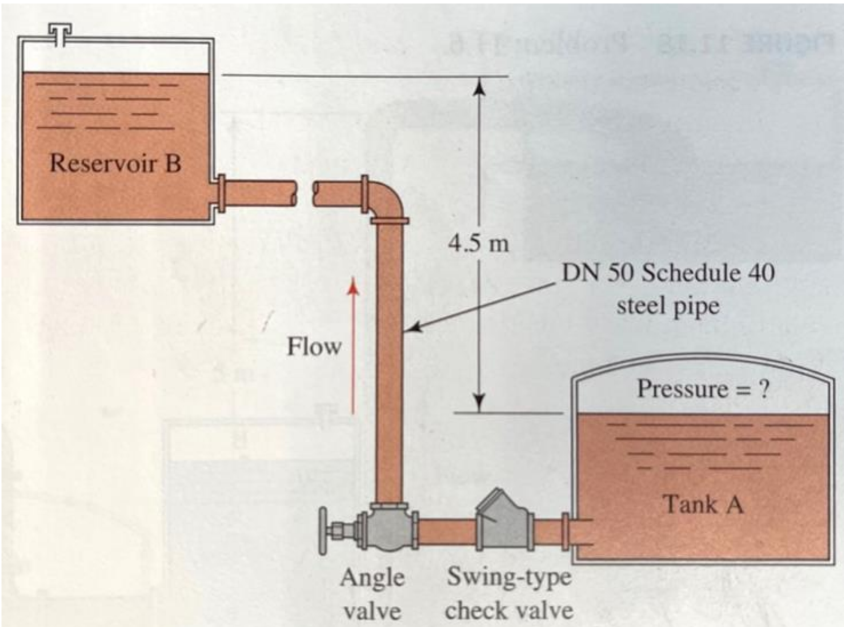
References:

1) https://www.greentechmedia.com/articles/read/montana-developer-ready-to-build-first-us-pumped-hydro-storage-in-years
2) https://www.energy.gov/eere/water/pumped-storage-hydropower
3) https://www.seattletimes.com/opinion/pumped-storage-hydropower-can-help-washington-meet-its-100-clean-energy-goal/

Appendix 2.

Using HydroFlo to Investigate Series Pipeline Systems

Ethenyl Benzene at 20ºC is to be forced from tank A to reservoir B by increasing the pressure in sealed tank A above the benzene. The total length of the DN50 Schedule 40 steel pipe is 38m. The elbow is standard. Calculate the required pressure in tank A to cause a flow rate of 435L/min.



How your results change if the pipeline is replaced with copper tubing Type K? Save and print your results.

How your results change if the pipeline is replaced by PVC Schedule 40? Save and print your results.

Compare all three scenarios:

- Which of the three solutions listed above do you recommend for implementation and why?

Discussing the economical and societal impact of each solution.