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Re-Designing Fluid Mechanics to Integrate Experiential Learning – A Collaborative Effort

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Re-Designing Fluid Mechanics to Integrate Experiential Learning with Videos and Workshops

1. Introduction and Background

Engineering programs are well known for their low retention, high attrition rates, and lack of diverse participation [1]. According to the American Society for Engineering Education (ASEE) the average retention rate for engineering students in the USA is approximately 50% [2] with around 60% of engineering students changing majors or leaving the university before graduation [3]. These problems are not unique to the USA. According to the Center for Research and Information of the Israeli Parliament (Knesset), as of 2022 only about 19% of all undergraduate students in Israel are enrolled to engineering faculties [4]. Further, according to the Israeli Central Bureau of Statistics, only ~60% of those enrolled to an engineering faculty finish their undergraduate degree on time [5]. It is thus unsurprising that both Israeli higher education institutions and those in the USA are struggling to train and educate enough engineering graduates to keep up with the industry's demands for skilled graduates [6]. This issue was recently highlighted in a review by Kamaras (2024) discussing the importance of quality higher engineering education as a path to economic and societal resilience in Israel [7].

The literature suggests that teaching and learning can mediate these issues. It was shown, for example, that active learning pedagogies can improve students' learning outcomes at scale, improve diversity within STEM disciplines, reduce failure rates, and support skill development [1], [8]–[12]. Active learning involves engaging students directly in the learning process through activities and discussions, rather than passively listening to a lecture. It emphasizes higher-order thinking and often includes collaborative exercises such as problem-solving, peer teaching, and group work [13] and can vary widely, from brief interactive activities within lectures to entirely problem-based learning courses [14]. This method is contrasted with traditional lecture-based instruction by encouraging students to actively participate and reflect on their learning. By involving students in active participation, they can better retain information and develop a deeper understanding of the material [15].

Notably however, implementing active learning in engineering education poses several challenges. One major issue is the increased demand on instructors to design and facilitate interactive activities, which is time-consuming and require new skills, in particular given the busy syllabi of these courses [14]. Additionally, active learning often necessitates smaller class sizes or additional instructional support, which can strain resources [13]. Resistance from both students and faculty accustomed to traditional teaching methods, due to the learning curve required to adjust to the new roles in the classroom, can also hinder the adoption of active learning [16].

Fluid Mechanics is a course taught in almost all engineering programs, including mechanical, civil, and chemical engineering, to name a few. It is often considered a favorite class to teach by many engineering instructors due to the opportunity to demonstrate how advanced math skills and fundamental principles of physics are naturally used to explain familiar observations, predict the impact of daily flow problems, and design basic systems such as home pipe systems. While engineering instructors may love to teach the course, students, on the other hand, often find it challenging to connect the advanced math and physics to realworld problems. Therefore, this course is sometimes referred to as a “weed out” course [17] (mainly for students without all relevant necessary pre-requisite courses) as it requires advanced mathematics and the ability to understand phenomena of flow, which is three dimensional and time dependant and therefore can be hard to visually represent [19]. Furthremore, additional issues include discontinuous learning throughout the semester, as well as multiple distractions on smart devices.

With consideration of these tensions, in this work we present a case study taking on these challenges of integrating active learning into a basic civil engineering course*: Fundamentals to Fluids Mechanics*, a foundational course taken by the sophomore students during their second year. The changes reported in this paper were implemented in the 2024 Fall-term and included updates to integrate experiential learning via videos with embedded questions, in-class hands-on exercises, and problem-solving demonstrations in lectures and tutorials. The following research questions are addressed:

RQ1) What is the students’ experience of the transformations made to the course?
RQ2) What is the impact of the changes on students’ perceived workload?

This paper presents the initial challenges of the course, the pedagogical transformations made to address these challenges, and their impact on students’ learning experience. An explanation of course changes is provided, in addition to the methodology used to evaluate the shifts. Finally, results of the transformation are shared, including lessons learned and a discussion of findings in the context of the active learning literature.

2. Method

2.1 The course and context

The course *Fundamentals of Fluid Mechanics* is a foundation course worth four academic credit points and includes three weekly hours of lecture and two weekly hours of a problem-solving tutorial delivered by a teaching assistance. The course is offered to students in their third or forth semester of their studies out of an eight-term recommended program at an Engineering Faculty at a technological university in Israel. This course is usually taken by students specializing in the Environmental and Water engineering tracks. In the Fall 2024, the course underwent a series of pedagogical and techno-pedagogical transformations aimed at providing students with more opportunities to participate thoughout the term and support their learning in this topic area (see the Intervention section).

2.2 The Students

Thirty-eight (38) students were enrolled to the course in the Fall 2024 term. A total of 22 students participated in an end-of-course survey. Out of the 22 survey respondents, all reported they are taking the course as part of the program requirement. With respect to gender, 55% of participants identified as female and 45% identified as male. A total of 37% identified as belonging to underrepresented minority groups (Non-jewish students). The engineering degree program breakdown was as follows: 45% enrolled to the transportation or geoinformation engineering programs, 45% enrolled to the water or environmental engineering programs, and 10% enrolled to another track. Finally, the self-reported GPA was as follows: 18% under 60 (D- to D+), 41% between 70-80 (C- to C+), 23% between 80-90 (B- to A-) and 18% 90 or over (A- to A+).

2.3 Study Design: Survey

The survey included 20 Likert-scale questions covering the various aspects of the changes made in the course. It examined the students' active engagement in the course, their perception of contribution to their learning and their satisfaction with the course and the learning process. All items were on a 5-Point Likert-scale, ranging from 1 (=did not help) to 5 (=helped a lot). The survey also included several open-ended questions asking students to describe their learning experience in the course. These questions mainly focused on giving students the opportunity to elaborate on their learning experience with the new instructional elements: the videos, the demonstrations, the added workshops, the homework and their overall impression of the course. An example of an open question is: "we would love to hear more about what went well and what can be improved in the course, or anything else you would like to add regarding the course"

2.4 Intervention

The educational intervention included a transition from a full lecture-based design to a partial flipped classroom design, including several main elements, as explained below. Table 1 summarizes the changes made to the course.

Table 1. Course design before and after the changes.

	Lectures	Tutorials	Homework	Assessments
Before the change	Weekly lecture-based sessions	Weekly lecture-based sessions	Weekly homework sheets	Homework sheets (15%) Midterm exam (35% of the final grade) Final exam (40%)
After the change	Weekly lecture-based meeting – some were devoted to demonstrations of problem-solving	Some remained lecture-based Some were converted into hands on workshops	Videos of Math developments Nine homework sheets (out of 12 weeks)	Embedded questions (10%) Homework sheets (15%) Midterm exam (30%) Final exam (45%)

Estimated work time dedicated to the pedagogical transformation, starting from initial conceptualization, creating and editing the video recordings, designing active tutorials, drafting questions and embedding them in the videos, was about 150 hours of all participants: the instructor, the teaching assisstant, and a Disciplinary-Based Educational Specialist (DBES). DBESs are disciplinary experts with training in the science of teaching and learning who serve as catalysts of pedagogical changes within departments [19]. DBESs work closely with the teaching staff to design, tailor, and adjust teaching practices and learning activities to the specific context in which they are to be used. They do so while keeping in mind evidence-based teaching practices within that specific field and provide support (pedagogical, technological or bureaucratical) to streamline challenges that may hinder effective teaching efforts.

2.4.1 Short Videos for Long Mathematical Developments:

Teaching fluid mechanics involves, at times, long mathematical derivations. The derivation of the famous Bernoulli's principle, using the integral momentum conservation, may take more than a full houre lecture to properly deliver in class. One of the main changes to the course was to identify mathematical derivations that are technical in nature and teach them using recorded lectures that the students had to study at home. A total of 16 videos, 6-20 minutes in length, were produced. Some videos were extracted and edited based on lecture recordings made during a prior run of the course (Fall 2017) while others were recorded especially for this course using the Lightboard technique, a transparent board allowing real-time writing while facing the camera (see Figure 1).

The instructor recorded the Lightboard videos himself in a self-directed video studio on campus. Recordings were made by a plan that was pre-made by the course’s staff and the DBES. Recording were shlightly edited by the teaching assistant (TA). Subtitles were not included. Once the videos were recorded, the teaching staff and DBES watched them together and decided where to include interactive iterms and of what sort.

The 2017 recordings were edited by the TA using FILMORA, a film editing software with basic editing funcions. The time required for the editing was approximately 50 hours. Creating the new recordings was not as time consuming as was the work on reviewing past recordings and planning how to fit them to the new course plan. The instructor, TA and DBES scanned the old recording, to find how to combine them within the new course plan, identifying which parts need new recordings, and plan the exact timeline of the explanation within each video. An overall estimate is that about 20 hours were needed for planning but less than 2 hours of actual recording time. Once the recordings were ready, the embedded questions took extra time from the staff, especially the TA

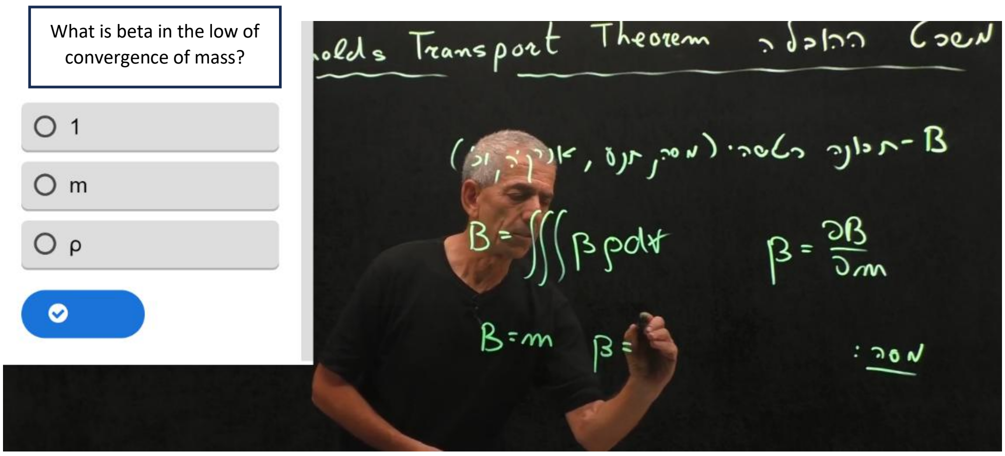

Figure 1. A screenshot of a video recorded using a Lightboard technology with an embedded question using H5p.

2.4.2 Embedded questions using H5P technology.

Questions were embedded in the video recordings to keep students engaged and focused while watching, and to have a quantitative evaluation of their learning processe. The continuation of watching the video was conditional on answering the embedded questions. In terms of difficulty level, questions ranged from easy to difficult and were designed to substitute the lecturer's ongoing conversation with the students during the traditional lecture-based session.

The questions were embedded in the recordings using H5P technology. Each video included between three to five questions. Some were multiple choice, some were short-answers, and others were true/false items. Some asked the students to generate hypotheses and predictions, some checked for relevant knowledge from previous courses and lectures, and some were designed to evoke critical thinking on the subject.

The high volume of questions meant that the teaching staff had to create a pool of about 100 items, with relevant and meaningful distractors. Questions were first drafted by the teaching assistant. The DBES embedded the questions using the H5P software. Drafting and embedding the questions was a time consuming process, partly because of the limited support of the h5p technology in languages other than English.

2.4.3 Transforming lectures: demonstrations of problem-solving

The traditional balance between lectures and tutorials was such that most of the problem solving examples were given by the teaching assistant during the tutorial hours. With consideration of the expected increase in student workload resulting from adding the mandatory watching of videos, some of the lectures were designed to include demonstrations of complex problem-solving referring to their homework exercises. The time allocation for this activity was gained through the use of video recordings that included the heavy mathematical developments in the course, as explained above. An additional goal of this change was to facilitate students' engagement with the homework problems and provide them with modeling of successful problem-solving strategies.

2.4. Active learning in tutorials

Some of the course's tutorials were redesigned to include more active learning. This was done through interactive digital worksheet. Students had the choice to work individually or in pairs or groups. Teaching staff, mainly the TAs, were available to answer questions and facilitate. These workshops were designed to reduce the overall workload on students considering the added time required to complete the videos. The presumable "lost" of tutorial sessions that were dedicated, before the change, to problem-solving were balanced by the problem-solving lectures.

2.5 Data Analysis

A preliminary data analysis was conducted using the SPSS software. Descriptive statistics are provided to compare and contrast the more influential changes perceived by the students.

3. Results

3.1 Impact of Active Learning

Table 2 provides survey results for the impact of active learning in the *Fundamentals of Fluid Mechanics* course. In general, the students offer positive support for the inclusion of active learning with means ranging from 3.38 (embedded videos) to 4.55 (homework). It was found that the homework assignments were most helpful. Given a max response of five, there is still an opportunity to improve the pedagogical approaches moving forward.

Table 2. Survey Results - Impact of Active Learning

Question	N	Mean	Std Dev
To what degree did the prep videos help you learn?	21	3.71	1.102
To what degree did the questions embedded in the videos help you learn?	21	3.38	1.161
Some of the lectures were in an active learning format. When the instructor gave general lines to problem solving, to what degree did such meetings contribute to your learning?	23	3.83	1.193
Some of the lectures were in an active learning format. To what degree did these meetings help you solve the home assignments later?	23	3.61	1.033
Some of the lectures were in an active learning format. To what extent did you understand the solutions and ideas the instructor presented?	23	3.83	0.984
Some of the lectures were in an active learning format. To what extent would you be happy if more lectures were in this format?	23	3.57	1.037
To what extent did solving homework assignments contribute to your learning in the course?	22	4.55	0.8

3.2 Perceived Knowledge Gains as a Result of Active Learning

Table 3 provides survey results for the perceived knowledge gains as a result of active learning. The learning gains for ‘Conservation of mass’ are the highest, and the learning gains for ‘Energy preservation and Bernoulli equation’ was the lowest. This provides good feedback on where to target future pedagogical changes.

Table 3. Survey Results - Perceived Knowledge Gains as a Result of Active Learning

Question	N	Mean	Std Dev
Indicate your knowledge and confidence in: Hydrostatics.	22	71.20	24.80
Indicate your knowledge and confidence in: Conservation of mass.	22	87.10	12.14
Indicate your knowledge and confidence in: Momentum in moving and static systems.	22	75.20	14.92

Indicate your knowledge and confidence in: Energy preservation and Bernoulli equation.	22	58.60	17.33

3.3 Comparison to Other Classes

Table 4 provides student feedback on how this course is compared to other courses. For the most part, students agreed this course was more enjoyable and engaging, but also included a heavy workload. This provides support for integrating more active learning while upholding the rigor commonly associated with engineering courses. (scale of 1 to 3)

Table 4. Survey Results - Comparison to Other Courses

Question	N	Mean	Std Dev
Compared to other similar courses - I enjoyed the course.	22	2.41	0.73
Compared to other similar courses - I am actively engaged.	22	2.23	0.69
Compared to other similar courses - I studied throughout the term (didn't binge).	22	2.77	0.43
Compared to other similar courses - I experienced a heavy workload.	22	2.41	0.74
Compared to similar courses - I understood the material.	22	2.09	0.61

3.4 Responses to Open-Ended Questions

Many students provided positive support for the active learning components. Example quotes are provided below.

- *The videos are good and very focused on the main topics; they are very helpful for students like me who sometimes struggle to differentiate between essential and non-essential material.*
- *In my opinion, the videos significantly contribute to learning and also help recall material from previous courses.*
- *The videos with embedded questions are a refreshing and quite cool innovation, especially those recorded using the Lightboard technique.*
- *The instructor-led practice is very helpful because this course genuinely requires more practice.*
- *The lectures are very interesting, and the students' active participation stands out positively.*

3.5 Lessons Learned

Given the current context (due to the ongoing Israeli-Hamas conflict), limited sample size (21 to 23 survey respondents), and shortened semester, assessing the overall impact on student achievements was challenging. However, some notable patterns still emerge and as these changes become more embedded and extended over time, re-evaluation of student outcomes will be possible.

Although the initial survey results show positive feedback regarding the implemented changes, there is still opportunity for improvement. For example, not all topics that were addressed by the activities were rated by students as topics they feel confident about. Furthermore, while the survey clearly shows students were actively engaged throughout the semester more intensively compared to other courses, they did not necessarily report greater understanding compared to other courses. To continue and evaluate these terns, future runs of the course (or similar courses going through similar transformations) will include more open ended questions to gain a richer and deeper understanding of student perspectives.

Further, during the development and implementation of the changes to the course, some challenges and considerations came up. First, what is the best way to assess the flipped classroom element and ensure its execution? Should it be based solely on video viewing? Should students be required to answer the embedded questions [correctly]? Should additional follow-up be allowed? Second, there was a discourse on how to best balance the workload associated with watching additional videos while keeping up with the workload associated with the essential homework (which is a critical component of the course). Third, sometimes there was a student confusion related to tasks and expectations. Throughout the course, additional time and energy was invested into clearly defining tasks and ensuring students completed them promptly. Going forward, outcomes and insights regarding these changes and challenges will be shared with other faculty to encourage integrating more active learning in the engineering classroom.

4. Conclusion

Active learning is an instructional approach that actively engages students in the learning process, often through self teaching, collaborative activities, and problem-solving. Incorporating active learning strategies in engineering education is considered more challenging than in other disciplines and yet it is not only enhances the learning experience but also prepares students better for their professional careers by developing a broad range of skills necessary for success in the engineering field.

In this paper, an overview and assessment of integrating active learning into a Fluids Mechanics course is provided. Three core active learning strategies were integrated into this course: embedded videos, in-class active learning, and homework. In general, positive feedback is provided by the students. Yet, there is still opportunity for improvement.

Creating transformation in engineering education cannot be done alone. Instead, the academic community plays a vital role in sharing best teaching practices in engineering education. Sharing best practices helps in developing standardized curricula that meet industry standards and accreditation requirements. Implementing best practices leads to more effective teaching strategies, resulting in better student learning outcomes. Academic communities provide access to a wealth of teaching materials, resources, and tools that can enhance the teaching and learning experience. Therefore, it is hopeful other engineering educators, especially in core courses such as Fluid Mechanics, will consider integrating more active learning into the classroom AND disseminating lessons learned via conference proceedings, presentations, and journal articles.

References

[1] M. Wilton, E. Gonzalez-Niño, P. McPartlan, Z. Terner, R. E. Christoffersen, and J. H. Rothman, "Improving academic performance, belonging, and retention through increasing structure of an introductory biology course," *CBE Life Sci. Educ.*, vol. 18, no. 4, 2019, doi: 10.1187/cbe.18-08-0155.

[2] B. B. L. Yoder and D. Ph, "E ngineering by the N umbers," pp. 11–47, 2011.

[3] M. W. Ohland, S. D. Sheppard, G. Lichtenstein, O. Eris, D. Chachra, and R. A. Layton, "Persistence, Engagement, and Migration in Engineering Programs.," *J. Eng. Educ.*, vol. 97, no. 3, pp. 259–278, 2008, doi: https://doi.org/10.1002/j.2168-9830.2008.tb00978.x.

[4] A. Viningrad, R. Goldsmith, and Y. Vorgan, "Engineering education in the higher education system and the workforce demand for engineers in Israel," 2022.

[5] I. Central Beauru of Statistics, "Students who completed their studies for a first degree among those who began studying in 2009 / 10 (follow-up until 2017), by duration of study for a degree in," vol. 10, p. 2017, 2017.

[6] Y. Melzer and A. Kimhi, "Employment in Israeli High-Tech : Past , Present , and Future," no. February 2024.

[7] J. Kamaras, "' Quality over quantity the key to Israel ' s high-tech advantage '," pp. 1–5, 2024.

[8] S. Freeman *et al.*, "Active learning increases student performance in science, engineering, and mathematics," *Proc. Natl. Acad. Sci. U. S. A.*, vol. 111, no. 23, pp. 8410–8415, 2014, doi: 10.1073/pnas.1319030111.

[9] B. L. Deslauriers, S. E. Harris, E. Lane, and C. E. Wieman, "Transforming the Lowest Performing Students: an Intervention That Works," 2003, [Online]. Available: http://www.cwsei.ubc.ca/SEI_research/files/Harris_Intervention_JCST2012.pdf.

[10] C. E. Wieman, "Large-scale comparison of science teaching methods sends clear message," *Proc. Natl. Acad. Sci. U. S. A.*, vol. 111, no. 23, pp. 8319–8320, 2014, doi: 10.1073/pnas.1407304111.

[11] I. V. Rossi, J. D. de Lima, B. Sabatke, M. A. F. Nunes, G. E. Ramirez, and M. I. Ramirez, "Active learning tools improve the learning outcomes, scientific attitude, and critical thinking in higher education: Experiences in an online course during the COVID-19 pandemic," *Biochem. Mol. Biol. Educ.*, vol. 49, no. 6, pp. 888–903, 2021, doi: 10.1002/bmb.21574.

[12] R. Lavi, M. Tal, and Y. J. Dori, "Perceptions of STEM alumni and students on developing 21st century skills through methods of teaching and learning," *Stud. Educ. Eval.*, vol. 70, 2021, doi: 10.1016/j.stueduc.2021.101002.

[13] M. Prince, "Does Active Learning Work? A Review of the Research," *J. Eng. Educ. (Washington, D.C.)*, vol. 93, no. 3, pp. 223–231, 2004, doi: 10.1002/j.2168-9830.2004.tb00809.x.

[14] R. M. Felder, *Teaching and learning STEM : a practical guide / Richard M. Felder, Rebecca Brent.*, First edit. San Francisco, CA : Jossey-Bass, a Wiley Brand, 2016.

[15] C. C. Bonwell and J. A. Eison, "Active Learning: Creating Excitement in the Classroom. ERIC Digest," ASHE-ERIC Higher Education Reports, The George Washington University, One Dupont Circle, Suite 630, Washington, DC, 1991.

[16] J. Michael, "Where's the evidence that active learning works?," *Adv Physiol Educ*, vol. 30, no. 4, pp. 159–167, 2006, doi: 10.1152/advan.00053.2006.

[17] L. M. Openshaw, "DigitalCommons @ USU Understanding the Effects of a Mobile Flow Visualization Learning Tool on Engineering Undergraduate Interest in Fluid Mechanics," 2023.

[18] K. Goodman, J. Hertzberg, T. Curran, and E. Austin, “Visual expertise in fluid flows: Uncovering a link between conceptual and perceptual expertise,” *Int. J. Eng. Educ.*, vol. 36, no. 3, pp. 1082–1096, 2020.

[19] S. D. Bush, J. A. Rudd, M. T. Stevens, K. D. Tanner, and K. S. Williams, “Fostering change from within: Influencing teaching practices of departmental colleagues by science faculty with education specialties,” *PLoS One*, vol. 11, no. 3, pp. 1–20, 2016, doi: 10.1371/journal.pone.0150914.