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JUNE 22 - 26, 2020 #ASEEVC
Paper ID #29210

Two Approaches to Concept Maps in Undergraduate Fluid Mechanics

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Abstract

In constructivist pedagogy, students create their own meaning of the course material. One way for students to represent connections between ideas is by creating a concept map. This paper describes different approaches to using concept maps as a study tool in undergraduate fluid mechanics courses at two different institutions. The two instructors worked together to create a concept map of the topics covered in the courses, which had similar learning outcomes and covered most of the same topics. The goal of creating this concept map was to provide the students with a visual representation of how the different topics were related. At the first institution, the instructor-created concept map was used primarily as a visual aid ("passive approach"). The instructor showed the map at regular intervals in class, where the map grew as students learned new material. At the second institution during the following semester, students were encouraged to create individual maps, which could be used as an aid during assessments ("active approach"). The instructor-created map was presented in class after allowing the students to develop their own maps. No significant differences in course performance were found compared with courses taught by the same instructors when concept maps were not used. Concept maps were found to be a useful tool for connecting and organizing course topics for both students and instructors.

Introduction

Constructivist learning theory, in which learners create their own meaning of new material and make connections with prior knowledge, is the basis for a variety of active learning approaches [1], [2]. Creating a concept map is one way for students to represent connections between ideas. Concept maps, or mind maps, are visual representations of the organization and connections between pieces of information [3]–[5]. Relationships between various concepts are shown by connecting lines or arcs. Concept mapping has been used as an educational tool for more than thirty years, but has recently gained attention in STEM (science, technology, engineering and mathematics) disciplines [6]–[8]. Within the mechanical engineering curriculum, examples of incorporating concept maps are more widespread for mechanics courses than thermal science courses [9]–[14].

Previous studies have reported the use of concept mapping as a technique to improve student understanding of course content as well as the use of concept maps to assess student learning. Several students have shown concept mapping to improve comprehension and retention of course material, but there is disagreement about the use of concept mapping as an assessment tool [9], [15]–[17]. Johnstone and Otis suggest that concept maps are personal tools to aid in a student's memory but may be misinterpreted by an outside reader [18]. Therefore, in this study, student-created concept maps were not used to assess learning.

This paper describes different approaches to using concept maps as a study tool in undergraduate fluid mechanics courses at two different institutions. In the passive approach at one institution, an instructor-created concept map was used primarily as a visual aid during class discussions. In the active approach at the second institution, students were encouraged to create their own concept maps and were given class time to discuss and modify their maps before seeing the instructor-created concept map. In this paper, the instructor-created concept map is presented, and both qualitative and quantitative results from student surveys are presented and discussed.

Pedagogical Approach/Methodology

The concept map used in the study was co-developed by instructors at two institutions where the courses had similar learning outcomes and covered most of the same topics. Textbook adoptions were also the same for both instructors. The goal of creating the concept map was to provide the students with a visual representation of how different course topics were related and improve understanding. In addition to benefiting student learning, another goal of the creation of this concept map was to aid one of the instructors in making connections between topics when teaching the course for the first time.

The instructors initially created individual concept map drafts before comparing and revising. The first drafts had many common features that both instructors deemed important, but each instructor had organized the visual representation differently. Before revisions began, the instructors agreed the ability to legibly print the concept map on a single page for student convenience was a priority. After a few rounds of revision, the final concept map, shown in Figure 1, was completed.

The instructors incorporated the completed concept map using different approaches. Results are presented as a consideration of two case studies.

Passive Approach

At the University of Evansville (UE), the instructor-created concept map was used primarily as a visual aid. The instructor showed the map at regular intervals in class, where the map appeared to grow as students learned new material. This use of concept maps will be designated the “passive approach”.

The passive approach was adopted for one section of an undergraduate fluid mechanics course with an enrollment of eight students at UE. Three students were international, and all students were male. Seven students were majoring in mechanical engineering, while one student was majoring in civil engineering. One student was a senior and in his second attempt to complete the course; the remaining students were juniors in their first attempt to complete the course.

Using the passive approach, students were introduced to the complete instructor-developed concept map on the first day of the semester. The instructor discussed the role of concept maps in student learning, as well as some tips for developing individual concept maps. Using the concept map as a rough outline for course learning objectives, the instructor presented a reduced version of the concept map highlighting the initial focus of the course and topics for the first exam, as shown in Figure 2.

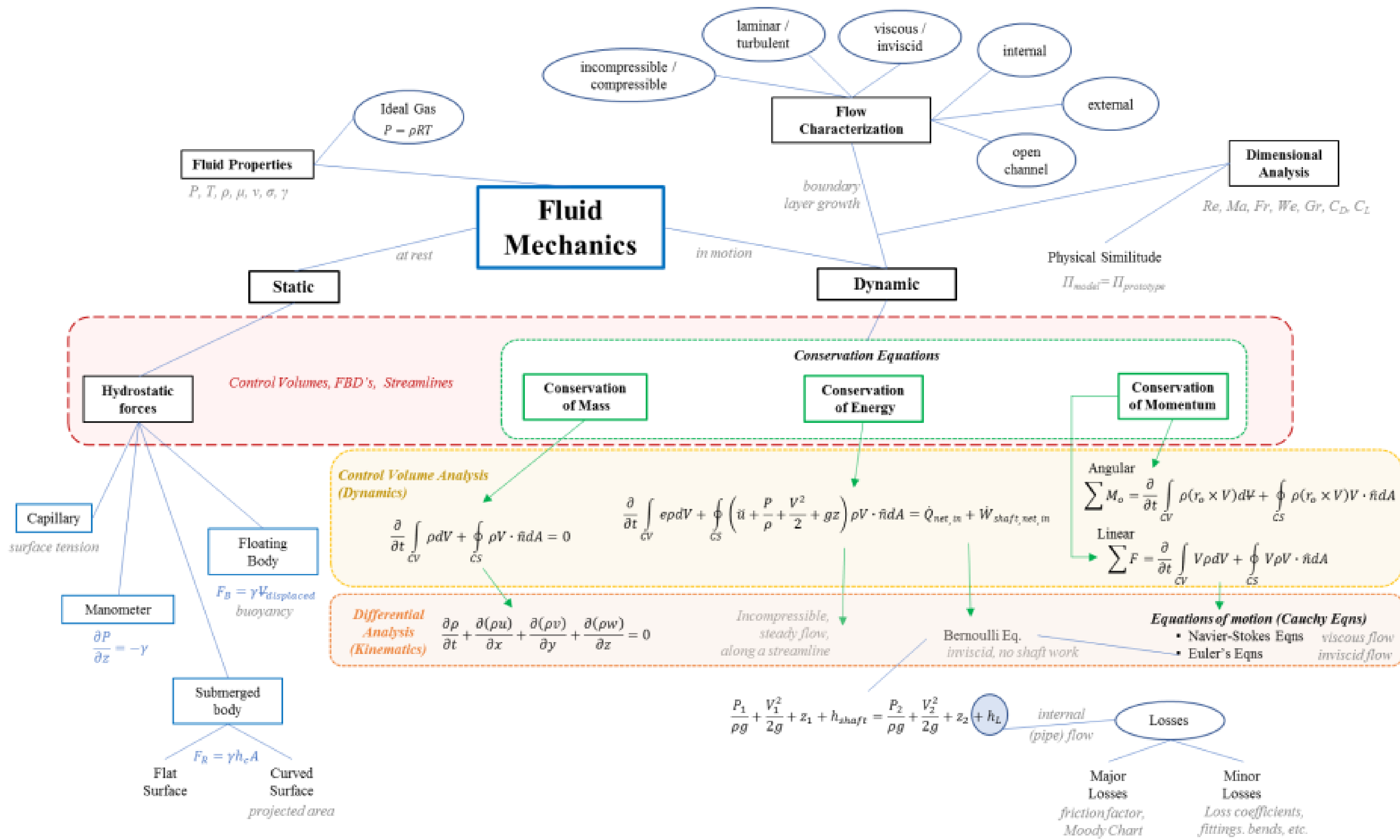


Figure 1: Concept map co-developed by instructors for this study

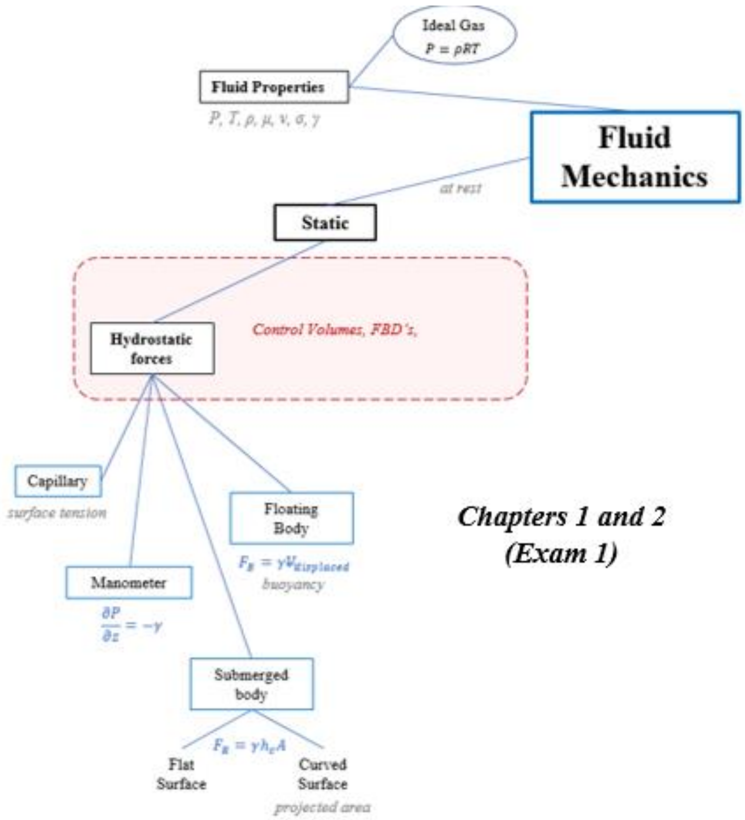


Figure 2: Reduced concept map

Throughout the semester, students were encouraged to develop their own concept maps or modify the version provided by the instructor. Concept maps were permitted as a reference material for exams, quizzes, and in-class activities, but students were not required to create individual concept maps. Reduced versions of the concept map were introduced in class at regular intervals as more course topics were covered.

At the end of the semester, the instructor reviewed the complete concept map, reminding students of the learning outcomes presented on the first day and summarizing their growth in knowledge and understanding as a result of completing the course. Students were asked to identify possible links that could be made to other courses to expand the concept map, and a few examples were given by the instructor. As a final note, students were encouraged to keep a copy of the concept map for a reference when preparing for the FE Exam, which must be attempted prior to graduation at UE.

Active Approach

Based on the first instructor's experience at UE, the second instructor modified the approach for using concept maps at Indiana University-Purdue University Columbus (IUPUC) during the following semester. Instead of providing students with a completed concept map, students were encouraged to create individual maps, which could be used as an aid during assessments. For this "active approach", the instructor-created map was presented in class after allowing the students to develop their own maps.

The active approach was adopted for one section of an undergraduate fluid mechanics course with an enrollment of 12 students at IUPUC. All students were male, majoring in mechanical engineering, and juniors in their first attempt to complete the course.

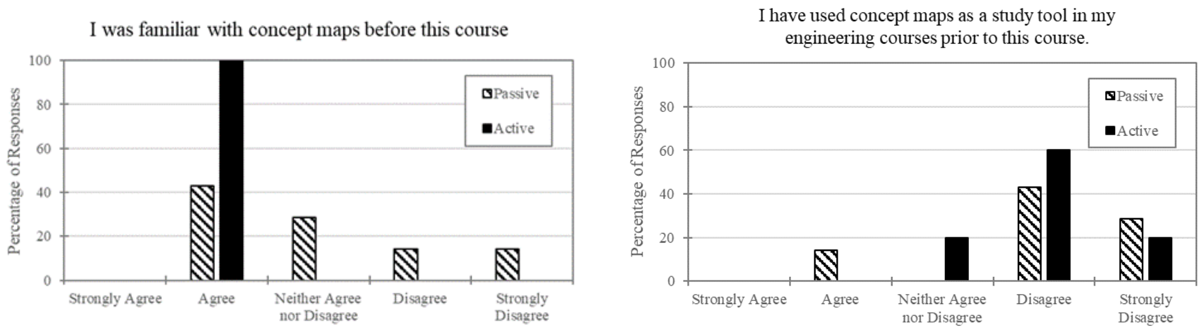
Concepts maps were introduced to students toward the end of class at the beginning of week 4 of the semester (15 weeks). At this point in the course, fluid statics topics and been covered, and the Bernoulli equation was introduced during this class period. On the board, the instructor wrote “fluid mechanics” and drew two lines coming out of it for “fluid statics” and “fluid dynamics”. Students were asked to identify topics that fall under fluid statics. They stated “manometers” and “buoyancy”. The instructor wrote these topics on the board, making connections between them and “fluid statics”. Someone suggested “submerged surfaces” and students debated about where to add that. Someone suggested “Bernoulli equation” and the instructor put that under “fluid dynamics”. The instructor noted the connections between ideas on the board and stated that it was the start of a concept map. Students were encouraged to create their own concept maps. Concept maps were permitted as reference material for quizzes and in-class activities, but students were not required to create concept maps.

Periodically throughout the course, students were given time during class to add to their concept maps and discuss their maps with other students. In week 11 of the course, the instructor presented a reduced version of the concept map co-developed by the instructors for this study, showing all concepts covered to that point in the course. Students were reminded that there was no “correct” version of the concept map and that theirs may look different. During the final week of the course, students were shown the complete instructor-created concept map. Student concept maps were collected at the end of the course but were not graded.

Results

The instructors asked students to complete anonymous surveys to further understand the use, impact, and experiences with concept maps in the undergraduate fluid mechanics course. The survey consisted of Likert Scale questions and optional open response prompts. The instructor at UE distributed the survey in the semester immediately following the course offering; seven out of eight students responded. The instructor at IUPUC distributed the survey in the same semester as the course offering; 5 out of 12 students responded. The results to the Likert Scale responses have been summarized as percentages of student responses, as shown in Figures 3-7, providing a comparison of active and passive approaches for incorporating concept maps. One student at UE responded “not applicable” to several prompts, which is not shown in the charts.

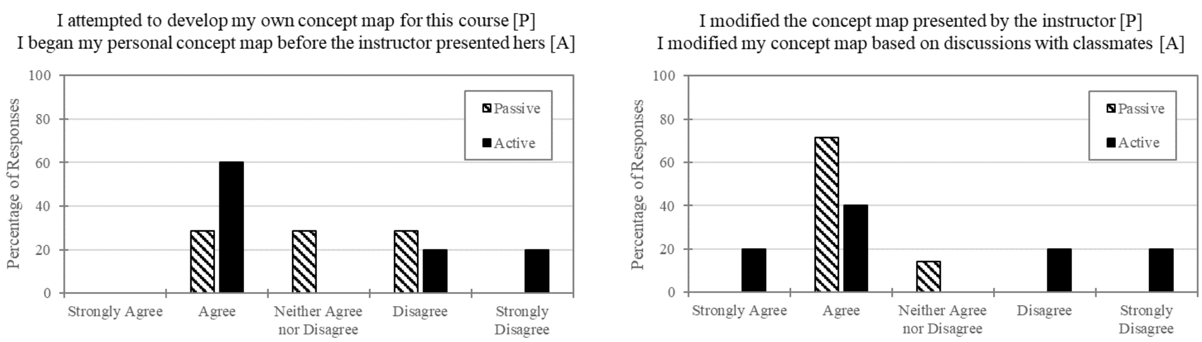
Two prompts requested information about previous student experience with concept maps. The responses, shown in Figure 3, indicate that students at both universities had some familiarity with concept maps prior to the course but generally had not used concept maps as a study tool for engineering courses.



(a) *(b)*

Figure 3: Prior experience with concept maps

The responses in Figure 4 indicate student participation in developing and modifying personal concept maps for the course. The prompt language varied slightly based on the pedagogical approach, as indicated in the chart titles with a (P) for passive and (A) for active.

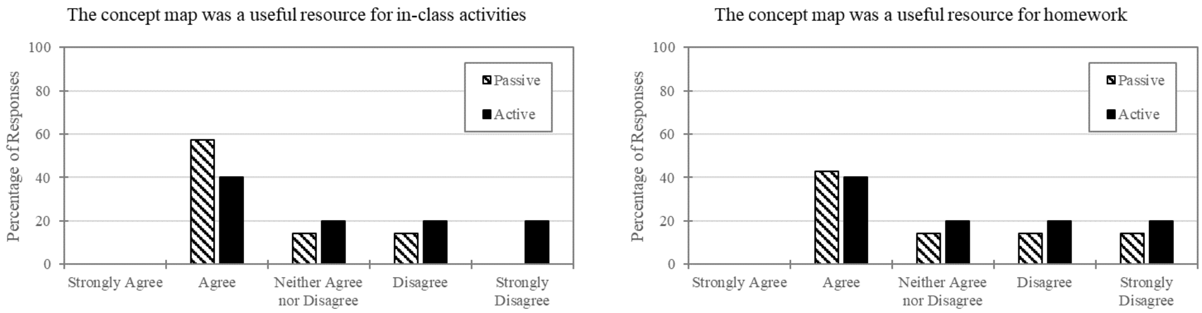


(a) *(b)*

Figure 4: Student participation in concept map development

For the passive approach, student responses were neutral in regard to developing personal concept maps for the course, which may be partially due to the lack of a formal assignment or academic credit as motivation. This is also noted in one student's open response shown later. Student responses were only slightly more positive for the active approach. For the passive approach, over 70% of students reported modifying the concept map provided by the instructor, which indicates significant usage of the tool and customization by students. For the active approach, students were nearly split, with 60% indicating modifying their map after discussion with classmates.

Student opinions regarding usefulness of the concept map on homework and in-class activities were similar for both approaches, as shown in Figure 5.



(a) *(b)*

Figure 5: Student perception of concept maps as reference material

The students found the concept map most useful for quizzes and exams under the passive approach, as shown in Figure 6.

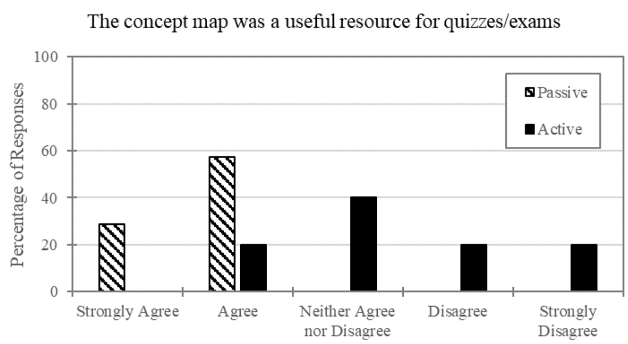
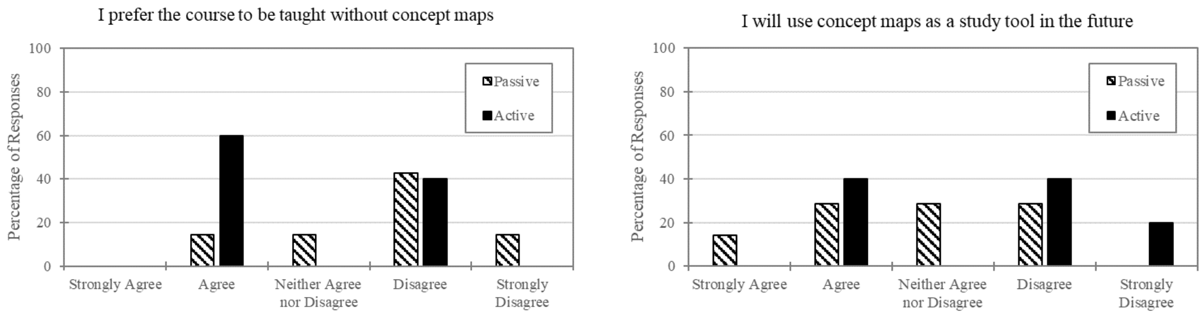


Figure 6: Student perception of concept maps an exam reference

As indicated in the open response comments presented later, students at IUPUC may have found the concept maps less useful on quizzes and exams based on the adopted grading scheme. Students in the active-approach course completed regular topic-specific quizzes, whereas students in the passive-approach course completed comprehensive exams at regular intervals. Students in the passive-approach course also commented on the benefits of concept maps for exam preparation in the open response prompts.

The responses may also be skewed by the additional resources available to students when completing homework or in-class activities. Both instructors restricted use of reference materials on quizzes and exams but allowed the concept map as an approved reference.

Presented in Figure 7, student responses indicated a preference for teaching the course with the concept maps at UE, but without the concept maps at IUPUC. In the passive-approach course, only one student preferred the course be taught without concept maps. Student plans for using concept maps in the future also differed across institutions.



(a) *(b)*

Figure 7: Student preference of learning with concept maps

Students were also asked to estimate the frequency of their use of concept maps in the passive-approach course. The responses provided in Table 1 indicate that about half of the students referred to the concept map weekly while the remaining students referred to the concept map every 4-6 weeks.

Table 1: Frequency of use – passive approach

Approximately how often did you refer to the concept map provided by the instructor while enrolled in the course?	
0.00 %	*Daily*
42.86 %	*Weekly*
14.29 %	*Monthly*
28.57 %	*Only before an exam*
0.00 %	*Only when the instructor discussed or presented the map in class*
14.29 %	*Never*

As part of the same survey, students were given an opportunity to respond to open response prompts. The responses are listed verbatim in Tables 2 and 3.

Table 2: Open response summary – prompt I

What aspects of the concept map did you find either useful or not useful for your learning in this course?	
PASSIVE APPROACH	**ACTIVE APPROACH**
• (no response) • Useful tool, found it unnecessary in my practice of fluid mechanics • It was nice to see how each concept related to another. • Having an organized reference to go back to before exams • To see what equation stemmed from each other • Organized equations well • Linking equations to each other	• (no response) *x3* • Concept maps were helpful in visualizing how different topics were related. • Never used it, because it doesn't do anything beyond connect concepts (as the name implies). Doesn't do a lot for me in a formula based class.

Six students from the course with the passive approach responded to the first open response prompt. Five of the six responses cited the organization and clear relationships of the concept map as helpful for their learning in the course. Three of those responses specifically mentioned the organization and linking of equations. The sixth response stated, "Useful tool, found it unnecessary in my practice of fluid mechanics."

Three students from the course with the active approach chose not to respond. One student found the visual representation helpful, while another student did not see as much benefit in relating concepts for a course that requires mathematical analysis.

Table 3: Open response summary – prompt II

Please provide any additional comments about the use of concept maps in this course	
PASSIVE APPROACH	**ACTIVE APPROACH**
• (no response) *x4* • I think it would be beneficial for the concept map to be arranged in a sort of chronological order for the solution process, as well as being complete such that every option or branch leads to the necessary equations/solution process • It would be nice as a class activity or a bonus grade to give extra motive for people to do it • You were presented with awards last year for a reason, keep on	• (no response) *x3* • Probably would have been far more useful in our Design course last year as it relied far more on abstract, interconnected concepts. • Concept maps were not used on quizzes only because the quizzes were over specific topics rather than the relationships between various topics.

Only two students from the course with the passive approach provided relevant feedback for the second open response prompt. One student suggested providing course credit or dedicated class time as additional motivation for students to create or modify a concept map for the course. The second student seemed interested in a more detailed concept map that acted as a flow chart, providing the equations and steps required to analyze any fluid mechanics problem.

Three students from the course with the active approach chose not to respond. Both students that provided a response commented on the potential usefulness of concept maps in courses that rely more heavily on multi-concept applications rather than focused quizzes. It is unclear how student responses would have compared if both courses had adopted the same grading scheme for the course.

No students provided negative feedback regarding the introduction of concept maps in undergraduate fluids mechanics in the open responses. Overall, students responded positively to the organization and visual representation of relationships between course concepts provided by the concept map.

Academic Performance

Two measures of academic performance were used for comparison at UE between the traditionally taught course and the course taught with the passive incorporation of concept maps. The traditional course offering had 16 students enrolled in the previous academic year. Both courses were taught by the same instructor and used the same final exam. Averaged grades for the final exam and the overall course grade are provided in Table 4.

Table 4: Academic Performance Comparison – UE

Teaching Approach	Final Exam Score		Overall Course Grade	
	Average	***Standard Deviation***	***Average***	***Standard Deviation***
Traditional Offering	80.9	10.86	83.7	8.78
Concept Maps - Passive	85.0	15.72	83.2	10.27

Overall student performance in the course was nearly indistinguishable when comparing course grades. The average score on the final exam was higher for the course with concept maps, but the results are statistically insignificant due to the small sample size and resulting standard deviations. Similar results were found for the active approach and traditional offering at IUPUC.

Overall course grades at IUPUC were not compared between the traditionally taught course and the course taught with the active incorporation of concepts. A laboratory portion of the course previously contributed to the course grade, but a curriculum change moved the laboratory component into a separate course during the year concept maps were incorporated. Different types of assessments were used at the two institutions in this study. No final exam was given in the course at IUPUC. Instead, a standards-based approach to grading was used, with quizzes over specific topics. Quizzes were graded “Pass” or “No Pass” based on specifications determined by the instructor [19]. Students could re-attempt quizzes. The traditional course offering had 15 students enrolled in the previous academic year. Both courses were taught by the same instructor and used assessments of similar difficulty covering the same topics.

For 6 of the 16 quizzes, all students passed the quiz by the end of the course. Of the other ten quizzes, no statistical significance was found. As examples, average grades for three quizzes are shown in Table 5. Averages were determined by converting “Pass” scores to one and “No Pass” scores to zero.

Table 5: Academic Performance Comparison – IUPUC

Teaching Approach	Submerged Surface Quiz		Linear Momentum Quiz		Pipe Flow Quiz	
	Average (out of 1)	***Standard Deviation***	***Average (out of 1)***	***Standard Deviation***	***Average (out of 1)***	***Standard Deviation***
Traditional Offering	0.9	0.3	0.7	0.4	0.9	0.3
Concept Maps - Active	0.8	0.4	0.7	0.5	0.9	0.3

Conclusions

This paper describes different approaches to using concept maps as a study tool in undergraduate fluid mechanics courses at two different institutions. Results from student surveys were summarized, and comparisons were made between the active and passive approach for incorporating concept maps. While the small sample sizes from each institution prevent the authors from making statistically significant claims, several useful conclusions may be drawn from the results.

Students at both institutions were generally familiar with concept maps but had not used concept maps as a study tool for engineering courses. The survey did not include a question about student use of concept maps in non-engineering courses for comparison. For many of the remaining survey prompts, student opinions were nearly split or neutral, and no statistical difference was noted in course grades or assignments at either institution.

Students in the passive-approach course responded more positively to using concept maps in future courses and continuing to teach the fluid mechanics course with concept maps. Students in the passive-approach course also perceived greater usefulness of the concept maps, especially on exams and quizzes. The students in the active-approach course had a slightly less positive perception of the benefits of concept maps, but this is likely due partially to the course evaluation methods. The passive-approach course included comprehensive exam questions as a major component of the course grade, whereas the active-approach course graded heavily on topic-specific quizzes. It makes sense that concept maps would seem less useful as a reference for a quiz focused on a single concept.

Student feedback from open response prompts indicates that some students place more importance, or expressed more need, on tools related to equations and analytical solution processes for the course, rather than conceptual understanding. This may be partially attributed to student motivation to quickly find the correct solution and prior learning experiences. Some students may also be more concerned with their ability to get the correct answer to a problem rather than their ability to discuss course concepts. These students may have difficulty recognizing the connections between concepts and equations. For such students, modifying a traditional concept map to include more equations may be more beneficial to their learning.

Open response results also suggested that students responded positively to the organization and visual representation of concepts provided by the map. This indicates there is value in presenting or encouraging the creation of a concept map. These positive responses suggest that including multiple means of representation of course material may be beneficial to students.

Unintended results from this study included the benefits to the instructors. Creating a concept map for a course may be especially helpful for instructors that are teaching new courses or course material they have not recently reviewed. Developing a concept map may also help the instructor identify new connections or alternative methods to organize and present course content. Additionally, inter-institutional collaborations on concept maps can stimulate focused pedagogical discussions and act as a tool for developing consensus regarding instructor expectations.

Overall, concept maps are a useful tool for connecting and organizing course topics for both students and instructors. Students will likely perceive greater benefits from using concept maps in courses evaluated on comprehensive applications. Students may also find the concept map more useful if it is modified to include more equations and analytical relationships. More data should be collected to increase the sample size and control for variations in course offerings for conclusive evidence to be gathered on the impact of concept maps in undergraduate fluid mechanics.

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