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Comparing the Impact of Individual v. Cooperative Bloom's Taxonomy-based In-class Assignments on Student Learning and Metacognition in an Undergraduate Fluid Mechanics Course

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Comparing the impact of individual vs. cooperative Bloom's Taxonomy-based in-class assignments on student learning in an undergraduate Fluid Mechanics Course

Abstract

This paper explores the effect of individual and small group cooperative Bloom's Taxonomy-based in-class assignments (ICAs) on student performance in formative and summative assessments in two sections of a junior-level Fluid Mechanics course. In most undergraduate engineering courses, assessments require students to *remember* basic concepts and *apply* those concepts to solve simplified numerical textbook problems. These problems often do not prepare students to fully grasp fundamental course ideas, retain knowledge in the long term, and apply those concepts to solve real-world engineering problems beyond the textbook. Motivated by this limitation and by the worldwide shift from traditional lecture to active learning environments, in our previous research, we found that a minimal revision of homework, quizzes, and in-class activities to include questions at three additional Bloom's Taxonomy levels of *understand*, *analyze*, and *evaluate* significantly enhanced students' comprehension, performance on summative assessments, and overall learning experience in an active learning environment. However, these positive results were evident only when the Bloom's Taxonomy questions were administered through active learning activities and not in a traditional classroom setting. In this study, the impact of individual vs. cooperative ICAs involving questions at the above-mentioned supplemental Bloom's Taxonomy levels on student performance was investigated. Interventions were incorporated in two traditionally difficult chapters of the course. Results suggest that while the performance on the homework was statistically similar for both student groups, no general trend about the effect of mode of administration of ICA (i.e., individual vs. small group) on student scores on formative assessments (quizzes) and summative assessments (exams) can be derived. The small-group ICA section outperformed the individual ICA section on the ICA for one chapter, while both sections had similar achievement on the ICA from another chapter. On the quizzes and exams, although the individual ICA section had scores higher than the small-group ICA students for assessments covering content from one chapter, the performance was statistically similar for the second chapter.

Introduction

Academic studies have found that traditional lecture-based instruction, where the faculty member as a 'sage on the stage' and students primarily (often passively) listen to the course content being presented, promotes a lower level of learning and low attention span (with attention level dropping after 10 minutes in a typical 50-minute lecture) and low knowledge retention [1], [2]. In contrast, active learning techniques, where the instructor is more of a 'guide on the side' have been shown to foster a positive learning environment, increase student engagement, promote communication skills, make the overall learning experience more effective and appealing, and improve student grades on summative assessments [3]-[5]. Particularly for individuals from underrepresented groups, active learning can help close the achievement gap on exam performance and course passing rates [6]. Examples of active learning implementations in the classroom include think-pair-share, polls, flipped classroom, minute papers, muddiest point, problem-based learning, game-based learning, etc. Cooperative learning is a subset of active learning that utilizes small groups to maximize student learning [1].

Our previous research has demonstrated that active learning enhances student performance on formative and summative assessments, when compared to grades from a traditional instructor-centered classroom [7]. Further, minimal modification of homework, take-home quizzes, and in-class assignments (ICAs) to include problems at Bloom's taxonomy categories of *Understand*, *Analyze*, and *Evaluate*, (which typically only include questions at *Remember* and *Apply* levels) can have additional benefits in some cases [7]. We also found that implementation of supplemental Bloom's Taxonomy problems in a traditional classroom was not beneficial to improving student grades and learning experiences, and concluded that these must be implemented in an active learning setting [8].

The multi-tiered Bloom's Taxonomy model, first developed in 1956 by Benjamin Bloom and collaborators, and later revised in 2001, hierarchically categorizes learning objectives into six categories: *Remember*, *Understand*, *Apply*, *Analyze*, *Evaluate*, and *Create* [9]. Problems from the first five cognitive levels test the ability of students to *remember* factual knowledge, *understand* fundamental ideas/ concepts, *apply* these concepts in various contexts to solve numerical problems, *analyze* ideas by comparing different solution approaches, and support decisions or justify choices (i.e., *evaluate*) using knowledge gained in class respectively.

In this study, we investigate the effect of the mode of administration of Bloom's Taxonomy-based ICAs — individual vs small groups — on student performance on formative and summative assessments. We aim to analyze whether small-group Bloom's Taxonomy assignments encourage students to discuss various approaches of thinking about a problem and better understand the underlying concepts through back and forth of ideas, thereby improving their grades on future individual assessments, or if individual ICAs are more effective at encouraging students to actively participate in their learning. Since cooperative learning activities can require significant instructor time investment to be planned and might consume valuable lecture time, only notable supplemental benefits of this learning technique might justify the time commitment [1]. To the best of our knowledge, existing comparative studies in this domain are limited and do not specifically analyze student performance on a variety of formative and summative assessments in an undergraduate mechanical engineering course [10]. The current study aims to fill that gap in literature. The methodology presented in this study and sample assessment questions provided in the Appendix can easily be utilized by other engineering educators to implement in any undergraduate course and can even be extended to large enrollment multi-section courses.

Methods

This study was carried out during Fall 2023 in a required undergraduate Fluid Mechanics class in the Department of Mechanical Engineering (MEEN) at Texas A&M University (TAMU). The course demographic is composed of a majority of juniors and some sophomores. Two class sections taught by the same instructor were included. The instructor has three years of teaching experience and has previously taught this course multiple times. The number of students, semester, categories of homework problems, take-home quiz questions, exam problems, and ICAs are listed in Table 1.

Table 1: Number of students, type of homework problems, categories of take-home quiz questions, exam problems, and ICAs of the two sections included in this study

Section	Semester	No. of students	Homework for Chapters 2, 6, and 8	Take-home quiz for Chapters 2, 6, and 8	Exam questions	ICAs for Chapters 6 and 8
Active learning + small-group in-class Bloom's taxonomy activities (AL+GBT)	Fall 2023	100	Questions at five Bloom's taxonomy categories: *Remember*, *Understand*, *Apply*, *Analyze*, *Evaluate*	Mandatory problems at *Remember* and *Apply* levels; bonus questions at *Understand*, *Analyze*, and *Evaluate* levels	*Remember* and *Apply* levels	Small group discussion-based ICAs at *Understand*, *Apply*, *Analyze*, and *Evaluate* levels
Active learning + individual in-class Bloom's taxonomy activities (AL+IBT)	Fall 2023	98	Questions at five Bloom's taxonomy categories: *Remember*, *Understand*, *Apply*, *Analyze*, *Evaluate*	Mandatory problems at *Remember* and *Apply* levels; bonus questions at *Understand*, *Analyze*, and *Evaluate* levels	*Remember* and *Apply* levels	Individual ICAs at *Understand*, *Analyze*, and *Evaluate* levels; small-group discussion-based solving of *Apply* problems

The AL+GBT section had 100 students while the AL+IBT section had 98 students. Thus, the results presented in this paper have been normalized. No significant difference was found among the GPAs of students in each section (p-value=0.246). The grading distribution for both sections was 10% HW, 5% In-class activities/participation, 15% Quiz, 20% Midterm 1, 20% Midterm 2, and 30% Final Exam.

Both sections had an active learning environment with individual online polling questions for each chapter using Mentimeter (most questions at the *Remembe*r level) and group-based discussion on *Apply* type numerical problems. Mentimeter is an interactive online platform that allows the audience to provide real-time feedback/ideas during classes or meetings through online polls [11]. Additional ICAs at three Bloom's taxonomy levels — *Understand*, *Analyze*, and *Evaluate* — were originally planned for three traditionally difficult chapters: Chapter 2 (Fluid Statics), Chapter 6 (Differential Analysis of Fluid Flow), and Chapter 8 (Viscous Flow in Pipes). However, due to instructor sickness, missed lectures for Chapter 2 were covered with Zoom recordings and substitute instructors. Thus, the planned interventions were executed only in Chapters 6 and 8. In the AL+GBT section, these activities were designed to be implemented in small groups of 2-4 students seated at each table and only one student from each table was instructed to submit the answer to the respective question via the Canvas online learning management system after discussion with their peers. The instructor and graduate teaching assistant walked around the classroom during these activities to answer any clarifying questions. In contrast, in the AL+IBT section, the supplementary ICAs were intended to be individual quizzes that each student would answer without discussion with classmates. Students could clarify any doubts by consulting the instructor or the graduate teaching assistant. Both types of activities were implemented at the end of the lecture period in student-centered technology-rich active learning classrooms within the same building on campus. The AL+GBT was allotted 15 minutes while 10 minutes was budgeted for the AL+IBT section since it was presumed that discussion with peers before typing up answers would require additional time.

As noted in Table 1, both class sections had the exact same homework, take-home quiz questions, and exam problems. To emphasize correct solution strategy rather than penalizing computing mistakes (as well as reduce grading burden on undergraduate graders), 80% of homework scores were graded for completion, while the other 20% was graded for accuracy. However, the bonus questions in the *Understand*, *Analyze*, and *Evaluate* categories in the homework were all graded for accuracy. The quizzes were take-home, open-book/notes/homework, and one hour long. Each quiz consisted of a mandatory section with *Remember* and *Apply* problems and a bonus section with *Understand*, *Analyze*, and *Evaluate* questions. The two midterm exams and the final only had problems at the *Remember* and *Apply* labels due to these being common exams held with other class sections not participating in this study.

Results

Chapter 2: Fluid Statics

Figure 1 shows the percentage of students receiving full/partial credit on problems at the three additional Bloom's taxonomy categories — *Understand* (1 problem), *Analyze* (1 problem), and *Evaluate* (3 problems) — for HW 2. Students typically had one week to complete the homework after it was assigned and could access instructor/teaching assistant office hours as needed. Note that no ICA intervention was made for this chapter due to instructor illness. Thus, student performance in formative and summative assessments for this chapter can be used as a baseline. We group students receiving partial and full credit together because partial credit indicates correct understanding of the problem and some progress in the correct solution direction even if the final numerical answer is incorrect. 77%, 85%, and 74% of AL+GBT students received credit at questions at the *Understand*, *Analyze*, and *Evaluate* levels while 83%, 91%, and 90% of the AL+IBT section received credit at these three levels. However, using the Chi-Square test, no significant statistical difference was found between the performance of students from the two class sections at any of the above-mentioned cognitive levels. Both sections performed best on the *Analyze* level, as demonstrated in Figure 1.

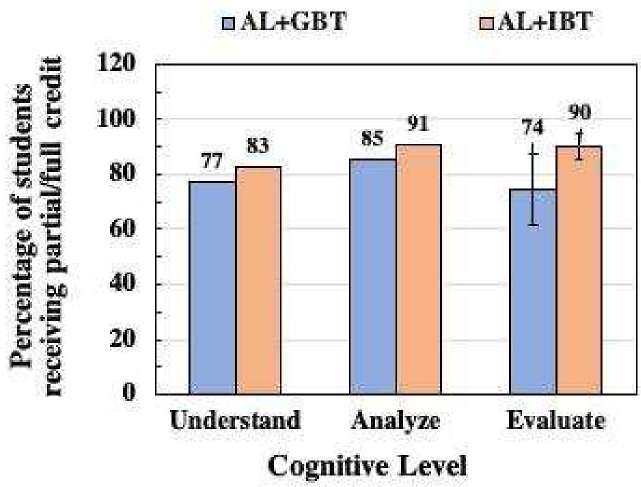
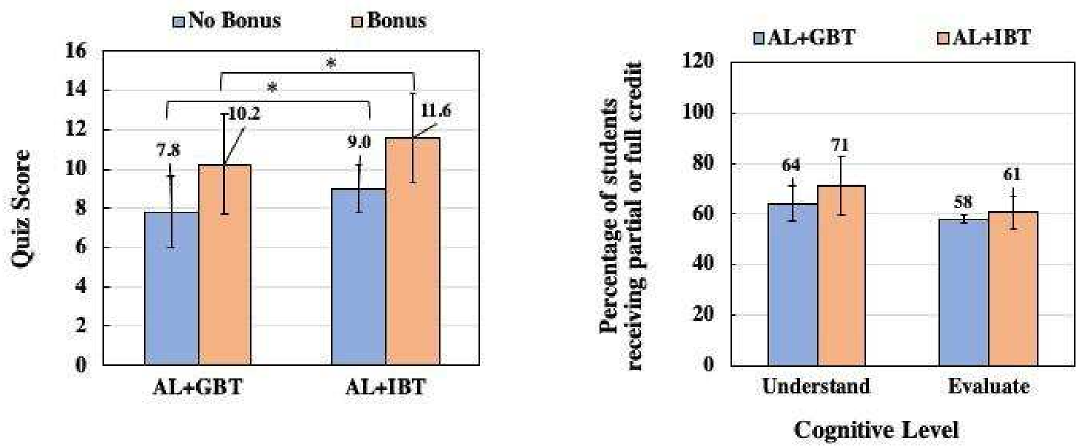


Figure 1: Percentage of students from the two class sections who received partial/full credit on the questions in the homework assignment for Chapter 2 (AL+GBT in blue and AL+IBT in orange). There was one *Understand*, one *Analyze*, and three *Evaluate* problems. Error bars represent the standard deviations.

Figure 2 shows the overall quiz score and the percentage of students receiving full/partial credit on problems at each of the cognitive levels evaluated in Quiz 2. The total points achievable was 10 for the main section with *Remember* and *Apply* problems and 4 for the bonus section. The overall score with and without bonus points was 10.2 and 7.8 for the AL+GBT section and 11.6 and 9.0 for the AL+IBT section, respectively. Mann-Whitney tests showed that the AL+IBT students performed significantly better than the other section. Note that each of the bonus categories had multiple questions. A greater percentage of students from each section received full/partial credit on questions at the *Understand* level than the *Evaluate* level likely because *Evaluate* is a higher cognitive level.



(A) (B)

Figure 2: Student performance on Quiz 2. (A) Total quiz scores (with and without bonus), out of 14 points. (B) The percentage of students who received partial or full credits on the quiz problems at different cognitive levels. Error bars represent the standard deviations.

The grades for students from the two class sections on questions from Chapter 2: Fluid Statics on Midterm 1 were compared using a Mann-Whitney test. As demonstrated in Figure 3, the AL+IBT section (average 91%) performed significantly better than the AL+GBT students (average 85%). Sample exam questions can be found in Appendix A4.

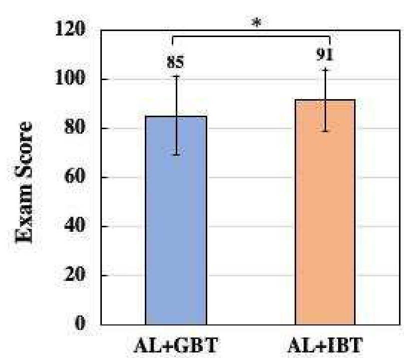


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Figure 3: Average student performance on Midterm 1 on content from Chapter 2: Fluid Statics.

Thus, as a baseline, both class sections had similar GPAs and similar performance on the homework for Chapter 2. However, without any novel in-class intervention, the AL+IBT section outperformed their peers on both the quiz and midterm.

Chapter 6: Differential Analysis of Fluid Flow

Three ICAs were administered for Chapter 6 in both sections, one at each of the additional Bloom's Taxonomy categories: *Understand, Analyze*, and *Evaluate*. Each of the activities was held on a different lecture day and the problems were introduced in order of low to high categories, i.e., first the *Understand* question, then *Analyze* and finally *Evaluate*. Sample questions can be found in Appendix A1. As shown in Figure 4, the AL+GBT section performed similarly on questions at the *Understand* and *Analyze* levels while getting a much lower grade for the *Evaluate* problem. The greatest percentage of students in the AL+IBT section received full credit for the *Analyze* problem with the lowest percentage being for the *Evaluate* problem. This result could be linked to the difficulty levels of the questions (refer to Appendix A1) as well as the *Evaluate* category depicting a higher level of learning. Overall, based on a Chi-Square analysis, no significant statistical relationship was found between type of ICA (group vs. individual) and the percentage of students receiving scores at different Bloom's taxonomy tiers. Students from both sections also individually attempted online polling questions at the *Remember* level and worked in groups on numerical problems at the *Apply* level, neither of which were submitted for a grade.

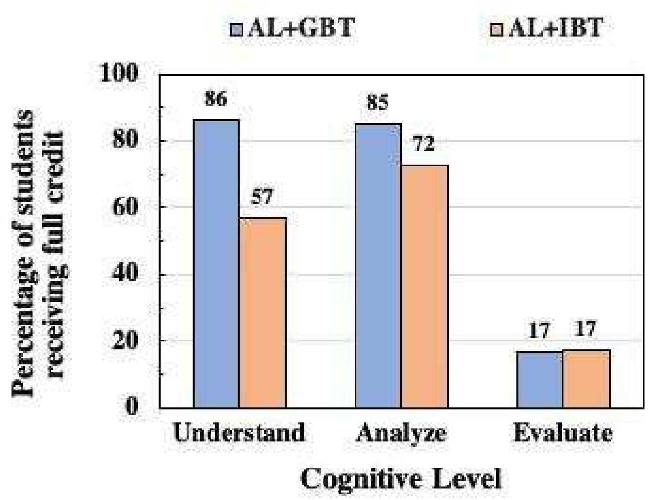


Figure 4: The percentage of students receiving full credit on the ICAs for Chapter 6: Differential Analysis of Fluid Flow in the AL+GBT (in blue) and AL+IBT (in orange) sections.

The percentage of students receiving partial/full credit for the homework problems at the supplemental Bloom's Taxonomy categories for Chapter 6 is depicted in Figure 5. Sample HW problems can be found in Appendix A2. 93%, 95%, and 95% of the AL+GBT section received credit at the *Understand*, *Analyze,* and *Evaluate* levels, while the percentages were 89%, 93%, and 82% for the AL+IBT section, respectively. These percentages are generally higher than those seen on HW 2. The difficulty level of the HW questions in each category as well as the chapter content might have influenced these results. Based on a Chi-square analysis, both class sections performed in a statistically similar fashion, a trend that mimics what was observed for Chapter 2. Since students could receive guidance from the teaching assistant/instructor on their solution strategy if they attended office hours and could also collaborate with peers as long as they were not plagiarizing, the performance in the homework seems to be statistically indistinguishable across the two class sections.

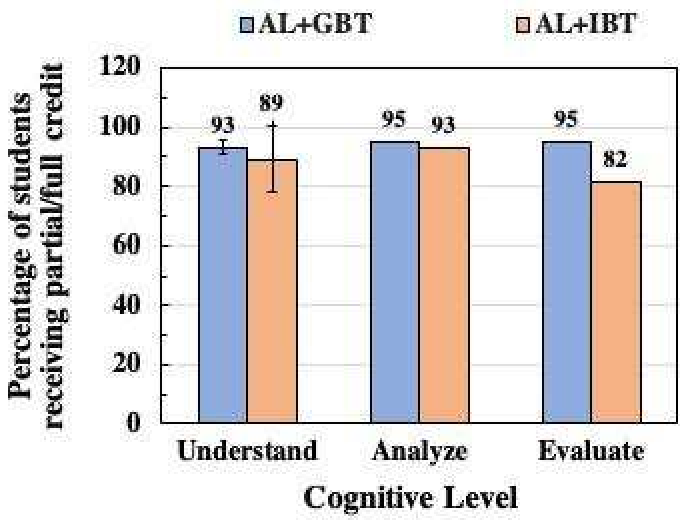
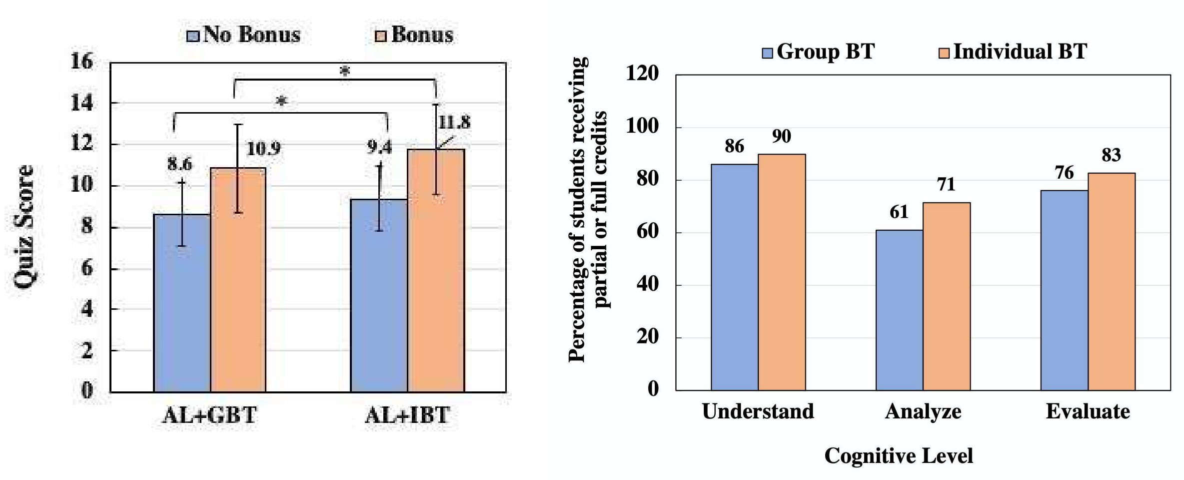


Figure 5: Percentage of students from the two class sections who received partial/full credit on the questions in the homework assignment for Chapter 6 (AL+GBT in blue and AL+IBT in orange). There were three *Understand*, one *Analyze*, and one *Evaluate* problems. Error bars represent the standard deviations.

Figure 6 shows the overall quiz score and the percentage of students receiving full/partial credit on problems at each of the supplemental cognitive levels evaluated in the quiz for Chapter 6. The total points achievable was 10 for the main section with *Remember* and *Apply* problems and 3 for the bonus section. The overall score with and without bonus points was 10.9 and 8.6 for the AL+GBT section and 11.8 and 9.4 for the AL+IBT section, respectively. Similar to what was observed in Chapter 2 using Mann-Whitney tests, the AL+IBT students performed significantly better than the other section. There were multiple problems at the *Remember* and *Apply* levels, and one question each at the *Understand*, *Analyze*, and *Evaluate* levels. Out of the three bonus categories, both class sections performed best at problems at the *Understand* level. This result seems reasonable since *Understand* is the lowest hierarchical level of Bloom's Taxonomy among those three. However, it is interesting to note that both groups had the worst achievement on the *Analyze* problem, which was not the highest cognitive level tested on.



(A) (B)

Figure 6: Student performance on Quiz 6. (A) Total quiz scores (with and without bonus), out of 13 points. (B) The percentage of students who received partial or full credits on the quiz problems at different cognitive levels. Error bars represent the standard deviations.

The grades for students from the two class sections on questions from Chapter 6: Differential Analysis of Fluid Flow on Midterm 2 were analyzed. As demonstrated in Figure 7, based on a Mann-Whitney test, the AL+IBT section (average 74%) performed significantly better than the AL+GBT students (average 58%). Thus, after the in-class Bloom's Taxonomy question interventions, the percent difference in performance between the two sections increased from 7% in Midterm 1 (Figure 3, average 85% AL+GBT vs 91% AL+IBT) to 27% (Figure 7, average 58% AL+GBT vs 74% AL+IBT) in Midterm 2. It must be clarified here that the topics in Midterm 1 have been traditionally considered by students to be easier than the content tested on Midterm 2. Therefore, the individual performances for each section declined in Midterm 2, as expected based on instructor experience.

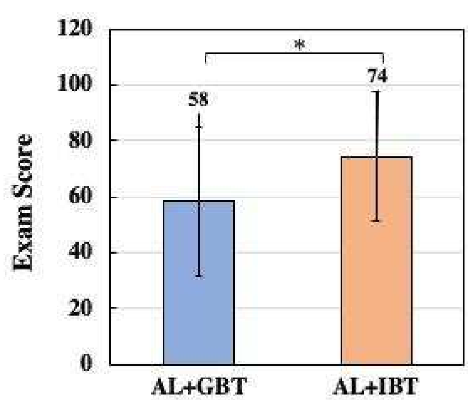


Figure 7: Average student performance on Midterm 2 on content from Chapter 6: Differential Analysis of Fluid Flow

Thus, to summarize trends observed in Chapter 6, both class sections had statistically similar performance for two of the formative assessments: the HW and ICAs. However, the AL+IBT section performed significantly better than the AL+GBT students in the quiz and the summative assessment (i.e., midterm exam).

Chapter 8: Viscous Flow in Pipes

Two ICAs were administered for Chapter 8 in both sections, one at the *Analyze* level and the other at the *Evaluate level*. Similar to Chapter 6, a third ICA was planned at the *Understand* level and implemented in the AL+GBT section. However, due to the lecture pace, it could not be administered in the AL+IBT section and thus, the results are not included here. Each activity was held on a different lecture day and the problems were introduced in order of category hierarchy. As shown in Figure 8, the AL+GBT section performed significantly better than the AL+IBT students, particularly on the *Analyze* problem. 81% and 85% of the AL+GBT students received credit on the *Analyze* and *Evaluate* questions, respectively, while the percentages were 5% and 79% for the AL+IBT section. However, when analyzing students receiving both partial and full credit on these questions (data not shown here), both AL+GBT and AL+IBT performed similarly in both categories. Thus, on this assessment, the ability to discuss ideas and solutions back and forth with peers allowed students to submit completely correct answers instead of being partially correct.

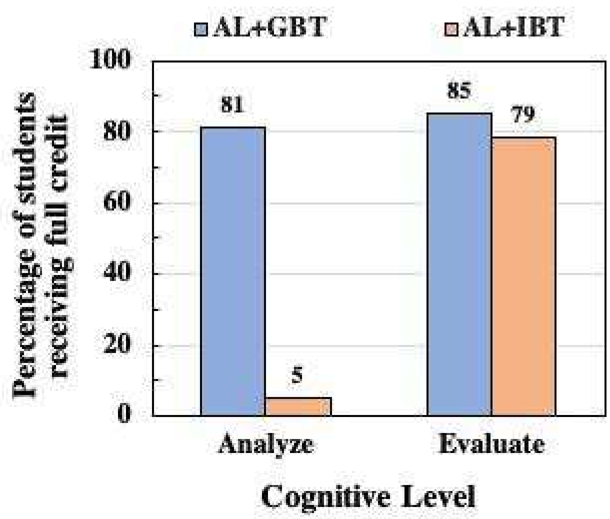


Figure 8: The percentage of students receiving full credit on the ICAs for Chapter 8: Viscous Flow in Pipes in the AL+GBT (in blue) and AL+IBT (in orange) sections.

Figure 9 shows the percentage of students receiving full/partial credit on problems at the three additional Bloom's taxonomy categories — *Understand* (2 problems) , *Analyze* (1 problem) , and *Evaluate* (2 problems) — for HW 8. 91%, 73%, and 40% of AL+GBT students received credit at questions at the *Understand*, *Analyze*, and *Evaluate* levels while 90%, 89%, and 48% of the AL+IBT section received credit at these three levels. As observed in HW 2 and HW 6, no significant statistical difference was found between the performance of students from the two class sections at any of the above-mentioned cognitive levels using a Chi-Square test. Both sections performed best on the *Understand* level and worst at the *Evaluate* level on HW 8, as demonstrated in Figure 9. When comparing with HW 2 and HW 6, no general trend can be found regarding the question category that is 'easiest' for the two class sections nor can a relationship be derived between Bloom's taxonomy tier (i.e., higher vs lower) and student performance.

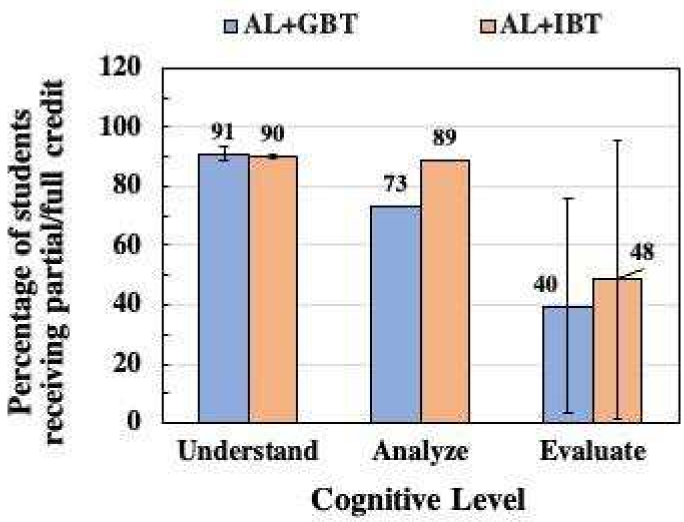
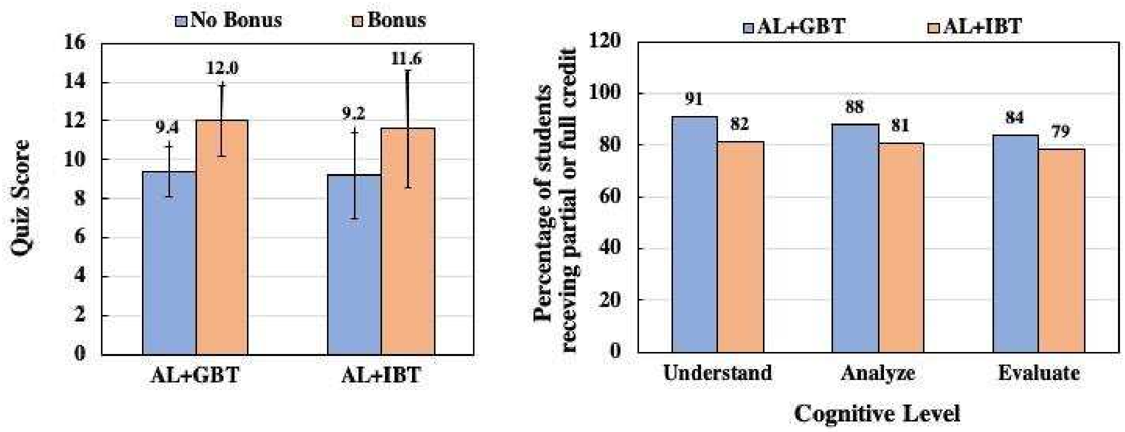


Figure 9: Percentage of students from the two class sections who received partial/full credit on the questions in the homework assignment for Chapter 8 (AL+GBT in blue and AL+IBT in orange). There were two *Understand*, one *Analyze*, and two *Evaluate* problems. Error bars represent the standard deviations.

Figure 10 shows the overall quiz score and the percentage of students receiving full/partial credit on problems at each of the additional cognitive levels evaluated in the quiz for Chapter 8. The total points achievable was 10 for the main section with *Remember* and *Apply* problems and 3 for the bonus section. There were multiple problems at the *Remember* and *Apply* levels, and one question each at the *Understand*, *Analyze*, and *Evaluate* levels. Interestingly, both class sections performed uniformly across each Bloom's Taxonomy category. The overall score with and without bonus points was 12.0 and 9.4 for the AL+GBT section and 11.6 and 9.2 for the AL+IBT section, respectively. Contrary to what was observed in Chapter 2 and Chapter 6, based on Mann-Whitney tests, the AL+IBT students performed in a statistically similar fashion to the AL+GBT section.



(A) (B)

Figure 10: Student performance on Quiz 8. (A) Total quiz scores (with and without bonus), out of 13 points. (B) The percentage of students who received partial or full credits on the quiz problems at different cognitive levels. Error bars represent the standard deviations.

The grades for students from the two class sections on questions from Chapter 8: Viscous Flow in Pipes on the final exam were analyzed. As demonstrated in Figure 11, based on a Mann-Whitney test, no significant statistical difference was found between the AL+IBT section (average 89%) and the AL+GBT students (average 92%). This result is contrary to what was observed in Midterms 1 and 2.

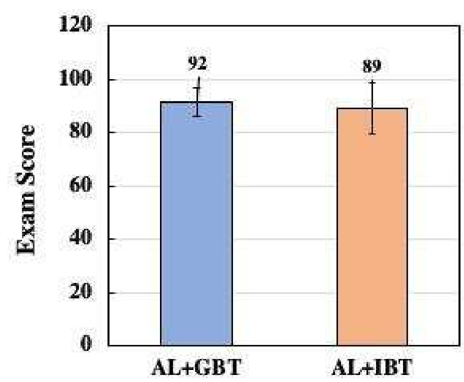


Figure 11: Average student performance on the final exam on content from Chapter 8: Viscous Flow in Pipes

Thus, to summarize trends observed in Chapter 8, both class sections had statistically similar performance for HW, quiz, and final exam. However, the AL+GBT section performed significantly better than the AL+IBT students in the ICAs.

A summary of the results observed from each chapter and each assignment type is shown in Table 2. Based on the limited data available, the effect of method of administration of in-class Bloom's taxonomy activity on student performance in formative and summative assessments is inconclusive. Additional iterations of this intervention in future semesters across all chapters of the course can reveal whether group or individual in-class activities are more likely to improve course grades.

Table 2: Summary of performance differences for the two class sections (AL+GBT and AL+IBT) on each assignment type from each chapter

Chapter Number (and content)	In-class Bloom's Taxonomy Intervention	ICA	HW	Timed take-home quiz	Exam
2 (Fluid Statics)	No	N/A	No statistical difference	AL+IBT performed better	AL+IBT performed better
6 (Differential Analysis of Fluid Flow)	Yes	No statistical difference	No statistical difference	AL+IBT performed better	AL+IBT performed better
8 (Viscous Flow in Pipes)	Yes	AL+GBT performed better	No statistical difference	No statistical difference	No statistical difference

Limitations

The homework and take-home quizzes for each section were graded by two different undergraduate graders, while the exams and ICAs were graded by two different graduate teaching assistants. While each of them followed detailed grading rubrics provided by the same instructor, personal grading philosophies (such as devoting sufficient time to comprehend partially correct answers and thereby allocate appropriate credit) and level of understanding of fundamental concepts (graduate vs undergraduate graders) could have influenced the results. Due to logistical limitations of allowable responsibilities and cap on maximum working hours, it is currently not possible to have the same grader for each assignment across the sections. Secondly, the innovations were implemented in two out of the nine chapters covered in this course, which led to limited results and the inability to draw overarching conclusions. In future semesters, similar interventions will be carried out in other chapters. Additionally, only one student from each table in the AL+GBT section was asked to submit the ICAs after discussion with peers. This method does not reveal whether the group activities increased understanding for each individual student or whether some students received full credit by relying on their peers. In the future, each student will be asked to turn in their response to the ICAs after discussion with their classmates to evaluate if the group discussion enhanced understanding for each individual. Furthermore, the student groups were formed informally by the students and varied during each lecture period based on where students chose to sit in the classroom. Thus, the groups might not have been uniform in terms of academic capability and the role of group formation on student performance and learning experience was not analyzed.

Conclusion

This paper investigates the effect of individual vs. small group cooperative Bloom's Taxonomy ICAs on student performance in formative and summative assessments in an undergraduate Fluid Mechanics course. While most undergraduate assignments only include problems at *Remember* and *Apply* levels, these ICAs were introduced at three additional Bloom's Taxonomy levels — *Understand*, *Analyze*, and *Evaluate* — in two class sections taught by the same instructor. Students from one class section worked on the ICAs in small groups of 2-4 while the other section was asked to complete the same activities individually. In both sections, these ICAs were administered on different lecture periods using the last 10-15 minutes of class. The interventions were implemented in two traditionally difficult topics: Chapter 6: Differential Analysis of Fluid Flow and Chapter 8: Viscous Flow in Pipes. Student performance in three types of formative assessments — ICA, homework, and take-home quizzes — and one kind of summative assessment — in-person midterm/final exams — was compared. Both class sections had statistically similar performance in the ICAs for one chapter while the AL+GBT section performed significantly better than the AL+IBT students on the second one. Additionally, the two class sections had similar achievement on both homework assignments, likely because they were able to access instructor/teaching assistant office hours and discussion with peer groups. On the quizzes and midterm/final exams, the AL+IBT section performed significantly better than the AL+GBT section on content from one chapter while the scores were similar on assessments covering the second chapter. Thus, no general trend about the effect of the type of ICA on student scores on formative or summative assessments can be gleaned from the limited data collected in this study. In the future, this study will be extended to include other chapters of the course in an effort to collect more data and be able to draw generalizations. Further, an end-of-semester survey will be administered to determine the impact of the two in-class active learning methods on student satisfaction and perceived learning. Finally, the role of formal self-selected group formation on student performance and attitudes will be investigated.

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Appendix A1: Sample In-class Activity Questions from Chapter 6: Differential Analysis of Fluid Flow at the three additional Bloom's Taxonomy categories

Bloom's Taxonomy Category	Problem
Understand	Explain why incompressible fluids do not undergo linear deformation.
Analyze	How are the continuity and linear momentum equations in Chapter 6 different from/similar to the continuity and linear momentum equations we learnt in Chapter 5?
Evaluate	Evaluate which boundary conditions on velocity is/are correct *[in a given problem]* and justify your answers.

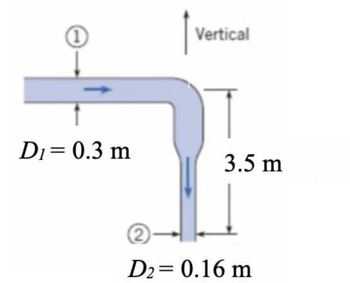
Appendix A2: Sample HW Problems from Chapter 6: Differential Analysis of Fluid Flow at each of the five Bloom's taxonomy categories included in this study.

Bloom's Taxonomy Category	Problem
Remember	Indicate whether the following statements are true or false. For false statements, explain why it is false: The curl of the velocity vector is zero for irrotational flow.
Understand	Explain why the volumetric dilatation rate is zero for incompressible fluids.
Apply	An incompressible viscous fluid is placed between two large parallel plates as shown. The bottom plate is fixed, and the upper plate moves with a constant velocity, U. For these conditions the velocity distribution between the plates is linear and can be expressed as $$u = U\frac{y}{b}$$ Determine **(a)** the volume dilatation rate

	(b) the rotation vector **(c)** the vorticity **(d)** the rate of angular deformation
Analyze	How is the rate of angular deformation that you calculated in part (d) similar/different to the ‘rate of shearing strain’ concept that we discussed in Chapter 1?
Evaluate	In a certain steady, two-dimensional and two-directional flow field, the fluid density varies linearly with respect to the coordinate *x*: that is, $\rho = Ax$ where A is a constant. If the x component of velocity is given by the equation $u = y$ (a) Determine an expression for v (the y component of the velocity). [*Apply*] (b) Based on your result in part (a), comment if you can determine an explicit expression for v. Support your answer with valid reasons. [*Evaluate]*

Appendix A3. Sample Quiz Problem from Chapter 8: Viscous Flow in Pipes. The same take-home quiz was administered to both class sections on the same day.

Gasoline (ρ = 800 kg/m^3, μ = 6.7 x 10^{-4} kg/m.s) steadily flows in a vertical pipe shown below at a velocity of 2 m/s at section 1. The pressure at section 1 is 124 kPa, and the total head loss between sections 1 and 2 is 2.75 m. (1 kPa = 1000 kg/m.s^2, g= 9.81 m/s^2)



Required section

2.1 Calculate the Reynolds number at section 1. Is this flow laminar or turbulent? **[2 pts]**. [*Apply*]

2.2 Calculate the gasoline velocity at section 2 **[2 pts]**.[*Apply*]

2.3 Calculate the pressure at section 2. Assume α= 1.0 at all locations **[4 pts]**. [*Apply*]

Bonus section

(a) ***Explain*** the reasoning behind the assumption for kinetic energy coefficients (given in 2.3) ***equal to 1.0 at all locations***. **[1 pt]** [*Understand*]

(b) Suppose the total head loss was not provided in problem 2. **How would your solution procedure for 2.3 be different? What additional information you would need?** 'Solution procedure' refers to the steps you take, in correct order, and equations and assumptions that you use, to solve the problem. **[1 pt]** [*Analyze*]

(c) If the pipe shown above was aligned horizontally, evaluate (without performing any numerical calculations), if the pressure at section 2 (calculated in 2.3) would increase/decrease/stay the same. **Include an explanation to support your answer**. Assume all other parameters remain the same as in the original problem. **[1 pt]** [*Evaluate*]

Appendix A4: Sample Exam Problem from Midterm 1 on Chapter 2: Fluid Statics

A temporary seawall consists of a long vertical wall of height H = 20 ft that is anchored to the seafloor at point A. The anchoring mechanism at point A can resist a maximum moment (torsional strength) of 20,000 *lb_f-ft per foot of wall length*. The temporary seawall is used to isolate seawater (γ_s= 64.0 lb_f/ft^3) from freshwater (γ_f = 62.4 lb_f/ft^3). Due to storms or tides, the depth of the seawater (h_2) may rise or fall while the depth of the freshwater (h_1) remains constant at 15 ft. What are the **minimum and the maximum values** of depth of the seawater (in ft) that the wall can withstand without collapsing **due to torsional failure, or by over-topping of the seawater**? [*Apply*]