2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
ASEE
Paper ID #37291

Classroom Climate Analysis of Flipped Structural Classrooms with Active Learning: A Case Study

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Abstract

From passive instruction to highly collaborative active learning, students' success in the classroom varies based on a variety of factors. With different possible learning constructs, how the classroom environment, or climate, is structured can make a significant impact on student success. When developing or adopting new pedagogical approaches, both faculty and student perspectives need to be better understood. To help fill the gaps in active learning knowledge from a student perspective, this research looked at different active learning classroom environments by assessing them with the established College and University Classroom Environment Inventory (CUCEI). The focus of this paper centers on a single instructor that has flipped then added active learning techniques across a steel design class and a computer modeling class. To see if, and to what extent, active learning impacts the classroom climate, data from before and after active learning were compared. As part of this, CUCEI compares climates based on seven psychosocial dimensions: personalization, involvement, student cohesiveness, satisfaction, task orientation, innovation, and individualization. This paper examines: 1) how climates change between traditional and active delivery, 2) does the quantity of active learning change the climate, and lastly, 3) is there a relationship between climate and student achievement.

Results show that climate perspectives do not necessarily increase or could possibly decrease when active learning is deployed. While much of the data was inconclusive, due to small sample sizes and a lack of statistical evidence, there were several observed trends that provide rich insights for educators. First, the steel course had several unique instances compared to the modeling class. In steel design, four psychosocial dimensions can best predict grades while for computer modeling only two psychosocial dimensions predict grades. Additionally for steel design, the most important climate characteristics for success are: students enjoy going class; students know exactly what has to be done; and faculty letting students decide some of the success metrics. As for computer modeling, key climate factors include: the level of in class instructor real-time support and instructors giving ample opportunity for students to pursue their class interests.

Keywords: Classroom Climate, Psychosocial, Active Learning, Design, Modeling, Student Achievement

Classroom Environments and Active Learning

In education literature, it has been documented that student learning gains can be enhanced by introducing more active learning environments [1]. From the mid-1990's to the present, many researchers have experimented with classroom environments that have varied technology support, classroom arrangement, lecture delivery styles, and in-class engagement techniques [2]. The fundamental intent to develop these Active Learning (AL) classrooms [3] and/or Technology-Enabled Active Learning (TEAL) classrooms [4] were to better promote and more comprehensively educate [5]. One important component to AL and TEAL is the environment. Formal educational environments can be described with respect to tone, ambience, culture, and atmosphere [6]. A well refined educational environment can translate into better communication [7], stronger rapport building [8], lower learning anxiety [9], and strengthen teacher-student interactions [10].

The modern university classroom continues to evolve whether it be activities, the class format and delivery or even the room's configuration [11]. When evolving these classrooms, Hadiyanto [12] states that changes can be done at the university level, college level, the department level, and/or at the instructor level. Often times in the university, college, or department levels, administrators control the development of the actual spaces while the instructor level is more delivery centered [13]. For the instructor level, emphasis is often placed on varying teaching techniques or activities and assessments [14].

Active learning remains a continued point of interest in engineering education research. Its popularity is centered on constructivist principles that promote key technical and professional skills in ways not possible through passive "chalk and talk" methods [11,15]. Active frameworks have many benefits such as: student preference [16], self-efficacy [17], and student engagement [18]; all of which contribute to the classroom climate. Perhaps the most popular method for active learning in recent engineering education literature is the inverted or flipped classroom where lectures are moved outside the class time [12-13]. A meta-analysis by Lo and Hew [19] involving 29 engineering education studies concluded that flipped classrooms promote student achievement with evidence suggesting that self-paced learning before class and increased problem-solving during class were the predominant reasons [20]. Another systematic review by Karabulut-Ilgu et al. [21] on the flipped classroom highlighted the following benefits: flexibility, enhanced interaction with peers and instructors, professional skills development, and student-to-student engagement.

Although most engineering studies have found no differences in measured learning gains [16,22-23], several studies have [24-25]. These conflicting results have given faculty "push back" support for not adopting due to "significantly" more preparation time [26] with limited room to overhaul the course reasons often given. In looking to study other possible flipped values, Velogel and Zappe [27] looked at if flipped classrooms created a more motivating climate. In Copridge et al. [28] their investigations found that instructor presence, better feedback, and just-in-time conversations were identified as important features towards classroom success which novice flippers may miss early.

To aid faculty in deciding if their class has advantages to be actively taught, a broader spectrum still needs investigated. As such, this study starts to explore climate, course type, and active learning (within a structural curriculum). This early case study work can help us better understand perception gaps verses learning gains.

Measuring Classroom Environments

Learning environment measurement research began in the 1960s when the first version of a Learning Environment Inventory (LEI) was developed [6]. Over the subsequent 60+ years of developing and refining LEIs, the field of learning environments has undergone growth, diversification, and internationalization [29]. Fraser and Walberg [30] noted that measuring classroom climates can take many forms, including [31]: students' and teachers' perceptions, external observer's direct observations, and systematic coding of classroom communication.

Across classroom environment literature, there are nine documented and available measurement instruments. Of these nine instruments, only two have been developed for higher education: CUCEI (College and University Classroom Environment Inventory) and SLEI (Science Laboratory Learning Environment Inventory). CUCEI is broader scoping while SLEI was specifically suited to assess science laboratory classes. Other studies have drawn from and modified these instruments to better suit a particular context. Representative adjustments have included, but are not limited to: 1) computer-assisted learning; 2) an expansion into new domains: investigation, open-endedness, organization, material environment and satisfaction; 3) gender equity and resource adequacy; and 4) student perceptions of specific teacher behaviors [32].

These instruments, have the capability to not only measure perceptions of 'actual' or human experienced environments but also 'preferred' / ideal what is possible environments. Item wording is similar for 'actual' and 'preferred' with only slightly different instructions [33]. Lastly, these instruments can be tailored to examine the student side or the teacher side. From the student side, studies have shown that this perspective provides a reliable vantage point to make judgements about classrooms due to students having encountered many different learning environments in their education while also experiencing enough classes to form accurate impressions of what works or doesn't[30].

For this research study, CUCEI with 'actual' wording was selected given its historical success [27]. Here the CUCEI was used to investigate the effect of the classroom flip on the classroom climate.

College and University Classroom Environment Inventory (CUCEI)

Higher education classroom climate research was conducted by Fraser in the late 1980's [29] and was refined into the 1990's [32-33]. From these studies, a refined framework was developed, validated, and enhanced. The resulting higher education instrument was the CUCEI [34]. The CUCEI inventory determines student perceptions around the seven psychosocial dimensions: personalization, involvement, student cohesiveness, satisfaction, task orientation, innovation, and individualization. Each of the seven CUCEI dimensions (or scales) were developed to cover Moos' categories [35] for conceptualizing all human environments. Moos' three general categories are: the relationship (R) dimension (covered by personalization, satisfaction, and student cohesion), the personal development (P) dimension (covered by task orientation) and the system maintenance and system change (S) dimension (covered by innovation and individualization) [27].

The established CUCEI has seven scales with each containing seven items which use both negative (reverse) and positive scoring [34]. Table 1 clarifies the meaning of each CUCEI scale. Students were asked to state their level of agreement on each item with a 5-point Likert scale (strongly agree, agree, neutral, disagree, and strongly disagree). This instrument was rigorously (statistically) evaluated for reliability, internal consistency, and discriminant validity. As such, it will not be tested for brevity, sample size, and since the scales were not adjusted in this paper.

Table 1: CUCEI Scales and Descriptions

Scale	Moos Category	Scale Description
1: Personalization	R	Emphasis on opportunities for individual interactions between faculty and student, especially on the concern of student welfare.
2: Satisfaction	R	The level of enjoyment students have in the class.
3: Innovation	S	The extent for which the faculty plans unusual activities teaching techniques and assignments to create student learning.
4: Student Cohesion	R	The level of which students know, help, and are friendly towards each other during class.
5:Task Orientation	P	The extent to which class activities are clear and well organized.
6: Involvement	R	The extent to students actively and attentively participating in class features.
7: individualization	S	The scope of which students are able to make their own decisions based on interests, abilities, and rate of work along with allowing differential treatment.

Note: P = personal development dimension; S = system maintenance and system change dimension; R= relationship dimension.

Clark et al. [36] used the CUCEI in a flipped freshman engineering programing course while Marks and Ketchman [37] used it in a flipped sustainable engineering elective. Both studies found high student scores in personalization and low scores for individualization. These opposite ranges indicate that a flipped classroom has a supportive classroom climate but doesn't indicate if it is more supportive than a traditional lecture-based class. Strayer's [38] research compared a flipped statistics class to a traditional class where it was found that the flipped classroom resulted in higher values for innovation and involvement but lower values for task orientation. Vologel and Zappe's [27] study examined alternating course, content, and instructor. Their results indicated high scores for individualization, innovation, and task orientation in flipped settings. These studies recognized that flipped classrooms can be innovative and have involved students but they can also be negatively impacted by a lack of activity clarity. Other studies show that both students and lecturers prefer a classroom climate that is better than it actually is [38].

Research Study Design

This study investigated classroom climate dynamics across two structural courses at The Pennsylvania State University (Penn State) within the Architectural Engineering (AE) program: AE 401 and AE 530. AE 401 covers basic steel design while AE 530 is graduate class on computer modeling of building structures. Results from these two classes sought to answer or at least provide insights into the following research questions.

- Do climate perceptions improve with more active course/material vs. a more traditional delivery?
    - Answer based on: Comparing Pre- and Post- within AE 401 and AE 530
- Does the quantity of active learning change the classroom climate and in which ways?
    - Answer based on: Comparing Post- AE 401 and Post- AE 530 due to the 2nd hr. of class lab time.
- Does the classroom climate for the seven psychosocial dimensions change given active learning?
    - Answer based on: Comparing Pre- and Post- AE 401 and AE 530 for each of the seven CUCEI scales.
- Is there a relationship between classroom climate and student achievement?
    - Answer based on: CUCIE scores and students' grades.

To answer these questions, the previously defined CUCIE was adopted and distributed at the end of each course (last class). The completion of the CUCEI was optional yet encouraged where no extra credit was given. Additionally, traditional end-of-semester student evaluations (SRTEs) were available for review. Baseline (Pre-) classroom climate values were documented before changes were made. It should be noted that the baseline climate data was not used when making the active learning improvements. The only reference materials used were general and discipline specific literature towards flipped classroom. For this study, the same course instructor taught all offerings of all courses reported here. This attribute removed instructor personality and teaching style complexities that would compound the CUCEI results. That said, single instructor is a limitation to see what is more critical to climate: topic differences, active approaches, and/or instructor influences. Bias and limitations for this study are presented later.

Cohorts and Curriculum

In these two classes, student cohorts were 4th year students in a 5-year AE program. AE 401 is the first of two required steel design courses that all structural specializing students take in their 4th year fall semester and AE 530 is largely taken in 4th year spring semester by structural students in our integrated degree program. In addition, AE 530 could have M.Eng., M.S., and Ph.D. graduate students enrolled. No students previously took these classes in any of the pre- / post- offerings. Table 2 provides cohort descriptive summaries along with the CUCEI response rates. Benchmark courses (pre-active learning) were taught in Fall 2018 and Spring 2019 while the post-active learning courses were taught in Fall 2021 and Spring 2022.

Table 2: Class Cohort Descriptive Statistics

Cohort Variable	AE 401 (fall only)		AE 530 (spring only)	
	Pre-	Post-	Pre-	Post-
Male Count	14	27	15	21
Female Count	7	7	9	5
BAE/MAE students	21	34	21	25
MEng, MS, PhD	N/A	N/A	3	1
Response % (count)	85.7% (18)	61.7% (25)	80.9% (17)	88.5% (23)
Course* GPA of Respondents	3.41±0.18	3.46±0.30	3.49±0.10	3.46±0.18

*Note: based on the final grade of the class, not their total semester GPA standing.

Course Structure

Both courses were previously established within the program. Throughout this study, their educational intent did not change. To better understand these courses, the primary learning goals are listed in Table 3. AE 401 is a traditional undergraduate steel design class that focuses on key limit states within the AISC 360-16 specification. One unique attribute of AE 401 as compared to many civil engineering structural steel classes, is that it is scoped specifically for gravity systems including deck and joist design alongside composite steel beams. AE 530 looks at educating structural engineers on how to properly build structural models, behaviors to expect or plan to capture with a model, and how to minimize errors when modeling. AE 530 is unique in that it is not a finite element course; instead, focus is placed on primarily 2D and 3D lateral system models that investigates only analysis (no design).

Table 3: Course Goals.

Course	Goals
AE 401	1) Take on the role of a designer and create structural solutions in steel. 2) Apply knowledge to evaluate limit states to see if members that were designed correctly. 3) Create gravity system solutions knowing the limit states. 4) Prepare you for advanced systems design.
AE 530	1) Develop skill sets to minimize errors and find errors within structural models. 2) Establish comprehension of larger building behaviors that need captured and how to model them. 3) Develop intuition and judgement to eliminate a modelers black box concern. 4) Understand the fundamental necessity and purpose toward using models in structural engineering.

In the post- offerings, both AE 401 and AE 530 were restructured from traditional lecture on board/PowerPoints with examples to that of a flipped class approach. In flipping AE 401, videos were a mix of PowerPoints and light board writing videos resulting in 105 videos (2 to 13min each; M=6.75min.). For the AE 530 flip, videos were mostly PowerPoints due to the graphical complexity with a total of 115 videos (2.5 to 13.25min each; M=6.75min.). Flipping each class freed up a total of 12hrs for AE 401 and 16hrs for AE 530 across a 15 week duration. Examples were still done in class. It was debated early on whether to flip examples but it was not done so that real-time engagement and reflective questioning opportunities remained. Having shifted 12 or 16hrs to pre-class time allowed for more interactive examples / scenarios, as well as, time to work on assignments. Here, examples were increased by approximately 10%. Table 4 provides a larger perspective of the before vs after the flipped restructuring. One unique attribute between AE 401 and AE 530 is that even pre-intervention, AE 530 had ~45min of time for homework while AE 401 did not have any in class time for homework. The active enhancement in AE 530 lengthen the homework time while also providing opportunities for short interactive discussion scenarios to get students thinking broader. Additionally, more time provided more software interface talks to help eliminate often asked questions received in emails and/or office hours.

Table 4: Pre- and Post-Active Classroom Formats

Class	Representative Key Features	
	Pre-active Learning	Post-active Learning
AE 401	• Lectures on chalk / whiteboard were done in class. • 1-2 examples per key topic. • Homework questions answered in office hours or before class starts. • 12 homework and 3 exams.	• Flipped videos (10-25min total) with pre-quiz (~5min). • 2-3 examples per key topic. • Review video quiz answers recall key points for examples. • ~35min of work / example time per class. • 12 classes as pure work sessions. • 12 homework and 3 exams.
AE 530	• Typical class: 1hr of lectures on modeling theory in ppt format, ~15min of software overview, ~45min to work on the homework. • 3 classes dedicated pure work sessions. • 20 of 30 first hours had lectures. • Limited examples on model approach outside of the 15min overview. • 10 homework of creating models and explaining results.	• Flipped videos (25-45min total) with pre-quiz (~5min). • Review video quiz answers recall key points for examples. • 8 classes as pure work sessions. • Typical class: 30min on modeling examples and approaches, ~15min of software interface overview, ~1hr-15min to work on homework. • Self-guided tutorials. • 8 homework that is more iterative/comparative and tied to hand calcs.

All courses at Penn State University have a required minimum 45hrs. of workload per credit. These three credit courses are 15 weeks long, averaging 9hrs. of work per week (across in-class and out-of-class). AE 401 meets three times a week for 50 minutes each session for 45 meetings over the 15-week semester giving approximately 6hrs. of outside work. AE 530 meets twice a week for 120 minutes each time for 30 meetings over the 15-week semester giving approximately 5hrs. of outside work. From an assessment perspective, both AE 401 and AE 530 used a mixture of assessment styles so that no one assessment technique favored a particular student learning style or provided a major grade impact.

Classroom Climate Results

Presented in this section are the results from the CUCEI for both AE 401 and AE 530. Results are first described as a whole to provide a broad context. Following that, statistical techniques are presented to examine similarities and differences with both before (pre-) and after (post-) intervention sample sets. Knowing the limited sample sizes (Table 2), some statistical techniques were not possible or had less defined rigor (as will be noted). The statistical techniques used in each section are discussed at that moment for easier reading. When the CUCEI had reverse questions, each of those responses were inverted prior to data analysis so that the highest score was always a 5 and the lowest always a 1. Please note that in the following sections, scale refers to each of the seven psychosocial dimensions while items describe the seven prompts within each dimension.

Classroom Climate Descriptive Statistics and MANOVA

First the means (M) and standard deviations (SD) for each CUCEI scale were determined (Table 5). In looking at the means across AE 530 from pre- to post-, they all dropped from between 0.03 to 0.50 points. Within AE 401, the same pattern emerged where all seven scales had a means decrease between 0.09 to 0.70. In AE 530, the seven scales indicated minimal variance as the pre- range SD was 0.18 to 0.68 while the post-range for SD was 0.31 to 0.76. Both ranges were very narrow; yet, the range did close on four scales in the post intervention. Moving to AE 401 data, a similar trend in SD was present. Here, the seven scales showed little overall variance as the pre- range of SD was 0.31 to 0.76 while the post-range for SD was 0.39 to 0.60. AE 401's SD range shrunk for two scales and expanded for five scales. If we look at the standard error means (SEM) for both classes, they all are very small thus indicating consistency across students. Having the means drop is concerning when, according to literature, active learning should correlate well to several of the CUCEI scales where larger results were expected. As a result, a deeper dive into the scales was needed with more advanced statistics.

Table 5: CUCEI Scales' Descriptive Statistics

7 Scales of CUCEI	AE 401 (M ± SD ; SEM)		AE 530 (M ± SD ; SEM)	
	Pre (n=18)	Post (n-25)	Pre (n=17)	Post (n=23)
1: Personalization	4.90±0.31 ; 0.04	4.58±0.50 ; 0.04	4.92±0.18 ; 0.02	4.72±0.31 ; 0.05
2: Involvement	3.58±0.36 ; 0.13	3.49±0.39 ; 0.09	3.58±0.48 ; 0.12	3.48±0.36 ; 0.08
3: Student Cohesion	4.67±0.76 ; 0.04	3.97±0.61 ; 0.07	4.58±0.40 ; 0.05	4.07±0.76 ; 0.08
4: Satisfaction	4.63±0.54 ; 0.06	4.29±0.60 ; 0.05	4.28±0.68 ; 0.07	4.23±0.54 ; 0.05
5: Task Orientation	4.48±0.45 ; 0.08	4.40±0.44 ; 0.05	4.39±0.48 ; 0.07	4.37±0.45 ; 0.06
6: Innovation	3.80±0.48 ; 0.14	3.75±0.51 ; 0.07	3.42±0.55 ; 0.11	3.39±0.48 ; 0.09
7: individualization	4.29±0.52 ; 0.09	3.71±0.60 ; 0.09	4.03±0.33 ; 0.10	3.68±0.52 ; 0.10

Note: SEM = standard error mean; SD = standard deviation; M=mean
These values come from scale averages across the seven items.

To better understand the seven CUCEI scales, a multivariate ANOVA (MANOVA) was conducted. MANOVA was selected as it extends the capabilities of ANOVA by assessing multiple dependent variables simultaneously. For a typical MANOVA with larger samples typically uses a $p < 0.05$; with our small sample, our study used a $p < 0.10$. Three MANOVA simulations were undertaken. One for comparing pre- to post- AE 530, one for pre- to post- AE 401, and one for post- only AE 401 vs AE 530. These results are presented in Table 6. AE 530 pre- to post- scale averages were not significant (with a Wilks lambda = 0.776, p 0.273). Additionally, the post- only AE 401 / AE 530 scale average comparisons were not significant (with a Wilks lambda = 0.756, p =0.105). However, when running the AE 401 pre- to post-, the seven scales' averages were highly significant (with a Wilks lambda = 0.446, p <0.001). Table 6 provides the individual p values for the separate ANOVAs. From this MANOVA, it was found that student cohesiveness was greater in AE 401 pre-intervention. All other scales across both courses were statistically unaffected by the active learning delivery.

Table 6: Individual p values of the separate ANOVAs.

The 7 CUCEI Scales	p value		
	Pre-Post AE530	Pre-Post AE 401	Post AE 401- AE 530
Personalization	0.02	0.013	0.246
Involvement	0.48	0.477	0.948
Student Cohesion	0.017	<0.001	0.601
Satisfaction	0.807	0.034	0.734
Task Orientation	0.850	0.537	0.796
Innovation	0.864	0.710	0.016
Individualization	0.020	0.001	0.817

Note: each of the 7 scales reflects the average of all item responses.

Classroom Climate Regression and Correlation

To understand possible student perceptions relative to their actual performance, an examination using a step-wise multiple regression analysis was performed looking at the final course grade (Tables 7 and 8). From the regression simulation, six items "entered the equation" that could predict or at least better indicate student performance relative to the final grade. They were: satisfaction (item 6) task orientation (item 1), personalization (items 3 and 6) and individualization (items 6 and 7). Interestingly, when the step-wise regression looked at AE 401 and AE 530, the scales did not overlap for the different courses. As Table 7 shows, AE 401 had four performance indicators while AE 530 only had two. Due to the other non-statistical significant results presented earlier, regression validity is limited; yet, these scales can provide indications for faculty to be on the lookout for or be cognizant of when teaching.

Table 7: Step-wise multiple regression results

Model		R	R Square	Adjusted R Square	Std. Error of the Estimate	Item Predictors
AE 401	1	.482a	0.233	0.214	5.695	Sat_6
	2	.604b	0.365	0.333	5.245	Sat_6, TOr_1
	3	.661c	0.437	0.393	5.003	Sat_6, TOr_1, Per_6
	4	.704d	0.495	0.442	4.799	Sat_6, TOr_1, Per_6, Indiv_7
AE 530	1	.327a	0.107	0.083	3.669	Per_3
	2	.444b	0.197	0.154	3.525	Per_3, Indiv_6

Note: Dependent Variable: final grade

Pearson's Correlation (R) was utilized to look at possible trends between actual performance and the seven scales (averaged over all of their items) from a different perspective. For actual performance, the final course numerical grades were utilized. The resulting R values for each of the seven scales are listed in Table 9. AE 401 had only one scale with a significant correlation (student cohesion) yet it was negative and was only for the pre-intervention. The remainder pre- and post- active learning scales resulted in very weak relationships. When adding active learning, four scales got worse, and three improved (Table 9). Two scales switch from positive to negative (innovation and personalization). With active learning in AE 401, five were negative (an increase in one). Additionally with AE 401, one post- scale (task orientation) did improve positively while the rest moved more negative. With regards to AE 530, only involvement in the pre-active learning was significant, however, it was negative. After active learning, AE 530 had all seven scales moving positively from 4 being very weak, 2 being weak, and 1 being moderate to post having 2 being very weak and 4 being weak. While not significant, the numerical values were higher indicating some possible improvement. In comparing pre-active learning, AE 530 had only two negative relationships while AE 401 had four. Post-active learning AE 530 had no negative relationships while AE 401 had five. Due to the overall low correlation scores, more conclusions cannot be drawn to see possible impacts.

Table 8: Multi-Step Regression Coefficients examining Pre- to Post- Cohorts

Model			Unstandardized Coefficients		Standardized Coefficients	t	Sig.
			B	Std. Error	Beta		
Pre- to Post- AE 401	1	(Constant)	104.66	5.39		19.42	<.001
		Sat_6	-4.34	1.23	-0.48	-3.53	0.001
	2	(Constant)	93.43	6.31		14.82	<.001
		Sat_6	-5.38	1.19	-0.60	-4.53	<.001
		TOr_1	3.68	1.27	0.38	2.89	0.006
	3	(Constant)	98.16	6.38		15.39	<.001
		Sat_6	-4.73	1.17	-0.53	-4.04	<.001
		TOr_1	4.92	1.34	0.51	3.68	<.001
		Per_6	-2.88	1.29	-0.31	-2.23	0.032
	4	(Constant)	100.03	6.18		16.18	<.001
		Sat_6	-4.44	1.13	-0.49	-3.92	<.001
		TOr_1	5.28	1.29	0.55	4.08	<.001
		Per_6	-3.02	1.24	-0.33	-2.43	0.02
		Indiv_7	-1.37	0.66	-0.25	-2.09	0.043
Pre- to Post- AE 530	1	(Constant)	66.69	9.49		7.02	<.001
		Per_3	4.12	1.93	0.33	2.13	0.04
	2	(Constant)	70.02	9.27		7.56	<.001
		Per_3	4.79	1.89	0.38	2.54	0.015
		Indiv_6	-1.50	0.74	-0.30	-2.04	0.049

Note: Dependent Variable: final grade

Table 9: Scale Measures vs Performance Correlations

Scales	AE 401		AE 530	
	Pre	Post	Pre	Post
Personalization	0.09	-0.26	-0.31	0.24
Involvement	-0.05	-0.07	-0.56*	0.23
Student Cohesion	-0.75**	0.07	0.14	0.23
Satisfaction	-0.26	-0.30	0.21	0.14
Task Orientation	0.03	0.07	0.19	0.16
Innovation	0.08	-0.16	0.14	0.30
Individualization	-0.31	-0.37	0.03	0.01

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Classroom Climate Factor Analysis

A factor analysis was conducted with each of the seven scales and each of their seven items two times. The first time was merging the pre-active learning data from both classes. The second time was with merged active learning data. This data merging was done to look at climate factors for generalizable traits before and after flipping. These two factor analyses looked for patterns to see which item(s) had the most impact or influence within each scale. For this study, the factor analysis used the principal component analysis for extraction with a varimax rotation method and Kaiser Normalization. For pre- data, rotation converged in 10 iterations while for post- data, rotation converged in 11 iterations. While all items are related within a scale, knowing each items' rank can better describe smaller details of the classroom environment. Results presented in Table 10 provide some support for the prior discussions. Here, the top two identified items were identified. Between pre- to post- active learning, only four items were repeated while the remainder 24 were unique. Seeing this, we can see that small changes in climate perceptions were shifting. It should be noted that due to small sample sizes, some of the items resulted in being in the wrong factor (listed out of order but were lower within that factored grouping).

Table 10: Top two sub-scales identified from a factor analysis for each CUCEI scale

7 Scales	Pre AE 401 & AE 530	Post AE 401 & AE 530
Student Cohesion	Coh_4; Coh_5	Coh_5; Coh_6
Personalization	Per_1; Per_7	Per_2; Per_7
Innovation	Innov_4; Innov_5	Innov_3; Innov_4
Individualization	Indiv_3; Indiv_7	Indiv_1; Indiv_4
Involvement	Involv_1; Involv_7	Involv_5; Involv_6
Satisfaction	Sat_4; Sat_7	Sat_2; Sat_3
Task Orientation	TOr_2; TOr_5	TOr_2; TOr_3

Notes: left item is 1st and right item is 2nd from the factor ranking.
Abbreviations match the CUCEI survey at the end of the paper.

Classroom Climate Recorded Scores

In looking at the Likert Scale responses (1 to 5) distributions to each of the 49 items (Table 11), one might expect there to always be a full range of responses (1 to 5). This was not the case for the data investigated within this work. Across the data, many of the responses ranged from 1 to 5 but some were shorter and were located at the higher end of the Likert range. Not having many lower ranking scores was holistically encouraging that students were generally pleased with the environment (given percentage of 4 and 5's as indicated in Table 11). Examining AE 401 more closely, response bands remained fairly consistent between pre- to post- with most answers being in the 4 to 5 range. Involvement and innovation had the same range of replies while task orientation shrunk from 1 to 5 to a 2 to 5 showing post- had slightly better "control" of the tasks. The other four scales broadened their range. A similar review of AE 530 data showed that scores of 4 to 5 were the most common response in both pre- and post-. Here for AE 530, four scales remained the same range (involvement, satisfaction, innovation, and individualization) while the rest broadened.

Table 11: Range of Likert Scale Reponses for the CUCEI Scales

	AE 401				AE 530			
	Pre		Post		Pre		Post	
	Range	% of 4's & 5's	Range	% of 4's & 5's	Range	% of 4's & 5's	Range	% of 4's & 5's
Personalization	4 to 5	100	3 to 5	91	4 to 5	100	2 to 5	95
Involvement	1 to 5	60	1 to 5	57	1 to 5	62	1 to 5	52
Student Cohesiveness	3 to 5	98	2 to 5	69	3 to 5	96	1 to 5	78
Satisfaction	3 to 5	96	2 to 5	83	2 to 5	86	2 to 5	86
Task Orientation	1 to 5	94	2 to 5	89	2 to 5	91	1 to 5	88
Innovation	1 to 5	66	1 to 5	61	1 to 5	52	1 to 5	52
Individualization	4 to 5	83	1 to 5	61	1 to 5	77	1 to 5	58

Discussion

Referencing our established research questions, our goal was to investigate if active learning classrooms result in a more positively impacted classroom climate from the student perspective. Our discussion here focuses on each of our earlier defined questions summarized question by question.

Q1: Did climate perceptions improve with more active course/material vs. a more traditional delivery?

Given the data, there is a lack of conclusive statistical evidence that active learning improves the classroom climate perspective of these courses within this study. That is not to say this is a generalizable trend for courses outside of this study. For these two pre- post- data sets, there is descriptive evidence that active learning lowers the climate; yet, statistically with a MANOVA analysis, there was no statistical evidence. Prior work by Velegol and Zappe [27] prompted us to expect higher scores in personalization and student cohesion (as active learning ideally promotes a more supportive classroom) and higher scores in individualization and task orientation (here stronger self-efficacy can be built with active strategies). This was not the case though. For the innovation scale, changes were not observed or really expected. This no change is supported by no new cutting edge techniques or innovative activities were deployed. It should be noted that there were new examples that better tie topics to industry but they were not "innovative" so this trend is logical. Adding to this, the involvement scale and student cohesion scale are fairly subjective to the student cohort and their personalities / preferred learning styles [11,31,34]. As such, a lack of change is not a positive or negative at this sample size and more data is needed to look at these two psychosocial dimensions.

A surprising results from the data was that task orientation, individualization, and personalization did not change. A few compounding factors were noted during faculty observations could have contributed to this unexpected and inconclusive data. First, the post- data was during the Covid-19 era where students were unaccustomed to a "baseline traditional class delivery" to properly compare their experience in the CUCEI responses. Another possible contributor is that the instructor often gave time right before class and post-end of class for more personalized question and answers in the traditional delivery which may have neutralized the results of more time within the class. Office hour attendance did drop and less end of class questions were commonly observed. Lastly for task orientation, it was observed with active learning, some students struggled to "jump" into the activities and instead got caught up in more casual conservations or questions were more centered on I am not sure what to do so I will wait or do something else until the instructor comes around.

Q2: Does the quantity/technical of active learning change the classroom climate and in which ways?

Comparing the MANOVA post- only results, there was no statistical difference. While both classes were uniquely different (content wise), the intent of the freed up time was the same, to provide just-in-time help and to build their problem solving skills with reflective questioning by the instructor. The percentage of 4 and 5 Likert scale responses (agree and strongly agree) were fairly equal between both post-active learning deliveries. More refined grading data analyses with the scales on different aspects could provide deeper insight moving forward.

Q3: How does the classroom climate for the seven psychosocial dimensions change given active learning?

From the recorded data, we can extract several trends regarding the psychosocial dimensions, though with limited statistical significance. MANOVA provided no statistical significance when switching to a flipped format except for student cohesion in AE 401 which decreased. As cohesion looks towards students helping one another, one possible explanation for the drop could be due to their lack of social interactions. This is possible due to the Fall 21 cohort having had two years of Covid-19 remote learning right before this class. Descriptive statistics show that in AE 401 and AE 530, all seven dimensions decreased from pre- to post-. For AE 401 active learning, the personalization dimension was the highest with task orientation being second and student cohesion being third highest. For AE 530 active learning, the personalization dimension was also highest (0.14 higher than AE 401) followed by task orientation (0.03 lower than AE 401), and in third was satisfaction. Interestingly, third didn't match between AE 401 and AE 530. These broad trends, seem to show that students are more into the satisfaction aspects of how the class is form and what they are getting out of the classroom as compared to working with others. This is logical as all of AE 530 assignments are individual and it can be hard to collaborate when modeling buildings in software and debugging errors.

From the factor analysis, the indicator items did shift after the flipped classroom adoption. From the top 14 identified items in pre- and post- data, only four items remained consistent (Coh_5, Per_7, Innov_4, and Tor_2). For the active learning delivery, the factor analysis (Table 10) stated that for student cohesion, students are interested in knowing each other and actually get to know one another. For personalization, the prime items are how friendly, considerate, and the level of individual engagement the instructor provides to the students. For individualization, active activities should consider a freedom to approach work in ways that best support that student and/or to have students choose activities will have the most reflective grade impact. Task orientation success centered on getting a certain amount of work done, as well as, the level of classroom organization. If the active classroom components are structured right, students will more critically pay attention to what others are saying and learning from those engagements.

Q4: Is there a relationship between classroom climate and student achievement?

Examining grades in conjunction with CUCEI results revealed several observable trends; yet, they are limited. In comparing pre-active learning, Pearson's results showed AE 530 had only two negative relationships while AE 401 had four. Post-active learning, AE 530 had no negative relationships while AE 401 had five. We can take away from this that perhaps more computer time for complex homework in AE 530 and more real-time help debugging software could have made a difference in the climate as compared to the AE 401 class where many students worked on the problems where faculty and student interaction was more limited (from casual observations). Statistically there was only two negative correlations found in the pre- data. For the post- data, no statistical significance was observed; yet, those negative results were removed. It is unclear if active learning was contributed to this.

Regression indicated four variables for steel design (AE 401) that could help faculty better understand the climate that may impact grades. They are: *Students enjoy going to this class (Sat_6)*; *Students know exactly what has to be done in our class (TOr_1)*; *the instructor is interested in students' problems (Per_6,)*; and *the instructor who decides what will be done in our class (Indiv_7)*. These indicators start to provide context in that the better the class is structured (to provide concise details) alongside better conveying who decides what is done for examples, problems, etc. could make an impact. Furthermore, faculty interest on how they are performing on these tasks matter. For computer modeling (AE 530), the regression analyses suggest that: *the instructor helps each student who is having trouble with the work (Per_3)* and *there is ample opportunity for a student to pursue his/her particular interest in class (Indiv_6)*. These make sense as computer modeling has some unique complexity where errors can easily be generated. Additionally, if problems permit multiple venues for a correct answer, allowing students to pick a suitable method they feel comfortable with allows for a better climate and resulting score.

Study Limitations; Study Challenges, and Future Work

Given the case study nature of this project with just two courses and two offering where the samples are less than 25 (per cohort), this study has several limitations. Given the 61-88% completion rate for the surveys, bias from student voluntary participation is expected to be minimal (compared to Fraser's response rates). That said, there could be bias either towards people to dislike the class(es) taking the survey or only those who enjoyed it participating. For this study, the same course instructor taught all offerings of all courses reported. While this attribute removed instructor personality and teaching style impacts, a single instructor, in and of itself, is a limitation in that their approach could make a difference in the classroom climate. This limitation was not adjustable due to the department curriculum arrangement of offering only one section of each class only once year where traditionally the instructor(s) remains the same for several years. For greater reliability and robustness, having another instructor teach the course would provide richer and deeper insights. For future work, a middle ground approach could be conducted to find a similar class elsewhere to benchmark; yet, having the same (or lack of the same) topical coverage could also pose limitations.

The other biggest limitation with this study was only having one active learning cohort each. Bias from that single group could have been a problem given the results that were presented. Additionally, active learning can at times be polarizing to some students. To overcome this limitation, more data should be collected in both the pre- and post- active learning stages. These larger sample sets would improve the robustness of the statistical evidence. A parallel track that could be looked at is for the instructor to vary the types of active learning (readings, discussions, quizzes, games, etc.) to see how different techniques impact climate and to what extent. This project had some of those features but were limitedly varied in each offering.

Conclusion

This study began to look for relationships between active learning and psychosocial dimensions of the classroom environment for a steel design and a computer modeling course. Using a previously established classroom climate inventory (CUCEI), it was expected that the introduction of a flipped classroom would improve certain aspects of the climate, particularly those that connect to the personalized time flipping can create. Unlike findings by other researchers, this study indicated that there was no real significant change in the climate. While largely inconclusive at this stage, there is not enough evidence to see if the climate shifts during flipping the class where it makes an impact. Flipping is still expected to provide some benefit as instructors are able provide clearer directions, just-in-time help, and more individual explanations (all of these are clearly within the CUCEI instrument). Given the mostly standard type(s) of assignments, innovation was not expected to improve; yet, personalization, individualization, and task orientation were anticipated to but didn't. It is unclear if active learning climates lead to higher student agency, self-efficacy, and motivation. It can be observed that students need the right engagement, activities, and settings to maximize the climate. At the same time, the instructor needs to match their teaching and delivery style with the content for the climate to be successful. While many aspects of this paper remain non-statistically proven, there remains several takeaways that educators can consider; they are:

- Holistically, thoughtful flipped classrooms result in at least the same level of classroom climate.
- Without adding cutting edge techniques or innovative activities, the likelihood of the innovation climate dimension is not expected to increase. Practical industry ties to topics do not likely impact the "innovative" climate dimension.
- For steel design classes, the most important climate characteristics for success are: students enjoy going class; students know exactly what has to be done; and faculty letting students decide some of the classroom success metrics.
- For computer modeling centered classes, the most important climate factors include: the level of in class instructor real-time support to help in class and instructors giving ample opportunity to for students to pursue their class interests.
- With steel design, task orientation correlations between climate and student assessment performance did improve positively. At the same time, extra time in computer modeling did not result in an increase of task orientation correlation.
- Care needs taken as students could struggle to "jump" into the activities and instead get caught up in more casual conservations or when they are not sure what to do, they will wait or do something else until the instructor comes around.

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Appendix: CUCEI Survey Questions

Likert 5 Scale:

1= strongly disagree, 2= disagree, 3= neutral, 4= agree, 5= strongly agree

PERSONALIZATION	
Per_1	The instructor considers students' feelings.
Per_2	The instructor talks individually with students.
Per_3	The instructor goes out of his/her way to help students.
Per_4	The instructor helps each student who is having trouble with the work.
Per_5	The instructor frequently moves around the classroom to talk with students.
Per_6	The instructor is interested in students' problems.
Per_7	The instructor is friendly and considerate toward students.

INVOLVEMENT	
Involv_1	The instructor talks rather than listens. (R)
Involv_2	Students put effort into what they do in class.
Involv_3	Students 'clockwatch' in this class. (R)
Involv_4	Students in this class pay attention to what others are saying.
Involv_5	Students often present their work to the class.
Involv_6	There are opportunities for students to express opinions in this class.
Involv_7	The instructor dominates class discussions. (R)

STUDENT COHESIVENESS	
Coh_1	The class is made up of individuals who know each other well.
Coh_2	Each student knows the other members of the class by their first names.
Coh_3	Friendships are made among students in this class.
Coh_4	Students have chances to get to know each other in this class.
Coh_5	Students in this class get to know each other well.
Coh_6	Students in this class very interested in getting to know other students.
Coh_7	it takes a long time to get to know everyone (R)

SATISFACTION	
Sat_1	I look forward to coming to classes.
Sat_2	I am satisfied with what is done in the class.
Sat_3	After the class, I have a sense of satisfaction.
Sat_4	Classes are not a waste of time.
Sat_5	Classes are engaging.
Sat_6	Students enjoy going to this class.
Sat_7	Classes are interesting.

TASK ORIENTATION	
TOr_1	Students know exactly what has to be done in our class.
TOr_2	Getting a certain amount of work done is important in this class.
TOr_3	This is an organized class.
TOr_4	Class assignments are clear so everyone knows what to do.
TOr_5	This class seldom starts late.
TOr_6	Activities in this class are clearly and carefully planned.
TOr_7	The group often gets side tracked ins tead of sticking to the point

INNOVATION	
Innov_1	New ideas are often tried out in this class.
Innov_2	New and different ways of teaching are often used in this class.
Innov_3	The instructor thinks up innovative activities for students to do.
Innov_4	Teaching approaches in this class are characterized by innovation and variety.
Innov_5	The instructor often thinks of unusual class activities.
Innov_6	Students seem to do the same type of activities every class. (R)
Innov_7	The seating in this class is arranged the same way each week (R)

INDIVIDUALIZATION	
Indiv_1	All students in the class given the freedom to approach the same assigned work in ways that best support them.
Indiv_2	Students are generally allowed to work at their own pace.
Indiv_3	Students have a say in how class time is spent.
Indiv_4	Students are allowed to choose activities and how they will work.
Indiv_5	Teaching approaches allow students to proceed at their own pace.
Indiv_6	There is ample opportunity for a student to pursue his/her particular interest in class.
Indiv_7	it is the instructor who decides what will be done in our class (R)