Understanding the Classroom Climate in a First-Year Engineering Course with Near-Peer Mentoring

Amber Kemppainen
Department of Engineering Fundamentals
Michigan Technological University
Houghton, MI USA
amber@mtu.edu

AJ Hamlin
Department of Engineering Fundamentals
Michigan Technological University
Houghton, MI USA
ahamlin@mtu.edu

***Abstract*— This research full paper is a study by the first-year engineering program at Michigan Technological University. Since 1999, the Department of Engineering Fundamentals has prided itself on our active, collaborative, first-year engineering program. While we have undergone many shifts in instructional models (e.g., blended learning, flipped learning), our dedication to this type of classroom environment has held firm. Most recently, our department moved to a flipped model of instruction and the inclusion of a significant peer mentoring presence in the classroom. With these major instructional changes, we evaluated the student perceptions of the classroom climate and identified that a majority of our students are experiencing a positive, active, and collaborative learning environment where they feel supported by their peers, student mentors and instructors and confident in their success as future engineers. This paper details our study approach, methods, and results**

I. Introduction

The First-Year Engineering Program at Michigan Technological University consists of a two-course sequence, ENG1101: Engineering Analysis and Problem Solving and ENG1102: Engineering Modeling and Design. It is a common first-year engineering program, so all first-year engineering students take these courses along with their math, chemistry, physics, composition, and another general education course in their first year. Throughout our First-Year Engineering Program's history, we have strived to encourage students to take an active role in their learning process by exploring course material with their peers. Early on in our program's development, this involved faculty delivering several mini-lectures followed by in-class activities during each class period. The activities were completed by teams of three to four students who shared a single desktop computer, with the support of one faculty member and one teaching assistant in a class of up to 64 students. Our first-year engineering courses transitioned to a blended model where students were expected to review course material (reading assignments, short video lectures, online quizzes, and/or short "how to" exercises) before coming to class [1], and finally to a fully-flipped model with an embedded near-peer mentoring program, the LEarning with Academic Partners (LEAP) Program [2], and a laptop requirement [3],[4].

In their current state, our first-year engineering classes meet twice a week for 110 minutes in our studio classrooms facilitated by a faculty instructor (five sections of 24 students, one instructor, five LEAP Leaders (near peer mentors)) and once a week in our mandatory 50-minute LEAP session using the Supplemental Instruction (SI) model that is facilitated by a LEAP Leader (one section of 24 students, one LEAP Leader).

In our flipped studio classroom, students are expected to spend 20-60 minutes before each studio session preparing for the lesson by completing reading assignments, watching pre-recorded lessons, and completing short assignments or quizzes. Once they get to their studio session, students apply what they learned in the pre-lesson and further explore this material by completing in-class activities within their team of three or four students, with support from their LEAP Leader and instructor. The studio sessions use a collaborative learning approach, where students work together in their teams on tasks in a loosely structured format, developing a shared understanding of the course material [5]. To provide a consistent learning experience across the eight studio sessions and to minimize differences due to instructors, all pre-lesson and in-class materials are prepared by course coordinators and distributed to the faculty instructors.

In the weekly LEAP sessions planned and facilitated by their LEAP Leader, students review concepts and deepen their understanding of material learned that week by explaining concepts to their peers using Supplemental Instruction (SI) strategies and techniques. The LEAP sessions use a cooperative learning approach where group interactions are defined and more structured than collaborative learning processes used in the studio sessions. For example, think-pair-share and jigsaw are cooperative learning strategies [5]. LEAP Leaders use several sources of information to help them plan their LEAP sessions, including their observations of challenges their students' faced while working on in-class activities, common errors observed when grading submitted assignments, and suggestions from their studio session faculty member. In this way, the LEAP Leader can tailor their LEAP session to address the needs of their students. While we have increased the size of our studio classroom from 64 to 120, we believe that shifting undergraduate student support from a teaching assistant role to

a near-peer mentoring role will have an overall positive impact on students' perception of their engineering classroom climate.

II. GOALS OF STUDY

The goals of our first-year program have always been to have an active, collaborative learning space for the students to help prepare them for their second-year courses and build their confidence as future engineers. With the most recent changes, we want to ensure that this goal has been maintained as students' perceptions of their classroom climate have been shown to impact their learning, motivation, satisfaction, and achievement [6]. The purpose of this current study is to address the following research questions: a) what are the characteristics of the classroom climate in our first-semester engineering course b)how do students perceive the support they receive in the classroom from their instructors, LEAP Leaders, and their peers, and c) which factors of classroom climate contribute the most to the development of their engineering identity.

III. METHODS

This study was conducted with the students enrolled in our first semester course: ENG1101: Engineering Analysis and Problem Solving in Fall 2023 (n = 869). There were 41 sections of this course taught by 9 different instructors. Each section had between 18 - 24 students with an average of 21 students. Our approach was to have students complete an end-of-semester survey through Google Forms in all sections. The form was set up to receive only entries from Michigan Tech and limit responses to one per person, so only our students could submit to the survey and there were no duplicate entries. No identifying information was collected from the students and this research was considered exempt by our IRB. The survey instrument utilized two scales: the Engineering Identity Scale [7] and the Classroom Life Inventory [8]. In both surveys, the questions were scaled to a five-point Likert-type scale from "Strongly Disagree" (1) to "Strongly Agree" (5). A total of 463 (53.2%) students consented to the study and completed the survey. Because no identifying information was collected, we cannot determine if specific sections or instructors are missing, so this data may not be completely representative of our population. However, this response does represent the responses for over half of the population.

The Engineering Identity Scale is an eleven-question survey, shown in Appendix A, Table II, that measures three factors of engineering identity: recognition, interest, and performance/competence [7]. An overall factor score for each subscale was created along with an overall Engineering Self-Efficacy score which is the sum of all items in the Engineering Identity scale. The classroom life inventory is a 59-question survey, shown in Appendix A, Table III, that measures twelve factors of classroom climate: cooperative learning, positive goal interdependence, resource interdependence, teacher and student academic and personal support, class cohesion, fairness of grading, achieving for social approval, academic self-esteem, and alienation [8].

We modified the Classroom Life Inventory survey slightly in order to properly characterize the classroom climate in both the studio session and LEAP session. For example, additional questions were added on LEAP Leader academic and personal support. Also, the cooperative learning scale questions were duplicated and framed in two ways, "In the studio session… " and "In my LEAP session…", to understand the cooperative learning that occurs in both and if the students perceive a difference between them. These modifications increased the number of questions from 59 to 82 and factors from 12 to 15. An overall factor score for each subscale was calculated for the classroom climate inventory measure.

The overall Google Form survey included 100 questions for the students to answer. It is important to note that with a survey this long, one possible limitation to the data analysis is the possibility of survey fatigue. To address this, only those responses with complete answers to all scale questions were included for that particular measure. If a student missed one response within a scale or did not answer any questions for that scale, those responses were removed from analysis. In the Results and Discussion section below, the number of students who complete each scale measure are noted.

IV. RESULTS AND DISCUSSION

In this section, we will first discuss the general observations from the Classroom Life Inventory data to address Research Question 1. Next, we will discuss student reported differences between the personal and academic support provided by the teacher, other students, and LEAP Leaders to address Research Question 2. Finally, we will discuss the results from the Engineering Identity scale measures and overall score as well as identify which factors of classroom climate contribute the most to the students' development of their engineering identity to address Research Question 3.

The first three subscales from the Classroom Life Inventory presented in Fig. 1 are: alienation, achieving for social approval, and academic self-esteem. With items such as "I am not doing as well in school as I would like to." and "I am often lonely in this class" in the alienation subscale, we expected most students to disagree with these statements. A total of 424 students completed all questions in this subscale. As you can see from Fig. 1, this is the case with the majority of students (59.4%, n = 252) disagreeing with these statements and only 3.4% (n = 15) of students agreeing with these statements. The achieving for social approval subscale asks students if they do school work to make others (e.g., teachers, LEAP Leaders, classmates, parents) happy and to be liked by other students. A total of 437 students completed these questions. We expected some students to be motivated by social pressure and the data does show that 12.4% (n = 54) of the students agreed with these subscale questions, while 48.5% (n = 212) of the students were neutral on these questions and 39.1% (n = 171) disagreed with these questions.

For the academic self-esteem subscale, a total of 436 students completed all the subscale questions. Based on previous studies, we know we have a diversity in student population with respect to their computational skills and computational self-efficacy at the beginning of the semester, but that their performance was similar overall at the end of the semester [9]. We expected to see this same spread in self-efficacy here as well. A total of 46.1% of students (n = 201) generally agreed with the self-efficacy questions (e.g., "school work is fairly easy for me" "I am a good student"), only 4.8% (n = 21) students disagreed

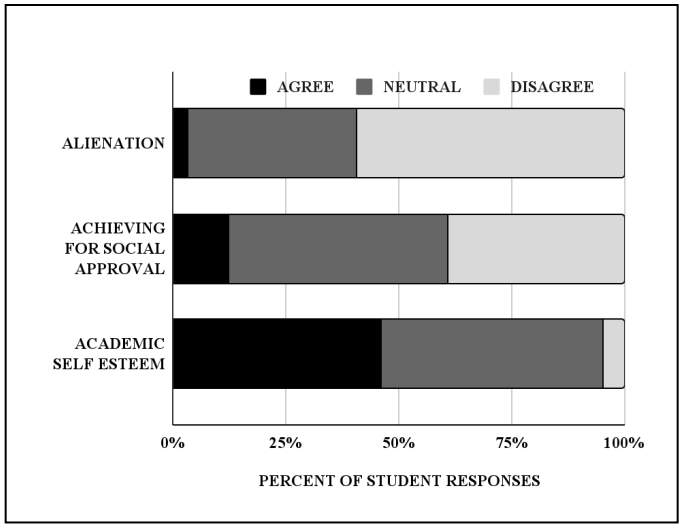

Fig. 1. Social Interactions / Approval Scales

with the subscale questions, while the remaining 49.1% of the students (n = 214) were neutral on this measure.

The next few items from the Classroom Life Inventory shown in Fig. 2 are: fairness of grading, cooperative learning in the studio session, cooperative learning in the LEAP session, and class cohesion. As we have designed our classroom and LEAP sessions for collaborative learning, we expect the majority of students to agree with both cooperative learning scales. Additionally, as we expect positive attitudes toward cooperative learning, we expect a positive relationship with fairness of grading as well [8]. For the fairness of grading subscale, a total of 432 students completed all the questions in this measure and a majority of them (68.7%, n = 297) agreed with the scale questions (e.g., "everyone has an equal chance to be successful if they do their best." "if a student works hard, they can definitely succeed"). Only one student disagreed on this scale. As expected, the majority of students agreed with the cooperative learning scale questions for the studio sessions and LEAP sessions, 71.5% (n = 303) and 67.3% (n = 292) of students respectively. A small minority disagreed with these scales 2 students (studio sessions) and 7 students (LEAP sessions), so it would appear that overwhelmingly that students see our classes as utilizing cooperative learning strategies with fair grading practices.

The last classroom interaction scale we have in Fig. 2 is class cohesion. A total of 430 students completed all the scale questions for this measure. Examples of these scale questions include: "in this class are my best friends" and "I like to work with others". Now, we expected there to be less agreement here. Many students understand that working with others is important, but many prefer to work by themselves on problems. This is represented by our results with only 31.9% (n = 137) of students agreeing with these questions and the majority of students (60.7%, n = 261), having a neutral opinion on these scale questions.

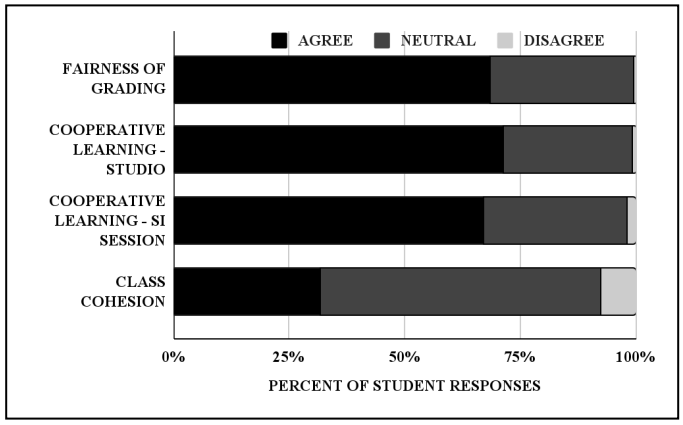

Fig. 2. Classroom Interaction Scales

The next two measures shown in Fig. 3 from the Classroom Life Inventory are positive goal interdependence and resource interdependence. Positive goal interdependence scale questions relate to how well students feel that they are trying to help each other learn the material, complete the assignments, and earn the same grade. Resource interdependence scale questions relate to how well assignments are geared for division of labor and individual contributions. An example question being "when we work together in small groups, we have to share materials in order to complete the assignment." The research suggests that these two measures are positively correlated with each other, so if one were overwhelmingly positive or negative, the other should be the same [8]. It is interesting to note that while the majority of students agreed with the positive goal interdependence questions (54.4%, n = 237), the majority of the students were in the neutral range of the resource interdependence scale (61.3%, n = 263). This may indicate that the students are dedicated to helping each other learn, but the assignments themselves could be improved to increase resource interdependence, shared responsibility, and collaboration. There is still a very strong positive correlation between the two variables (r = 0.629, p = 0.000), which would seem to indicate that while students overall agree more with one scale over the other, the overall responses are much closer than they would appear.

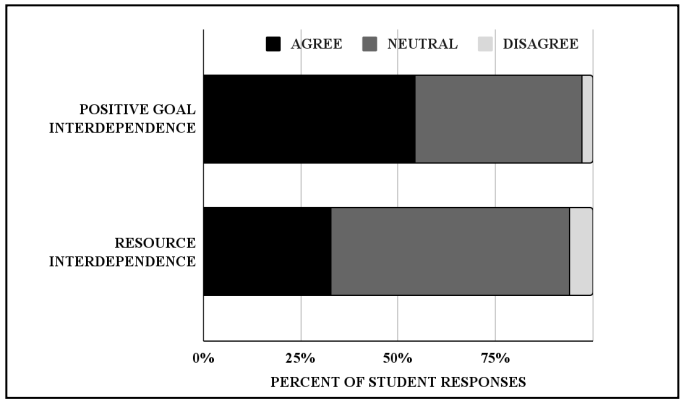

Fig. 3. Classroom Life Inventory: Interdependence Scales

Fig. 4 and Fig. 5 take a closer look at the academic and personal support measures of the Classroom Life inventory respectively. We have grouped the support by teacher, LEAP Leader, and students to see any differences between the groups. As you can see in Fig. 4, the majority of students agreed that their teachers (76.4%, n = 331), LEAP Leaders (85.1%, n = 370), and peers (58.2%, n = 259) care about their learning and want to help them learn. These results make sense as the course instructor and LEAP Leaders are responsible for the course instruction and the LEAP Leader has an additional class period to work with the students each week. In Fig. 5, it appears that students find they are receiving the most personal support (caring about them and liking them) from their peers (88% agreement, n = 382), then LEAP Leaders (54.9% agreement, n = 236), and teachers (48.7% agreement, n = 210). These results make sense in that the students will feel closest to their teammates and classmates, then the near-peer mentors, and finally their instructor.

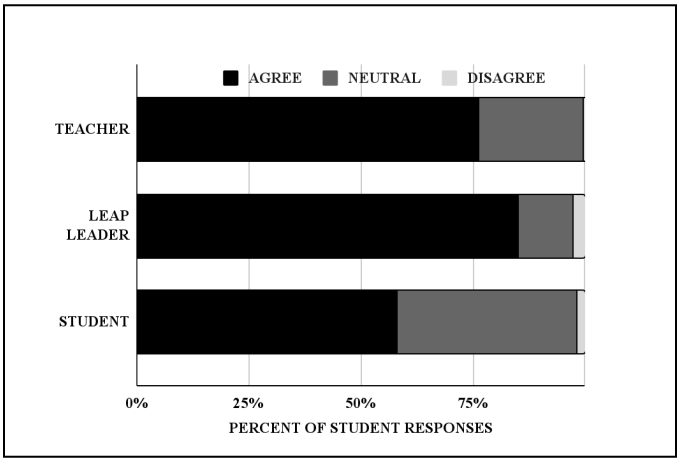

Fig. 4. Classroom Life Inventory: Academic Support

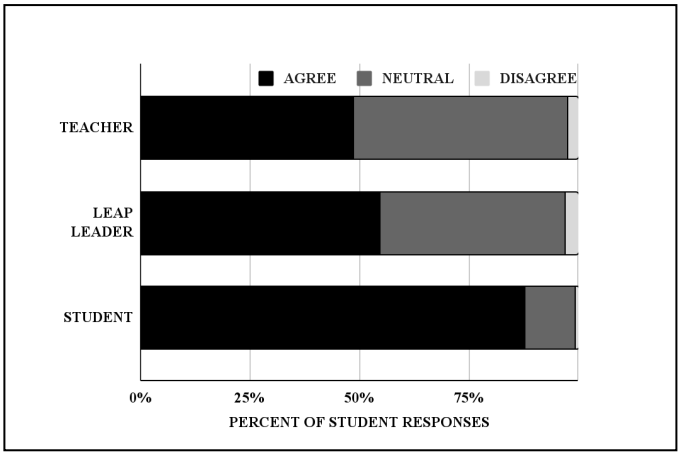

Fig. 5. Classroom Life Inventory: Personal Support

Fig. 6 shows the results from the Engineering Identity Scale measures: recognition, interest, and performance/competence. The majority of students agree that by the end of their first-semester engineering class they feel that they are recognized as an engineer (57.9%, n = 257), they are confident they understand the concepts they studied in class (70.6%, n = 302), and are interested in learning engineering and find it fulfilling (81%, n = 354).

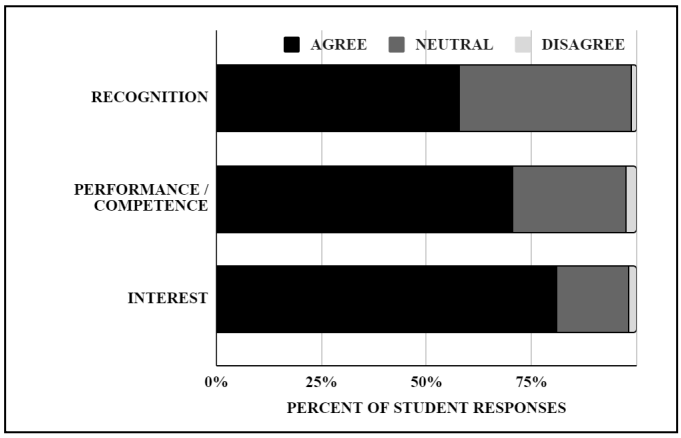

Fig. 6. Engineering Self-Efficacy Scales

In order to determine which factors from the classroom life inventory most contributed to the overall measure for Engineering Self-Efficacy, a hierarchical multiple regression was performed by testing each subscale score in the regression model. Table I shows the regression model results. In general, several Classroom Life Inventory measures positively contribute to the development of the first-year students Engineering Self-Efficacy. The largest contributor appeared to be the personal support by their LEAP Leader, which contributed to 29.6% of the variation in the Engineering Self-Efficacy scale scores. This makes sense as the LEAP Leader has an additional time period with the students each week directly focusing on mastering the concepts that are most challenging the students. The students' academic self-esteem scale scores contributed a statistically significant increase in R^2 of 11.4%. This makes sense as one key developer of self-efficacy in a specific area is successful completion of mastery experiences [10] and with a large percentage of the students positively responding to questions such as "schoolwork is fairly easy for me" for their engineering coursework, this should positively contribute to their self-efficacy in this area. Lastly, the addition of the cooperative learning - LEAP session scale added an additional 7.1%. Again, the extra time spent mastering these engineering concepts in the LEAP sessions were a significant contribution to these students' engineering self-efficacy. These three factors predicted a total of 48.1% of the variation in the student's Engineering Self-Efficacy scale scores.

TABLE I. HIERARCHICAL MULTIPLE REGRESSION ANALYSIS PREDICTING ENGINEERING SELF-EFFICACY

Predictor	ΔR^2	B
LEAP Leader Personal Support	0.296	0.282
Academic Self Esteem	0.114	0.356
Cooperative Learning - LEAP Session	0.071	0.341
Total R^2	0.481	

V. Conclusions

This study allowed us to characterize the classroom climate in our first-semester engineering course. While we do have some limitations with our data collection in that we cannot determine if specific sections are not represented, we do have over half of our 870 students' responses. In general, students perceive our classroom as one where they do not feel alienated, the grading is fair, and they are engaged in collaborative and cooperative learning in our learning spaces (studio and LEAP session). The students are engaged in helping each other learn the material, but there may be more opportunities to tailor the assignments to increase resource interdependence. Students receive the greatest amount of their academic support from their instructor and LEAP Leader, but the greatest amount of their personal support from their peers. At the end of the first semester engineering class, the majority of students feel recognized as an engineer, confident they understand the concepts they studied in class, and are interested in learning engineering. The greatest factors contributing to their Engineering Self-Efficacy are the personal support of their LEAP Leader, their academic self-esteem, and the cooperative learning occurring in their LEAP session.

Acknowledgment

The authors would like to thank the Engineering Fundamentals faculty for helping gather data, the LEAP Leaders for supporting their students, and our first-year engineering students for providing feedback.

References

[1] M. A. Fraley, A. J. Hamlin, A. J. Kemppainen, and G. L. Hein, "Using Pre-lesson Materials and Quizzes to Improve Student Readiness and Performance," *2015 ASEE Annual Conference & Exposition*, Seattle, Washington, USA, 2015, pp. 26.1677.1-26.1677.16, doi: 10.18260/p.25013.

[2] A. J. Kemppainen, A. J. Hamlin and N. D. Manser, "Supplemental Instruction in a First-Year Engineering Course: A study from the Learning with Academic Partners (LEAP) Program," 2018 IEEE Frontiers in Education Conference (FIE), San Jose, CA, USA, 2018, pp. 1-6, doi: 10.1109/FIE.2018.8659249.

[3] J. H. Sticklen, A. J. Hamlin, A. Kemppainen, B. Hamlin and D. Oppliger, "Sustainable Change in a First-Year Engineering Program," *2018 IEEE Frontiers in Education Conference (FIE)*, San Jose, CA, USA, 2018, pp. 1-5, doi: 10.1109/FIE.2018.8659234.

[4] A. J. Hamlin, A. J. Kemppainen, B. H. Hamlin, N. L. Veurink, and J. H. Sticklen, "Three Years After Rollout: A Report on Systemic Changes in a First-Year Engineering Program" *2020 First-Year Engineering Experience (FYEE)*, East Lansing, Michigan, USA, 2020, doi: 10.18260/1-2--35780.

[5] X. Yang, "A Historical Review of Collaborative Learning and Cooperative Learning," *TechTrends*, vol. 67, no. 4, Jul. 2023, pp. 718-728, 2023, doi: 10.1007/s11528-022-00823-9.

[6] J. J. Barr, "Developing a Positive Classroom Climate. IDEA Paper# 61." *IDEA Center, Inc*, Oct. 2016.

[7] A. Godwin, "The Development of a Measure of Engineering Identity," *2016 ASEE Annual Conference & Exposition*, New Orleans, LA, USA, June 26-29, 2016, doi: 10.18260/p.26122.

[8] D. W. Johnson, R. Johnson, and D. Anderson. "Social interdependence and classroom climate." *The Journal of Psychology,* vol. 114, no. 1, pp. 135-142, 1983.

[9] A. Kemppainen, M. Fraley, A. Hamlin and G. Hein, "How important is high-school computing experience for first-year engineering student success?" *2016 IEEE Frontiers in Education Conference (FIE)*, Erie, PA, USA, 2016, pp. 1-5, doi: 10.1109/FIE.2016.7757602.

[10] A. Bandura, "Self-efficacy: toward a unifying theory of behavioral change," *Psychological review,* vol. 84, no. 2, pp. 191-215, Mar. 1977, doi: 10.1037/0033-295X.84.2.191.

Appendix A

TABLE II. Items developed to measure engineering identity.

Construct	Question
Recognition	• My parents see me as an engineer. • My instructors see me as an engineer. • My peers see me as an engineer. • I have had experiences in which I was recognized as an engineer.
Interest	• I am interested in learning more about engineering. • I enjoy learning engineering. • I find fulfillment in doing engineering.
Performance / Competence	• I am confident that I can understand engineering in class. • I am confident that I can understand engineering outside of class. • I can do well on exams in engineering. • I understand concepts I have studied in engineering. • Others ask me for help in this subject. • I can overcome setbacks in engineering.

TABLE III. Hierarchical Multiple Regression Analysis Predicting Engineering Self-Efficacy

Construct	Question
Alienation	• I am not doing as well in school as I would like to. • I find it hard to speak my thoughts clearly in class. • School work is fairly easy for me.** • I should get along with other students better than I do. • Whenever I take a test I am afraid I will fail. • I often get discouraged in school. • I have lots of questions I never get a chance to ask in class. • In this class I am often lonely. • I am a good student.** • I often feel upset in school. • In this class I sometimes think the scoring system is not fair.
Academic Self Esteem	• I am not doing as well in school as I would like to. ** • School work is fairly easy for me. • Whenever I take a test I am afraid I will fail.** • I am doing a good job of learning in this class. • I am a good student.
Achieving for Social Approval	• I do school work to make my teacher happy. • I do school work to make my LEAP Leader happy. • I do school work because my classmates expect it of me. • I do school work to make my parents happy.

Construct	Question
	• I do school work to keep my teacher from getting mad at me. • I do school work to keep my LEAP Leader from getting mad at me. • I do school work to be liked by other students.
Class Cohesion	• In this class are my best friends. • In this class I like to work with others. • In this class everybody is a friend. • In this class I am often lonely.** • In this class all of the students know each other well.
Cooperative Learning - Studio Session	• In the studio session, I like to share my ideas and materials with other students. • In the studio session, I can learn important things from other students. • In the studio session, I like to help other students learn. • In the studio session, I try to share my ideas and materials with other students when I think it will help them. • In the studio session, it is a good idea for students to help each other learn. • In the studio session, I like to cooperate with other students. • In the studio session, students learn lots of important things from each other.
Cooperative Learning - LEAP Session	• In the LEAP session I like to share my ideas and materials with other students. • In the LEAP session I can learn important things from other students. • In the LEAP session I like to help other students learn. • In the LEAP session I try to share my ideas and materials with other students when I think it will help them. • In my LEAP session it is a good idea for students to help each other learn. • In my LEAP session I like to cooperate with other students. • In my LEAP session students learn lots of important things from each other.
Fairness of Grading	• In this class everyone has an equal chance to be successful if they do their best. • In this class if a student works hard, they can definitely succeed. • In this class students get the scores they deserve, no more and no less. • In this class I deserve the scores I get. • In this class I sometimes think the scoring system is not fair.**
Positive Goal Interdependence	• When we work together in small groups we try to make sure that everyone in our group learns the assignment material. • When we work together in small groups our job is not done until everyone in our group has finished the assignment. • When we work together in small groups, we all receive the same grade.
	• When we work together in small groups, our grade depends on how much all members learn. • When we work together in small groups, I have to make sure that the other members learn if I want to do well on the assignment.
Resource Interdependence	• When we work together in small groups, we cannot complete an assignment unless everyone contributes. • When we work together in small groups, the teacher divides up the material so that everyone has a part and everyone has to share. • When we work together in small groups, we have to share materials in order to complete the assignment. • When we work together in small groups, everyone's ideas are needed if we are going to be successful. • When we work together in small groups, I have to find out what everyone else knows if I am going to be able to do the assignment.
LEAP Leader Academic Support	• My LEAP Leader cares about how much I learn. • My LEAP Leader likes to see my work. • My LEAP Leader likes to help me learn. • My LEAP Leader wants me to do my best in schoolwork.
LEAP Leader Personal Support	• My LEAP Leader really cares about me. • My LEAP leader thinks it is important to be my friend. • My LEAP Leader likes me as much as they like other students. • My LEAP Leader cares about my feelings.
Student Academic Support	• In this class other students want me to do my best schoolwork. • In this class other students like to help me learn. • In this class other students care about how much I learn. • In this class other students want me to come to class every day.
Student Personal Support	• In this class other students think it is important to be my friend. • In this class other students like me the way I am. • In this class other students care about my feelings. • In this class other students like me as much as they like others. • In this class other students really care about me.
Teacher Academic Support	• My teacher cares about how much I learn. • My teacher likes to see my work. • My teacher likes to help me learn. • My teacher wants me to do my best in schoolwork.
Teacher Personal Support	• My teacher really cares about me. • My teacher thinks it is important to be my friend. • My teacher likes me as much as they like other students. • My teacher cares about my feelings.

** Scale reversed