Supplemental Instruction in a First-Year Engineering Course: A study from the Learning with Academic Partners (LEAP) Program

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***Abstract*— This innovative practice full paper reviews the formation and effects of the LEarning with Academic Partners (LEAP) program at Michigan Technological University in the first two years of operation. The LEAP Program combines the job requirements of a traditional Teaching Assistant (TA) with those of a Supplemental Instruction (SI) Leader. While each program has their benefits, to date, no one has evaluated the effects of a combined program such as the one established at Michigan Tech. To determine these effects, we focused our analysis on measuring course performance and student attitudes of student groups in a second semester first-year engineering course, ENG1102 - Engineering Modeling and Design: Spring 2017 (no LEAP), Spring 2017 (no LEAP/pilot LEAP with optional attendance), and 2018 (LEAP with mandatory attendance).**

Keywords—first-year, supplemental instruction, LEAP

I. Introduction

The LEAP Program was established as part of an evolution of the first-year program in the Fall of 2017 at Michigan Technological University. At this time we transitioned from an active classroom to a flipped classroom environment, as well as, introduced a classroom with an increased capacity from 60 to 120 students. To support the students in this new environment, we wanted to incorporate a near-peer mentoring program. One model that provides near-peer support is the Supplemental Instruction (SI) model. Our program, however, had different needs than those satisfied by a pure SI program. While SI programs typically support large lecture classes, the first-year engineering program offers an active, collaborative learning environment. This environmental difference is driven by a hallmark of our program, which is that our program relies heavily on the use of computational tools to solve problems. Therefore, our class setting typically requires the assistance of TAs to help with challenges in the classroom and for grading homework, but we realized that there is a gap outside of class that the SI Leader position may fill.

We therefore structured the LEAP Program to combine elements of each successful model. First, the LEAP Leaders undergo training in facilitation techniques, active learning strategies, and session planning as do SI Leaders. In addition, they are expected to assist with student questions in class and grade assignments as in the TA position, and are provided with training on classroom etiquette and a tutorial on using Canvas, our Learning Management System, to grade student work. Combining these elements eliminates the anonymity of the SI session as the LEAP Leaders know exactly who the students are and how they are performing in class. However, it gives the LEAP Leaders additional insight as to the challenging content of the course their students are struggling to grasp. As there are clearly both pros and cons to this adapted model, this paper seeks to determine how the LEAP Program affects student attitudes and performance in the first-year engineering classroom.

II. Supplemental Instruction

Supplemental Instruction (SI) was formally started in 1973 at the University of Missouri - Kansas City and has since branched out to campuses worldwide. As of April 2016, SI had been implemented in over 1500 institutions in over 30 countries and served approximately 750,000 students per semester [1]. Although the program goes by different names in different countries (e.g, Peer Assisted Study Sessions (PASS) in Australia, Peer Assisted Learning (PAL) in the UK), the premise of the program is the same [2]. SI targets historically difficult classes and provides regularly scheduled review sessions to help students master the challenging content of these classes. These SI sessions are designed to be informal and anonymous; a place where students can ask questions without fear, participate in peer learning, develop their organizational and study skills, and prepare for exams [3]. Typical participation rates are 38% for students at the University of Missouri-Kansas City [4].

SI claims three primary benefits for those students who participate versus those students who choose not to participate: 1) increased grades in the target course [3, 5, 6], 2) decreased rates of D, F, and W grades in the target course [3, 6], and 3) increased persistence at the university [3, 6, 7]. Additionally, these benefits are more pronounced in underrepresented minority students [5]. In addition, studies have found that students participating in SI have increased information processing skills, motivation levels, increased satisfaction levels, reduced anxiety, enhanced social relationships, and increased engagement over students who did not participate in SI [5].

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As students have the choice to participate in SI, several studies considered self-selection by controlling for differences in ability and/or motivation levels. After taking the ability self-selection factor into consideration, SI still provided benefits in terms of increased grades over those students who chose not to participate [5]. Differences in motivation can be considered by making SI mandatory as did the 2001 offering of a first-year history course [8]. In this case, students in the voluntary SI session had the highest motivation, and performed better than the students who did not attend SI. However, the students in the mandatory SI session showed the highest performance and the lowest DFW rates of all three groups [8].

III. LEAP Program Overview

Michigan Tech has a common First-Year Engineering Program (FYEP) that is housed in the Engineering Fundamentals Department, within the College of Engineering. Students that are placed into Calculus I or higher when they enter college, take ENG1101 - Engineering Analysis and Problem Solving their first semester and ENG1102 - Engineering Modeling and Design their second semester. Students that are not ready for calculus I, take a three-semester sequence that includes ENG1001 - Engineering Problem Solving, ENG1100 - Engineering Analysis, and ENG1102 - Engineering Modeling and Design. LEAP has been implemented into all the first-year engineering courses.

The LEAP Program was piloted in the 2016-2017 academic year. In the fall, three of the 14 sections of ENG1101 had LEAP sessions scheduled as part of the course. To accommodate LEAP sessions, the course schedule changed from meeting for 80 minutes three days a week in the traditional manner to meeting as a whole class for 110 minutes twice a week and meeting with their LEAP group (18-24 students) once a week for 50 minutes for their LEAP Session. The LEAP sessions use active, peer-learning strategies to review material covered during the week that students found particularly challenging. The LEAP Leaders plan and facilitate activities for their LEAP sessions. Since the Leaders helped their students during class, they know which topics the students have difficulty with and plan activities around those content areas. The LEAP sessions are not recitation sessions where students work through problem sets, nor are they tutoring sessions where the tutor explains the material or work through homework assignments. The goal of the LEAP session is to have the students help each other gain a deeper understanding of the course material through discussions and activities. In Fall 2016, since the LEAP sessions were scheduled into the ENG1101 course meeting time, attendance was required at LEAP sessions and comprised 10% of the overall course grade.

In the spring (2017), three of the 14 sections of ENG1102 had LEAP Leaders. Each LEAP Leader was assigned to a subset of students to assist during class and for assignment grading. Each Leader prepared and facilitated a 50 minute LEAP session that any student in their section was invited to attend. The LEAP sessions were not a part of the class and were offered in the afternoon or early evening when there were fewer course conflicts. Since the LEAP sessions were not scheduled into the regular meeting time of the course, attendance was optional. Most of the students that attended LEAP sessions attended a session led by their LEAP Leader. During this LEAP pilot year, a number of students experienced having a LEAP Leader in one of their first-year engineering courses and a TA in the other. Results from a survey of these students indicate that a majority of the students preferred having a LEAP Leader over a TA [9]. Comments from students regarding their LEAP Leaders and TAs are summarized by Kemppainen et al., 2017.

In 2017-2018, LEAP was implemented into all sections of the following first-year engineering courses: ENG1001, ENG1101, and ENG1102. ENG1101 was taught in a new learning environment with an increased capacity of 120 students. Each LEAP Leader was assigned up to 24 students in a class, with up to five LEAP Leaders in each class.

One LEAP Leader in each class was selected to be a Head LEAP leader to facilitate LEAP session planning and ensure grading consistency between LEAP Leaders. Each LEAP Leader ran a LEAP session for their students once a week in a separate room. The LEAP sessions were part of the normal class schedule, so attendance at these sessions was mandatory. LEAP attendance and participation accounted for 10% of the overall course grade in ENG1101.

In ENG1001, LEAP sessions were also included in the normal class meeting time; however, they occurred every other week for half of one 80-minute class period, with a quiz being administered in the other half of the session. LEAP Leaders were assigned up to 24 students. LEAP attendance and participation comprised 10% of the ENG1001 course grade.

In ENG1102 in the fall, LEAP sessions were run similar to ENG1001. They typically occurred every other week for half of an 80-minute class period with a course assessment administered in the other half of the class. In the spring, LEAP sessions occurred in one-half of an 80 minute class period every week. The other half of the class period was spent on an instructor determined activity. These activities included quizzes, project presentations, project work time, and assignments. In the fall, each Leader was assigned up to 24 students, in the spring Leaders were assigned up to 32 students. LEAP attendance and participation comprised 2% of the ENG1102 course grade in the fall and 10% in the spring.

The study group for this analysis focused on one instructor's sections of ENG1102 - Engineering Modeling and Design since they have consistently taught this class over the past few years and implemented various forms of undergraduate assistance within their sections. Additionally, the content of ENG1102 has not changed substantially, while there have been substantial revisions in ENG1101 content and instructional format. Eliminating instructor variability and content variability will help us determine the overall effects of the LEAP Program on student attitudes and performance in our first-year engineering program. To determine these effects, we focused our analysis on measuring performance on specific course objectives in ENG1102 in the past two academic years: 2017 and 2018. We focused on evaluating the sections of ENG1102 taught by one instructor who taught both years and had sections that represent all of the groups we wish to evaluate: no LEAP, voluntary LEAP session attendance, and mandatory LEAP session attendance.

IV. LEAP Implementation in ENG1102

At Michigan Technological University, ENG 1102 is the culminating course in the FYEP, with a major focus of the class being the development of physical and computational models in an engineering (problem-solving) context. The structure of ENG 1102 over the study period followed a learner-centered approach where students were given access to content (essential session prep) before the class period with specific tasks listed for them to accomplish. Tasks included reading assignments, practice problems, or graded quizzes depending on the material covered. In most cases, each class period had a corresponding essential session prep that counted within their final course grade, and needed to be completed before coming to class. Once in class, students were supported by undergraduate teaching assistants and guided through curriculum that allowed them to apply the content and develop problem-solving skills in a hands-on and collaborative environment. A common theme among the ENG 1102 sections during the study period was the design project. This project required students to design a physical model of a brewery within constrained capacity and size requirements using NX, while also writing a MATLAB code that provided process control and simulation of the brewery. The goal of the project was to enhance the engineering design and modeling skills of the students. Aside from similar design projects, common assessment between the ENG 1102 sections included individual assignments, lab practicals in both MATLAB and NX, in addition to final exam questions related to course content. This study will use performance on these common course artifacts to examine the impact of the LEAP program in the course.

Despite the common curriculum deployed in the ENG 1102 sections, the implementation of the LEAP program was not common across the sections during the 2017 and 2018 study periods, which provides the experimental set-up for this paper. In detail: the no LEAP group had 59 students matriculate with no implementation of the LEAP program components, while the voluntary LEAP group matriculated 58 students with the LEAP program being offered as optional (not required), and in the mandatory LEAP group, 119 students participated in the course with the LEAP program component incorporated as a mandatory course requirement. In the mandatory group, 10% of the course grade was determined by the students' participation in the required LEAP session, whereas, no course credit was given in the opposing sections. It is for this reason that only common course artifacts, such as, individual assignments, lab practical performance and selected final exam question performance from all three sections are used in this paper for comparison.

V. Analysis Methods

The main goal of this paper is to determine the effects of the implementation of the LEAP Program on student performance. As mentioned previously, our sample includes students who were enrolled in sections of ENG1102 who had: a) one TA per class, but no LEAP sessions, b) one LEAP Leader per 24 students and voluntary LEAP sessions outside of regular class time, and c) one LEAP Leader per 32 students and mandatory LEAP sessions within regular class time. Students were sampled from sections taught by the same instructor to reduce the effects of different instruction. We compared grades for several common performance metrics between the sections: individual homework, MATLAB lab practical, NX lab practical, final exam, final ENG1102 grade. In addition, we broke down the final exam into specific course topics to determine if the effects of the LEAP program differed by topic area. The multiple choice final exam questions were classified into one of the following four categories: 1) drawing, which includes questions on drawing conventions, section views, identification of surfaces in orthographic projections; 2) solid modeling with NX; 3) MATLAB programing; and 4) MATLAB user-defined functions. A one-way ANOVA with a Tukey post-hoc test was used to determine significant differences between the groups.

VI. Performance Results

Starting with group comparisons, we compared the performance on ENG1102 course metrics between the no LEAP, voluntary LEAP, and mandatory LEAP sections. Table I shows the average and standard error on each of these metrics. Significant differences were determined by comparing the no LEAP group to the other two groups using a one-way ANOVA. In general, the students in the voluntary and mandatory LEAP groups performed better on all the ENG1102 course metrics than the no LEAP group. These differences are significant ($p<0.05$) for the majority of the performance measures. First the individual homework between the mandatory LEAP and no LEAP groups is significant, with the mandatory LEAP group having a 6.4% higher average. Second, the final exam performance was on average 10.8% higher in the mandatory group than the no LEAP group. Additionally, final grades were higher than the no LEAP group for both the voluntary and mandatory LEAP groups (+2.9% voluntary, +5.6% mandatory). The difference in final grades between voluntary and mandatory LEAP groups approached significance ($p = 0.058$). No significant differences were found on the MATLAB and NX lab practicals between the groups.

TABLE I. Comparisons on selected ENG1102 Performance Measures [a]

Performance Measure	ENG1102 Sections		
	No LEAP (n = 59)	*Voluntary (n = 58)*	*Mandatory (n = 119)*
Individual Homework	84.9 ± 2.1	90.5 ± 1.5 (0.061)	91.3 ± 1.1 (0.008)
MATLAB Lab Practical	77.3 ± 3.9	82.9 ± 4.1 (0.600)	78.0 ± 3.0 (0.988)
NX Lab Practical	92.5 ± 2.7	93.7 ± 2.6 (0.939)	88.5 ± 1.5 (0.380)
Final Exam	64.1 ± 1.9	67.0 ± 1.9 (0.280)	74.9 ± 1.2 (<0.0001)
Final Grade	84.7 ± 1.1	87.6 ± 0.7 (0.010)	90.3 ± 0.67 (<0.0001)

[a] p values shown depict comparisons with no LEAP condition

The instructor noted that there were some differences on the Final Exams given to the different groups, which may

have effected student performance. The instructor felt the Spring 2018 exam contained additional questions related to the design project in the 2018 offering (mandatory LEAP group), possibly increasing their overall exam score. To further investigate this impact, we separated the exam questions into different topic areas, excluding design project questions, and performed a one-way ANOVA. These results are shown in Table III. Both the voluntary and mandatory LEAP groups had higher averages in all exam question categories than the no LEAP group. While the differences between for the voluntary group were not statistically significant, there were statistically significant differences between the no LEAP and mandatory LEAP groups in two categories (NX and MATLAB Functions) and approached significance for a third category (MATLAB Programming).

TABLE II. COMPARISONS ON ENG1102 FINAL EXAM CATEGORIES [A]

Performance Measure	ENG1102 Sections		
	No LEAP (n = 54)	*Voluntary (n = 55)*	*Mandatory (n = 119)*
Drawing	70.4 ± 3.0	72.3 ± 2.5 (0.628)	79.2 ± 3.7 (0.132)
NX	58.6 ± 2.2	60.9 ± 2.3 (0.462)	72.0 ± 4.1 (0.031)
MATLAB Program	62.3 ± 3.2	64.8 ± 3.7 (0.611)	74.3 ± 4.0 (0.059)
MATLAB Functions	60.1 ± 4.2	70.1 ± 4.1 (0.095)	82.6 ± 3.4 (0.0002)

a. p values shown depict comparisons with no LEAP condition

All students in the voluntary LEAP group had the opportunity to attend one or more of the LEAP sessions offered by the LEAP Leaders in their section each week. To determine if there is any difference between the students that attended the LEAP sessions, we compared the performance of the students that choose to attend one or more LEAP session to those that did not attend any LEAP Sessions. Approximately 38% (n = 22) of the students within the voluntary LEAP group did not attend any LEAP sessions, while 62% chose to attend at least one LEAP session throughout the semester. As shown in Table II, the students that attended the voluntary LEAP sessions had higher averages on all the performance measures; however, none of these differences are statistically significant. The higher averages for the voluntary LEAP attended group may be in part to self-selection.

TABLE III. COMPARISONS ON SELECTED ENG1102 PERFORMANCE MEASURES WITHIN VOLUNTARY LEAP GROUP

Performance Measure	ENG1102 Voluntary LEAP Sections		Significance (p)
	Not Attended (n = 59)	*Attended (n = 58)*	
Individual Homework	86.8 ± 2.7	92.7 ± 1.6	0.348
MATLAB Lab Practical	76.5 ± 7.3	86.8 ± 4.7	0.621
NX Lab Practical	87.5 ± 6.5	97.4 ± 1.1	0.199
Final Exam	66.4 ± 3.1	67.4 ± 2.5	0.984
Final Grade	85.5 ± 1.4	88.8 ± 0.7	0.100

VII. STUDENT ATTITUDES

At the end of each semester, we solicited student feedback through an end of term survey regarding the contributions the LEAP Leader and the LEAP Sessions made to their learning (Table IV and V). Students were asked to rank their agreement with a number of statements on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree). The complete survey can be found in Appendix A. These questions were based on Michigan Technological University Course Evaluations. One of the questions was not asked in the 2017 survey and another question was modified for the 2018 survey. In Spring 2017, we had a response rate of 82% and Spring 2018, we had a response rate of 50%.

In both offerings of the LEAP Program (voluntary or mandatory), the majority of students stated that their LEAP Leaders displayed a personal interest in their learning, created an accepting atmosphere, and were positive role models. Students in the mandatory group appear to have a higher level of agreement with these statements, but that could be a product of the difference in response rates. Approximately three-quarters of the students found their LEAP Leader to be a key part of their learning environment for ENG1102. Only 25 students in the voluntary section attended any LEAP sessions and completed the last question. Seventy-six percent (n = 19) found the LEAP Sessions to be helpful. It is important to note than none of these students disagreed with this statement, and the students who did not agree, attended the fewest amount of LEAP Sessions.

TABLE IV. STUDENT FEEDBACK ON THE LEAP PROGRAM (VOLUNTARY, N = 45)

Survey Question	*Response (Mean ± SD)*	*% Agreement*
My LEAP Leader displayed a personal interest in students and their learning.	4.3 ± 0.8	82.2
My LEAP Leader created an accepting atmosphere.	4.4 ± 0.8	88.8
My LEAP Leader is a positive role model.	4.4 ± 0.9	86.7
Taking everything into account, I consider my LEAP Leader to have been a key part of the class learning environment that helped me in this class.	4.0 ± 0.9	75.6
The LEAP Sessions were helpful.[a]	4.2 ± 0.8	76.0

[a] only completed by students attending LEAP Sessions (n = 25)

TABLE V. STUDENT FEEDBACK ON THE LEAP PROGRAM (MANDATORY, N = 62)

Survey Question	*Response (Mean ± SD)*	*% Agreement*
My LEAP Leader displayed a personal interest in students and their learning.	4.4 ± 1.0	87.1
My LEAP Leader created an accepting atmosphere.	4.6 ± 0.8	91.9
My LEAP Leader is a positive role model.	4.4 ± 1.0	88.7
Taking everything into account, I consider my LEAP Leader to have been a key part of the class learning environment that helped me in this class.	3.9 ± 1.3	74.2
The LEAP Sessions helped me to learn the course material and reinforced course concepts.[a]	3.8 ± 1.3	70.5
Having LEAP Leaders in class was helpful to my learning.	4.0 ± 1.2	75.4

[a] Question modified from Spring 2017 survey question "LEAP Sessions were helpful."

VIII. CONCLUSIONS

In this paper, performance measures for three groups of students with varying levels of near-peer support were compared. The no LEAP group had one undergraduate teaching assistant in a section of 60 students; the voluntary LEAP group employed three LEAP Leaders for 58 students in a section where attendance in weekly LEAP sessions was optional and held outside of normal class time; and the mandatory LEAP group employed five LEAP Leaders in a section of 120 students and attending the LEAP sessions was required and occurred during class. In general, the students in the voluntary and mandatory LEAP session groups performed better than those students in the no LEAP group, with students in the mandatory group performing significantly better than either group. The majority of students for both the voluntary and mandatory LEAP sessions found their LEAP Leaders to be positive role models who created an accepting environment.

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APPENDIX A: LEAP LEADER AND LEAP PROGRAM EVALUATION

Survey Question	Survey Response (1 = Strongly Disagree, 5 = Strongly Agree)				
My LEAP Leader was knowledgeable about the course content					
My LEAP Leader was enthusiastic about the subject matter of the course.					
My LEAP Leader provided timely feedback on my work (homework, assignments, exams, etc.) and helped me to understand the instructor's feedback.					
During class, the LEAP Leaders provided guidance and assistance with the in-class activities.					
My LEAP Leader engaged students by encouraging team participation.					
My LEAP Leader came prepared and organized for each LEAP session					
My LEAP Leader displayed a personal interest in students and their learning.					
My LEAP Leader created an accepting atmosphere.					
My LEAP Leader is a positive role model.					
Taking everything into account, I consider my LEAP Leader to have been a key part of the class learning environment that helped me in this class.					
I understand that the LEAP Program is the integration of peer learning assistants within the classroom and in LEAP sessions.					
Having LEAP Leaders in class was helpful to my learning.					
The LEAP Sessions helped me to learn the course material and reinforced course concepts.					
Which LEAP session activities were most effective for your learning? (select all that apply)					
Handouts and worksheets, Games (e.g., Kahoot, Jeopardy, Horse Races, Tic Tac Toe), Response Systems (e.g., Quizlet, Mentimeter), Practice Quizzes or Quizzes, Practice Problems and Examples, Group Discussion, Question and Answer, Working with my team, Working Individually					
Which LEAP session activities were least effective for your learning? (select all that apply)					
Handouts and worksheets, Games (e.g., Kahoot, Jeopardy, Horse Races, Tic Tac Toe), Response Systems (e.g., Quizlet, Mentimeter), Practice Quizzes or Quizzes, Practice Problems and Examples, Group Discussion, Question and Answer, Working with my team, Working Individually					
The advice I would give to my LEAP Leader as she/he prepares to be a LEAP Leader again would be _____. (Please be as specific as possible in terms of how your LEAP Leader could help more, even if you feel that your LEAP Leader was excellent.)					
What about the LEAP Program was most beneficial to you?					
What suggestions do you have to improve the LEAP Program?					