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Analyzing Longitudinal Performance from Multi-Course Alignment for 1st Year Engineering Students: Calculus, Physics, and Programming in MATLAB

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Background

Many first year students struggle to synthesize concepts across Programming for Engineers, Calculus I, and Physics I courses[1]. While calculus and physics are the tools that can be utilized by engineers to solve problems, students are often unable to see that the knowledge presented in the mathematical and physics context can be transferred to solve engineering problems. Students also tend to think of programming as an isolated component of engineering, when they should view programming as yet another tool to verify results or to solve more complex problems, reducing risks of algebraic errors[2].

Outside-the-classroom interactions with faculty members, meaningful interactions with peers, and on-campus living-learning community involvement have been shown to positively affect student persistence in college[3]. Since fall 2013, Embry-Riddle Aeronautical University (ERAU), in Daytona Beach, FL has linked three fundamental engineering courses to provide students with a STEM (science, technology, engineering, and mathematics) small-learning-community (SLC). The same set of students is registered concurrently for the matching Physics I, Calculus I and Programming for Engineers courses.

Table 1 presents the topics taught in each of the STEM SLC courses. The STEM-SLC faculty focused on creating mini-projects for their courses that would leverage the common topics, these are the bold faced topics. For detailed results and an in depth-review of examples of the developed mini-projects please refer to the previously published ASEE conference paper[4].

Table 1: Description of Calculus I, Physics I and Programming Courses

Course	Description
Calculus I	**Graphs and functions**; differentiation and **integration** of algebraic and elementary trigonometric functions; **related rates**; applications of first and second derivatives[5].
Physics I	**Vectors** and scalars quantities; geometrical optics, kinematics; **free body diagrams, Newton's Laws of Motion**, work, work-energy, conservation of energy, conservation of momentum, **center of mass** and its **motion**[5].
Introduction to Programming for Engineers	Software design and development: specification, requirements, design, code, and test; scripts, data-types, input and outputs, **flow-control**, functions, **arrays**, **files** and **plotting**.

Purpose

The purpose of this research is to expand the investigation of the impact of the STEM SLC. The second phase of the study is to analyze if the feeling of community impacted the following:

- student performance of the fall 2014 cohort group,
- student success in future core engineering courses – specifically Physics II, Calculus II, and Statics, and
- overall grade point average (GPA) of the STEM-SLC students vs. the control group.

Methods

Pedagogy

Three faculty members linked their courses to create a STEM (science, technology, engineering, and mathematics) small-learning-community (SLC). The same set of students is registered for the three linked courses: Calculus I, Physics I, and Introduction to Programming using MATLAB. During the semester, all three faculty developed specific assignments incorporating concepts from each of the three disciplines. All three faculty collaboratively developed the real-world application problems that required leveraging knowledge horizontally across all three courses.

Participant Selection

For the first cohort in the fall 2013, students were randomly selected from the incoming newly admitted students to be within the SLC. These students were sent a letter before the semester started, explaining that three courses were linked, the purpose for such link, and the option to opt-out if they wished. For the following year cohorts, through advertising in the colleges, from advisors, and from word-of-mouth from previous SLC students, students self-selected the SLC courses. During online self-registration, students are made aware that selecting this specific section of Physics I automatically selects the linked sections of Calculus I and Programming for Engineers.

Three faculty volunteered to participate in the project originally. The same faculty remained constant for the first academic year. In the spring 2014, the Calculus I faculty was no longer able to participate due to other teaching requirements. By then, the existence of the SLC community also had become known amongst faculty and self-recruiting happened: a new Calculus I faculty requested her participation starting spring 2014. As we have prepared planning for the fall 2015, knowing that this time the Physics I faculty can no longer participate, another faculty has already expressed interest in taking over.

Results

Due to faculty teaching loads, and opportunities to teach multiple sections of the same course, this study yields two cohorts of students:

- “The SLC students”: The SLC students are specifically enrolled in all three courses, and grouped in the same sections. The Physics I and Calculus I classrooms allow for 45 students, while Programming is limited to 26 due to computer classroom size. Therefore, SLC students are split across two sections of Programming.
- “The Programming Control group”: the faculty teaching these two sections of Programming also taught two additional sections where freshman to senior level students were enrolled, thus no longer being related to the SLC. Among all these other students, some were still enrolled in Calculus I and Physics I but with other faculty. This category is designated as the programming *control group*, as their performance in all three courses can be compared with those in the SLC. Faculty in Calculus I and Physics I only taught one section of SLC students, with no other non-SLC sections. Therefore they have no actual control-groups.

Performance Results Fall 2014

In the Programming class, the fall 2014 grade distribution shows similar trends to the grade distribution from fall 2013-spring 2014[4]. Table 2 shows that 16% more students in the SLC passed the MATLAB course than students in the programming control group.

Table 2: Pass/Fail rates in the MATLAB class for fall 2014 cohort

FA14 Students	Passing (A/B/C)	Failing (D/F)	AU	W
SLC (n=47)	**66%**	25.5%	0%	8.5%
Control Group (n=16)	50%	37.5%	6.25%	6.25%

Table 3 compares the specific grade distribution of each of the three courses between the SLC and the control group. For this year, and for the Calculus I and Programming STEM-SLC courses, there were fewer failures (D/F) in the SLC compared to the control group (25.5% vs. 37.5% in Programming, 24% VS. 31.25% in Calculus I).

However, the specific distribution within the passing range is interesting. The SLC earned 15% more B’s in the Programming class and 6.75% more C’s in Calculus I than the control group. These results support the findings from our previous study[4] that found potentially at-risk students were more successful than the at-risk students in the control group as more of them were in the passing range A/B/C.

The pass and fail rates in Physics I between SLC and the control group remain equal (50% and 31%) but the specific distribution is again interesting. There was a 13% increase in the number of A's earned and a 12% decrease in the number of F's, again indicating that the SLC students are more successful than those not enrolled in the SLC.

Table 3: Grade distribution in each class for fall 2014 cohort

	FA14 Students	A	B	C	D	F	AU	W
Programming (MATLAB)	SLC	23.4%	**21.3%**	21.3%	10.6%	**14.9%**	0%	8.5%
	Control Group	18.75%	**6.25%**	25%	12.5%	**25%**	6.25%	6.25%
Calculus I	SLC	19%	19%	**25.5%**	11%	13%	10.5%	2%
	Control Group	18.75%	18.75%	**18.75%**	18.75%	12.5%	12.5%	0%
Physics I	SLC	**13%**	**11%**	25.5%	23%	**13%**	6%	8.5%
	Control Group	0%	25%	25%	6%	**25%**	13%	6%

Reisel, et al. has shown that greater participation in study groups correlated with higher grades in associated math courses[6]. From student feedback, the SLC students state they are studying together in groups and reminding each other of important deadlines. The library also has reported an increase in requests for group-study rooms. These student study groups are able to use these rooms to discuss, explain, and practice problems for their exams. This increase in group activity parallels the observed increase in student performance. The SLC has provided an environment for student to identify potential study partners and to develop these much-needed study groups.

Longitudinal Results in Calculus II and Physics II

The SLC students from the fall 2013 and spring 2014 semesters are now completing fundamental courses such as Calculus II, Physics II and Statics. Performance between the STEM SLC and the control group were compared to measure the longitudinal impact of the program. Calculus II and Physics II are taken the second semester freshman year for students seeking a Mechanical, Civil, or Aerospace Engineering degree.

As the SLC students have been presented with multiple approaches to solving problems, it was expected that these students' understanding, problem-solving abilities, and critical thinking skills would be improved. These students are, therefore, expected to perform better in their subsequent fundamental core courses.

Table 4 and Table 5 present the pass/fail rates of both fall 2013 and spring 2014 cohorts. All students were not combined into one cohort to be able to reflect the fact that some students from the fall cohort have taken a course (Calculus I, Physics I, or both) multiple times to pass the class while students from the spring 2014cohort are doing so in the current spring 2015 semester. Therefore, only students who started at the same time are compared.

Results for the fall 2013 cohort shows a similar pass/fail percentage in Calculus II regardless of the participation in the STEM-SLC. It however shows a greater percentage of students in the control group having successfully completed Physics II.

Table 4: Fall 2013 cohort Pass/Fail rates in Calculus II and Physics II

	Fall 2013 cohort		Pass (A/B/C)	Fail (D/F)	AU/W
Calculus II	SLC	(n=24)	81%	14%	5%
	Control-Group	(n=10)	89%	11%	0%
Physics II	SLC	(n=24)	79%	21%	0%
	Control-Group	(n=10)	89%	11%	0%

However, students from the spring 2014 SLC cohort had a higher performance overall in both Calculus II and Physics II, as shown in Table 5. The continuous improvements of the mini-projects during the spring 2014 helped provide a better foundation for this later course.

Table 5: Spring 2014 cohort Pass/Fail rates in Calculus II and Physics II

	Spring 2014 cohort		Pass (A/B/C)	Fail (D/F)	AU/W
Calculus II	SLC	(n=12)	66.7%	16.7%	16.7%
	Control-Group	(n=9)	56%	22%	22%
Physics II	SLC	(n=10)	90%	10%	0%
	Control-Group	(n=9)	78%	0%	22%

Longitudinal Results in Statics

Students in the majors aforementioned would take Statics in their third semester. Therefore, students from the fall 2013 cohort should have enrolled in Statics. Yet 46% of the SLC vs. 60% of the control group have not yet enrolled in statics. Of the spring 2014 cohort, only 4 students have completed Statics, all from the SLC.

Of those who have completed the course, and regardless of the cohort date, Table 6 shows a 100% passing rate in the SLC vs. 75% of the control-group. At this time, the results for performance in Statics remain premature, as the sample size remains small. Sample size will increase as the spring and fall 2014 cohorts continue to complete classes at ERAU this spring 2015.

Table 6: Pass/Fail rate in Statics

Cohort			Pass (A/B/C)	Fail (D/F)
Fall 2013	SLC	(n=13)	100%	0%
	Control-Group	(n=4)	75%	25%
Spring 2014	SLC	(n=4)	100%	0%

Grade Point Average of SLC Students and the Control Group

The final purpose presented here is the comparison of overall GPA of the STEM-SLC students vs. the control group. Multiple research show a higher GPA from students who participated in learning communities than those who had not. Hurny and Hurny indicate a 16.6% higher GPA in SLC students after the first academic year[7]. Table 7 shows similar results are originally found in this study, as in a 15% higher GPA after their first semester, though only 12% after their first academic year, and only 4% higher after three semesters. This particular aspect of the study will continue to be monitored until the first two cohorts graduate.

Table 7: Student GPA from fall 13, spring 2014, and fall 2014 cohorts

Cohort		Average GPA
FA14	SLC (n=47)	2.534
	Control Group (n=16)	2.200
SP14	SLC (n=24)	2.995
	Control Group (n=20)	2.670
FA13	SLC (n=34)	3.067
	Control Group (n=14)	2.938

Survey Results

To continue to measure the impact of the integrated multi-disciplinary problems on student learning, a mid-term focus group comprised of the STEM SLC students was interviewed. Students identified 1) what enhanced their learning, 2) what hindered it, and 3) what they could do to improve their learning experience:

- Overall, students indicated they liked having the same group for Math, Physics, and Programming class and saw the fact the three faculty communicated as adding a professional aspect to the class. Over half of the students indicated they were part of a study-group, either for one class, or for a combination of the three courses.
- The responses related to the hinder were more aimed at each course itself (harsh grading, attendance policy, etc.), but no comments were made on the SLC aspect itself.
- The typical answer came out as to how they could improve their learning: read directions more carefully, and practice more examples.

Conclusions, Observations, Limitations, and Future Research

Overall Results

Since the fall of 2013, linking courses through a STEM-SLC has shown a continuous increase in student performance for all three 1st-year engineering courses: Programming, Calculus I, and Physics I. Specifically more students are successful in the STEM SLC than those that are not. This increase is likely due to the increased study groups and the overview of similar problems in the three courses.

The fall 2013 cohort, which was the first time this learning community was started, seemed to have performed relatively the same in Calculus II and Physics II, whether or not enrolled in the SLC. The results for the Statics course were still premature due to a small sample size. However, due to improvements of the mini-projects and lessons learned from the first cohort feedback[4], the spring 2014 cohort has shown a higher performance of the students from the SLC in the Calculus II and Physics II courses.

Observations

In the fall 2013, all faculty noted that students in the SLC to be more participative and louder than other sections. This required all three faculty to be more active in keeping the class focused. The timeframe of the two SLC programming sections were 2:15pm and 3:15pm. In the fall 2014, the two SLC programming sections were specifically scheduled in the morning (9:30AM and 11AM) to see if the time was a factor in the participation. The students were not as participative or as outspoken. The spring 2015 SLC students were split between a morning section of programming (10:30am) and an afternoon section (2:15pm). The afternoon class was more active thus showing time does contribute to the level of participation regardless of SLC students or others.

Challenges

Previous challenges mentioned in the first research paper[4] are still applicable:

- students still lack the pre-requisites for Calculus I,
- some students do not want the community aspect, and feel alienated from the group,
- ensuring that the three faculty who teach Programming, Calculus I, and Physics I courses are scheduled at different times, is difficult. Only one SLC section of Calculus I and one SLC section of Physics I was taught in the fall 2014 semester due to the demand of those faculty to teach other courses in their department. This results in only a small control group, all based on the programming course.

One of the newly noted challenges found is the lack of motivation by the students. While faculty noted an excellent atmosphere in the classroom in 2013 and 2014 that fostered participation, study groups, and co-teaching between students, the opposite also appeared. The students in the SLC of spring 2015 were very quiet and the overall attitude of the class was not as optimistic. For example when a test did not go well in one of the courses in the SLC, the shift or decrease in motivation was observed in the other sections of the SLC. In the other sections, this feeling dissipates due to the other students not having gone through similar "bad" exams. This led to poor results on some of the in-class assignments.

Future Research

Based on the current results presented in this paper, a few points require more data, specifically for retention analysis. End of year survey asked students whether they would be returning to the university, and to explain their reasons if not. The open-ended answer led to poor feedback that is too inconclusive to analyze.

Future specific year-end surveys will particularly focus on:

- the advantages and challenges of being in an SLC, from a student's point of view,
- the impact of the integrated problems across the three courses on their understanding of Physics I concepts,
- the detailed aspect of creating study-groups. In the SLC, are these study groups with the same students across all three courses, or different students still within the SLC? For the control groups, do these students even form study groups on their own? If yes, how fast compared to the students in the SLC?
- their specific reason for leaving ERAU.

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