Bridges to Engineering: Success for Transfers

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Abstract

The Grove School of Engineering (GSOE) of the City College of New York partnered with two community colleges to improve the transfer and success of students moving into a bachelor's program in engineering. A broader goal of the project was to increase the success of all students enrolling in the Grove School of Engineering.

The project took place from fall 2005 through spring 2012. Its three main components were: 1) Introducing lower level undergraduate students to research, 2) A summer research course for community college students considering the GSOE, and 3) Harmonization of science, math and some entry level engineering science courses across the participating schools. We tracked enrollment, persistence and academic achievements of participating students and compared these to similar groups of Grove students who did not participate. At the end of the project we have indications that undergraduate research experience has a positive effect on persistence in and appreciation of engineering. Course harmonization between the partnering colleges promises to have positive effects as well, not only for transfers from the partnering colleges, but also for other students. This paper discusses the "Bridges" project and its findings in the context of other relevant developments, such as changes in admissions criteria and rising enrollments at the Grove School of Engineering.

1. Introduction and problem statement

The Grove School of Engineering (GSOE) is part of the City College of New York (CCNY), an urban commuter college offering over 100 degrees in liberal arts and social science, science, education, engineering, medical studies and architecture. The diverse student body of CCNY consists of about 13000 undergraduates and over 3000 graduate students, including more than 200 Ph.D. students in engineering. Grove's student body reflects a similar diversity, with over 2200 undergraduates, about 480 master's students and approximately 200 Ph.D. students. At present, the school offers eight ABET accredited undergraduate programs in biomedical, chemical, civil, computer, electrical and mechanical engineering, computer science and environmental science & systems engineering. The school offers seven masters programs and six Ph.D. programs including one through the CUNY system's graduate school. CUNY stands for City University of New York, of which CCNY is one of the eleven senior colleges. Under the pressure of increased demand for an affordable well-regarded education in engineering, and as a result of a retention study, the GSOE gradually raised its admissions criteria, starting in fall of 2006. After an initial drop in enrollment, present enrollment levels are almost back to fall 2004 levels. Retention and graduation rates have improved significantly, to the point that at present it is a challenge to meet the demand for upper level engineering courses.

Table 1 shows the numbers of new entrants and total enrollment in the Grove School of Engineering for a number of academic years. We restricted ourselves to regular USA citizens or permanent residents ("USA students") to be able to compare retention between cohorts over time. The rightmost column shows the retention rate in the third year as a percentage of the initial cohort. About 20-25% of new students each year are from community colleges in the system and the majority of these transfers are from under-represented groups. We expect that improving retention and graduation among system community college transfers will be especially beneficial to under-represented groups in engineering.

Table 1. Enrollment, ethnic and gender composition, previous achievements and retention rates for academic years 2004 through 2010 in the Grove School of Engineering for regular USA students.

Student Type	Ac. Year	N	Women (%)	Black (%)	Hisp. (%)	Minor. (%)	URG (%)	SAT Total	SAT Math	High School GPA	Transf. Creds.	Retained in 3rd yr. (%)
Freshmen	2004	331	12.7	23.3	26.3	49.6	55.9	1030	554	84.3		42.6
	2006	166	15.1	16.7	27.7	44.4	56.0	1082	589	85.3		52.4
	2008	265	16.5	13.6	27.9	41.5	52.5	1099	596	86.5		57.0
	2010	285	18.9	10.2	19.6	29.8	41.1	1131	617	87.2		64.6
CUNY	2004	141	11.3	27.0	30.5	57.5	58.9				32.3	36.9
Comm.	2006	80	12.5	32.5	25.0	57.5	58.8				38.7	46.8
College	2008	72	9.7	25.0	34.7	59.7	63.9				40.6	55.6
Transfers	2010	141	12.1	26.2	23.4	49.6	56.7				41.5	51.3
All New	2004	644	14.4	23.0	28.1	51.1	57.6					
Students	2006	337	16.0	20.8	25.5	46.3	55.2					
	2008	435	17.2	14.9	27.6	42.5	53.6					
	2010	601	18.3	16.5	19.0	35.5	46.3					
Total	2004	1970	17.0	24.8	27.4	52.6	60.1					
Enrolled	2006	1574	17.3	22.0	26.4	48.4	56.7					
	2008	1602	16.3	18.5	25.7	44.2	53.6					
	2010	1867	16.5	14.2	25.7	39.9	49.8					

Note. Retention+graduation for Ac. Year 2010 only for fall 2010 new entrants since spring 2013 registration is still ongoing. URG= Under Represented Group (women and/or minority).

Table 1 shows that retention for transfers from the seven CUNY Community Colleges in 2004 is especially low: Less than 37 % of those who started in Engineering returned in their third year (none had graduated by then). The third-year retention rate among freshmen was not high either, with less than 43% of the original cohort returning in the third year. To address the low retention rates, especially of CUNY community college transfers to the Grove School of Engineering, a project was proposed and funding obtained to gain insight into the main barriers and address these with a range of interventions.

The project objectives were:

- Increase in the number of students enrolling in, retained in and graduating from bachelors degree programs in engineering,
- Improved preparation in academic skill areas providing the foundation for success in upper division engineering coursework through course harmonization,
- Enhanced readiness for research participation at the upper division level in engineering through early undergraduate research experience,
- More seamless and successful transitions between community and Senior College engineering programs through a summer research course and course harmonization.

The project started in the fall of 2005 and the implementation of interventions started in 2006 with a number of undergraduate research projects, followed by the start of the first harmonized course and the first summer research course for potential transfers in 2007. Section 2 describes the interventions in more detail.

This paper focuses on determining the effect of the three main project activities on persistence and achievement, controlling for higher admissions criteria and increased demand by careful selection of comparison groups. We also describe more qualitatively the most salient other benefits for students from their answers to a number of open-ended questions in two surveys.

During the project period two important changes occurred that we had to take into account in the effect evaluation. The most significant change is a gradual rise in admissions criteria for both freshmen and transfers, starting in fall 2006, when the first project activities were being implemented. Retention and graduation rates have increased significantly since then as shown in Table 1, so the question is to what extent the increase can be attributed to the raised admissions criteria or to the project interventions. Another important change is the sharply increased demand for the affordable engineering education offered by the Grove school, driven in part by the economic recession. This development limits the project objective of increasing the number of students enrolling in engineering, but not the objective of raising retention and graduation rates.

Reading suggestion: The rest of the paper may be read from beginning to end, from description of the project to conclusions, or by topic. E.g., undergraduate research is reported in sections 2a, 3a, 4a, and 5a. Sections 2b, etc., are about the summer research course for potential transfers. Sections 2c, etc., are about course harmonization.

2. Description of the project interventions

2a. Introducing lower level undergraduate students to research

Starting in 2006, during every academic year seven to fourteen undergraduates participated in a research project under the guidance of a faculty member. Guidelines for selection were a cumulative GPA of 3.00 or higher and promising study progress. The students were recruited through the school's office of undergraduate research, which coordinates and oversees research and internship opportunities, and organizes events such as poster presentations and networking opportunities for Grove students. The office invites faculty members on a regular basis to provide descriptions of available research projects that undergraduate students can take. Grove students are informed on a regular basis when opportunities become available through e-mail and the school's web site. The selected "Bridges" students received a stipend and were required to write a report or paper about their work and present it with a poster at an undergraduate research symposium. Special efforts were made to recruit women and minority students. Appendix 1 provides a typical example of an undergraduate research project.

2b. The summer research course for potential transfers

Since 2007 the Grove School of Engineering offers a four-week summer research course for community college students interested in transferring to a bachelor's program in engineering. The purpose of the course is to introduce potential Grove students to the practice of engineering research in the engineering disciplines the school offers. The course consists of a group research assignment, lab and library visits, guest lectures on engineering ethics and statistics, group reports and presentations, math tutoring, and writing exercises analyzing a research article and exploring a research problem. A program description is provided in appendix 2. The students were recruited by Grove's office of student programs using its contacts in many community colleges and other feeder schools in the region. Women and minority students were especially encouraged to apply for the summer research course. Each summer from 2007 through 2012, between seven and fourteen students took the summer research course. An instructor with a degree in engineering teaches the course. The students received a stipend for their participation to offset any loss of income from summer jobs. There have been some potential transfers from four-year colleges as well, but the majority, more than 80%, came from community colleges within the university system.

2c. Harmonization of introductory math, science and engineering courses

Several introductory courses in math, science and engineering science taken by students in the partnering schools were harmonized to produce the same learning outcomes. Lead faculty teaching the courses in the partnering schools met and compared syllabi and course topics, and aligned course content with the learning outcomes. This activity is expected to facilitate a better transfer of community college students to a bachelor's program in engineering, such that if they take the next course in a sequence in the bachelor's program, they are as well prepared as Grove's own students (those who started as freshmen in Grove). The first harmonized course was offered in fall 2006. In subsequent years more harmonized courses were offered and earlier activities were evaluated, reviewed and modified if needed.

3. The literature

3a. The impact of undergraduate research and summer research experience

The impact of undergraduate research, including summer research experiences, has been researched extensively and the findings indicate a beneficial effect on intellectual, professional and personal growth for students and increased job satisfaction and professional outcomes for faculty[1, 2]. Students from under-represented groups in particular are thought to benefit from an undergraduate research experience, since they often experience less access to the informal mentoring and networking opportunities and the quality high school education that traditional students enjoy. Participation in undergraduate research has proven to be an effective strategy to remedy such gaps in access for under-represented groups. A study on the impact of undergraduate research found that it is important to control for previous academic achievements such as SAT scores and GPA in evaluating the effects of undergraduate research[3].

3b. The impact of course harmonization

In our case course harmonization means ensuring that course outcomes for the same course in different institutions are the same, and that course content and other learning experiences are aligned with the expected course outcomes. Courses that are part of a sequence were also aligned to each other, to ensure that a lower level course, e.g., Calculus 1, would prepare the student adequately for taking Calculus 2. Students were supposed to benefit by experiencing less of an academic gap between what they had learned at the community colleges and the requirements of a bachelor's program in engineering.

Biggs[4] perceives the benefits of "constructive alignment" in terms of an enhanced focus on the quality of student learning, by making explicit not only the course content the student is expected to learn, but also the level and nature of mastery. The concept of constructive alignment is very similar to the assessment cycle required by accrediting agencies such as ABET[5] and Middle States[6]. Through intentional course design, all students are encouraged to use higher-order thinking, not just the academically gifted ones. Biggs states: "The learner is in a sense 'trapped', and finds it difficult to escape without learning what he or she is intended to learn." In our case the course outcomes were already formulated as requirements for accreditation by Middle States and ABET. This provided an excellent basis for faculty in the three partnering institutions to compare, discuss and adjust the courses, leading to greater mutual understanding of each others' approaches, expectations, curricula, institutional cultures and student characteristics. It was easy to find many articles and books on the impact of undergraduate research, but such was not the case for literature on the impact of course harmonization. Our expectation was that we should see increased pass rates in a number of courses affected by course harmonization, especially among transfers from the partnering community colleges to Grove.

4. Research design and methods

4a. Effect evaluation

We evaluated the impact of the undergraduate research experience by means of a survey and by tracking the participants on retention and academic achievements. The survey asks the research participants about the impact of their research experience on motivation, persistence, future plans and satisfaction with their education. The questions are based on literature about achievement motivation[7, 8]. Achievement motivation is conceptualized as a combination of interest, perceived usefulness, the required effort, and the perceived difficulty of a task. In our case, the task is obtaining a bachelor's degree in engineering. The closed questions are formulated as Likert items with a 5-point answering scale. Students were also invited to provide their own comments. Secondly, we compared the participants to a similar group of non-participants on persistence and academic achievement. We define persistence as retention or graduation in engineering as of fall 2012. Academic achievement is defined as the cumulative GPA and average number of credits obtained by the last semester in engineering before moving elsewhere, graduation in engineering or still being retained. We accounted for raised admissions criteria during the project period by choosing the comparison group from the same cohorts as the research participants, and further ensuring they had comparable previous academic accomplishments in their previous schools and their first two years at Grove. The analyses consist of simple contingency tables for discrete categories (graduation and retention) and analysis of variance for continuous variables (GPA and study progress).

The participants in the summer research course were asked to complete a learning outcomes and satisfaction survey at the end of the course. The students who transferred to Grove were tracked on persistence and academic achievement. The community college students among them were compared to community college transfers who did not participate in the summer research course. The satisfaction survey is based on the same achievement motivation literature as the undergraduate research survey. The learning outcomes survey asks students how much they learned from each of the components of the course. To account for changing admissions criteria we chose the comparison group from the same cohorts as the summer course participants. The effect analysis uses the same methods as the undergraduate research effect study.

The effect evaluation of the course harmonization effort consists of an analysis of first-attempt pass rates in a number of courses taken by transfers from community colleges to Grove, who took the pre-requisite course(s) in their previous school. We compared the pass rates in follow-up courses before and after harmonization of the pre-requisite and follow-up course in three groups: Transfers from the partnering community colleges, transfers from other community colleges within CUNY, and students who enrolled as freshmen in Grove. We expected course harmonization to have beneficial effects in all three groups, but most strongly in the group of transfers from the partnering community colleges. Changing admissions criteria are accounted for in the effect evaluation, since the eligibility for taking a certain course implies that the students are supposed to be academically on the same (minimum) level, either by having fulfilled placement criteria or the pre-requisite, no matter under which admissions criteria they entered.

4b. Populations and samples

Table 2 shows the populations and sub-populations in the effect evaluations. The comparison groups were chosen to control for raised admissions criteria by ensuring similar previous academic accomplishments among participants and non-participants. The groups in the undergraduate research effect evaluation consisted of students from the cohorts spring 2003 through spring 2010. These groups may be compared to the group of all GSOE cohorts in the second column. It is clear that both groups in the undergraduate research effect evaluation consist of the more academically accomplished students.

Table 2. General population and numbers of students in the effect evaluations.

	All GSOE USA regular freshmen and transfers in cohorts spring 2003 - spring 2010	Groups in effect evaluation			
		Undergraduate research		Summer research course	
Group		Participants	Non-participants	Participants	Non-participants
Total N	3837	77	523	37	312
% Minority	46.4%	33.8%	32.4%	59.5%	50.0%
% Women	17.2%	33.8%	20.1%	18.9%	12.5%
Retained in fall 2012	15.2%	26.0%	23.7%	35.1%	39.4%
Graduated through fall 2012	20.9%	70.1%	67.7%	13.5%	9.0%
Retained or graduated as of fall 2012	36.1%	96.1%	91.4%	48.6%	48.4%

5. Findings

5a. The impact of introducing lower level undergraduate students to research

Students were eligible for an undergraduate research project if they showed satisfactory study progress, preferably had a cumulative GPA of 3.0 or higher and promising study progress. Therefore we selected only students into the comparison group who were retained into the third year in engineering, with a cumulative GPA of at least 3.0 and at least 48 credits completed in the first two years. We further restricted ourselves to USA citizens or permanent residents ("USA students") since this was a requirement for the stipend.

The undergraduate research group consists of all 77 USA students who participated in undergraduate research, and who enrolled in their third year. The comparison group consists of all 523 USA students in the same cohorts who did not do undergraduate research, who had a cumulative GPA of 3.00 or higher at the start of their third year, with at least 48 credits earned in their first two years.

Table 3 shows the results of the comparison on a number of group descriptives, academic achievements and persistence through the spring of 2012, the most recent semester for which data were available. Statistically significant differences are indicated. The column "Direction" shows whether the difference is in favor of the undergraduate research group (+), in favor of the comparison group (-), or negligible (=).

Table 3. Group descriptives and student success for undergraduate research participants and non-participants.

Group Descriptives	Comparison Group	UG Research Group	Significance of Difference	Direc-tion
N students in group	523	77		
SAT (1)	1165	1156		-
SAT Math (1)	640	629		-
High School GPA (1)	89.5	90.2		+
Transfer Credits (2)	40.5	38.8		-
Cum. Credits at start of 3rd year	60.6	60.8		=
Cum. GPA at start of 3rd year	3.41	3.26	$p<0.001$	-
% Women	20.1%	33.8%	$p<0.01$	+
% Minorities (Black or Hispanic)	32.4%	33.8%		+
% Under-Represented Groups (Women and/or Minority)	43.4%	54.5%	$p<0.05$	+
% Freshmen at start in Engineering	60.0%	51.9%	$p=0.11$	
Academic achievement & persistence by fall 2012				
GPA at graduation or final semester in Engr.	3.38	3.28	$p<0.10$	-
Number of semesters retained in Engr.	7.6	8.6	$p<0.001$	+
Avg. Credits obtained per semester in Engr.	14.7	14.8		=
Total Credits earned at graduation or final semester while in Engineering (excl. transfer cr.)	96.4	108.5	$p<0.001$	+
% Graduated in Engineering as of fall 2012	67.7%	70.1%		
% Retained in Engineering in fall 2012	23.7%	26.0%		
% Of N students who left Engineering	8.6%	3.9%	$p<0.10$ (3)	+
% Of minorities who left Engineering	8.3%	11.5%		-
% Of women who left Engineering	8.6%	0.0%		+

(1) Freshmen only. (2) Transfers only. (3) Left Engineering vs. Graduated or Retained
All 2x2 contingency tables were evaluated with Fisher's exact test (one-sided)

The group descriptives show that the comparison group is quite similar to the undergraduate research group on previous academic achievements. Both groups have on average about the same SAT and high school scores among Grove students starting as freshmen, and the same number of transfer credits among transfers. There is a slight edge in favor of the comparison group. The average number of credits obtained during their first two years is essentially the same for both groups. The average cumulative GPA of the undergraduate research group is somewhat lower than that of the comparison group, reflecting the inclusion of a number of 24 students whose GPA was lower than 3.00 but who showed promise otherwise, e.g., through high test scores or an upward trend in their academic record. Half of the students in this group are African-American (n=5) or Hispanic (n=7), a slightly higher percentage than among the entire group of research participants. Their inclusion ensured sufficient participation of minority students. The percentage of women in the research group is significantly higher than in the comparison group while the percentage of minority students is about the same in both groups. The percentage of freshmen is somewhat higher among non-participants, but we verified that the findings on academic achievements and persistence showed a similar pattern for freshmen and transfers.

The undergraduate research group shows a small improvement in their cumulative GPA at the end of their final semester in Engineering, whether they are graduated, still retained or has moved elsewhere. The difference with the comparison group has become less significant. They earned on average 12.1 credits more through their final semester in engineering than the comparison group, and were less likely to have left Engineering at the start of the fall 2012 semester. The larger number of credits is mainly due to the greater persistence of the research group; on average they persisted about one semester longer in engineering than the non-participants. The graduation rate among research participants is slightly higher than in the comparison group. None of the female research participants has left engineering by fall 2012, versus 8.6% of the women in the control group. The percentage leavers among minority students is slightly higher for the research participants, but it concerns only three students, and the difference with the comparison group is far from statistically significant.

We can conclude that in our study, undergraduate research participation correlates positively with persistence and academic achievement when previous academic performance is taken into account. This is the case for students in general and for women in particular. For minority students there appears little difference at first sight. However, the minority students in the research group started out with on average a 0.32 pt. lower initial GPA than the minority students in the comparison group, with about the same number of credits obtained in the first two years while attending the GSOE. Further analysis not shown in Table 2 found that they ended up with half the difference in GPA, and earned on average twelve more credits than the minority students in the control group. It appears that the minority students in the research group caught up with the comparison group. The research experience may have contributed to their improvement by providing them with a network of peers, close contact with a faculty member and a clearer perspective for their future in engineering. The comments made on the satisfaction survey support this assumption. This is true for non-minority students as well of course, but women and minority students experience barriers in gaining access to networks and mentors more often than students who do not belong to under-represented groups.

Some results and comments by students on the satisfaction survey

In the summer of 2010 we conducted an on-line satisfaction survey among the 61 students who had completed an undergraduate research project by that time. The response rate was low, and even after repeated reminders it was less than 30%. The respondents were all very positive about their experiences. Except for two students, they found engineering more interesting, worth the time and effort and useful for their future plans as a result of their involvement with research. The remaining two students found the experience made no difference to their motivation, which was already high to begin with.

We illustrate the personal benefits of undergraduate research by providing a number of comments from participants. Any identifying information is removed.

On how research experience influenced their motivation for engineering:

> "I learned that research is a field that one can make a career in. Also, the professor and TA were very intelligent and helpful. Although the topic was complicated for a sophomore like me, they made it easier for me to understand by providing me with the relevant papers on the topic and suggesting me to search articles from scientific database to get more feel of the topic. I developed a strong interest in Engineering Materials during the literature research that I did for the project."

> "It gave me a chance to experience the day to day life of a research engineer. This made engineering seem more practical to me."

On access to opportunities:

> "We worked on a scientific project to do mechanical testing on Advance Composite material. At the end of the project the professor helped me to get a summer research internship with [name of prestigious engineering school]. There the project was on nanotechnology and surface chemistry."

On how to improve the research experience:

> "Although it was good that we got an opportunity to work on a project provided by professor, I believe there should also be opportunity for students to develop the topic/project description by themselves."

> "Encourage students and advertise research opportunities."

> "There should be career services and/or Grad School Prep class to help students with senior statuses."

> "I would have liked more help in math and analysis at an earlier stage in the research."

> "Everything is very good and the path on which Grove is correct and I can't wait to see long-term results of these initiatives. One thing that I would like to see more is more collaborative research between departments, such as EE and Comp. Sci - as the two fields overlap significantly in the real world."

5b. The impact of the summer research course

In the summers of 2007 through 2012, a total of 69 prospective transfers to engineering attended a four weeklong summer course. We were able to track 66 of the participants, of whom 62 (94%) enrolled in the Grove School of Engineering. Of the 65 students whose previous school was known, 53 (81.5%) were from community colleges within the same system. The rest came from senior colleges and one from an external community college.

For the effect study we compared the system community college transfers who took part in summer research with the system community college transfers who did not participate. The transfers in the comparison group came from the same cohorts as the transfers in the research group, to control for changes in admissions criteria over time. In both groups we left out the transfers starting in spring 2012 or later, because we do not have data about their achievements yet, and we restricted ourselves further to USA students only. This gave us 37 summer research participants, to compare to 312 non-participants.

Table 4 shows the results of the comparisons. Significance levels are indicated for (almost) statistically significant differences. The direction of the difference is symbolized with a "+" if it is in favor of the research group, a "-" if in favor of the control group, and a "=" if it is negligible.

Table 4. Group descriptives and student success for summer research participants and non-participants transferring from system community colleges.

Group Descriptives	Comparison Group	Summer Course Group	Significance of Difference	Direc-tion
N students in group	312	37		
Transfer Credits	41.8	49.3	$p<0.05$	+
% Women	12.5%	18.9%		+
% Minorities (Black or Hispanic)	50.0%	59.5%		+
% Under-Represented Groups (Women and/or Minority)	57.4%	67.6%		+
Academic achievement & persistence by fall 2012				
GPA at graduation or final semester in Engr.	2.47	2.60		+
Avg. Credits obtained per semester in Engr.	8.0	9.4	$p=0.12$	+
Total Credits earned at graduation or final semester while in Engineering	23.1	27.1		+
% graduated in Engineering through fall 2012	9.0%	13.5%		+
% retained in Engineering as of fall 2012	39.4%	35.1%		_
% of N students who left Engineering	51.6%	51.4%		=
% of minorities who left Engineering	58.3%	54.5%		+
% of women who left Engineering	53.8%	57.1%		-

All 2x2 contingency tables were evaluated with Fisher's exact test (one-sided)

Table 4 shows that the summer research group had a slight advantage in their number of transfer credits to Grove, which could explain their somewhat higher graduation rate. The research group also had a higher percentage of women and minorities. Overall there was little difference in attrition between the two groups. More than half had left Engineering by the fall of 2012. We see small differences in final GPA and study progress in terms of the average number of credits obtained per semester in favor of the summer course group. The summer course also succeeded in attracting a higher percentage of women and minority students than in the control group, and they were at least as successful as the women and minorities in the comparison group. E.g., of the five students who already graduated in engineering, three were minority and one was a woman. Of the 28 non-participants who already graduated, 15 were minority and/or female. In both groups there was also one student who switched and went on to graduate in physical sciences or math, both from under-represented groups. Due to the small numbers the differences are not statistically significant, but the overall trend is in favor of the summer research participants. The main effect of the summer research course lies probably in its ability to attract more students from under-represented groups to engineering, provided any outreach efforts explicitly target such groups that can be found most often in community colleges. The participants appreciated the summer course and it contributed to their understanding of engineering, as the survey findings in the next section show.

Survey findings

At the end the summer research course the participants were asked to complete a short survey to indicate how much they thought they had learned about engineering and how satisfied they were with the course. Out of 69 participants 61 (88%) completed the survey. Table 5 shows the responses on the learning outcomes questions. The mean scores are the average, minimum and maximum of the yearly group scores, from a total of six groups in the summers 2007 through 2012. The questions themselves provide a good overview of the activities in the course.

Table 5. Results of the learning outcomes survey among summer research participants.

1. How much did you learn in each of the following topics of the Summer Research Course? (1=nothing, 2=a little, 3=something, 4=a lot)		Mean Score	Min.	Max.
n	Ethics and conduct in research, such as examples of poor ethics and cultural impact on ethics.	3.75	3.43	3.90
o	Give an oral presentation with slides on a group assignment.	3.70	3.29	4.00
e	Give an oral presentation about a research article and an abstract.	3.66	3.27	4.00
b	Write an abstract for a research article.	3.58	3.07	3.89
f	Discuss a research article and abstract.	3.54	3.27	3.80
a	Use the library to find the information that I needed for the Summer Research Course.	3.47	3.10	3.78
g	Planning of a research project.	3.45	3.09	3.78
d	Relate a research question to current needs and trends.	3.44	3.09	3.80
j	Communicate results of research orally and in writing.	3.43	2.91	3.90
q	Do research on a topic outside of my major.	3.37	3.17	3.60
p	Write a report on a group assignment.	3.33	2.73	3.80
c	Identify good research questions.	3.31	3.09	3.67
m	Present and critique selected journal articles.	3.29	2.93	3.60
k	The use of statistical methods in research.	3.27	2.93	3.78
i	Analyzing data from research.	3.17	2.91	3.40
h	Choose appropriate methods for data collection (research tools).	3.16	2.64	3.56
l	Write an essay about a research problem or paper, addressing theoretical explanations & statistical methods, and using references.	3.05	2.64	3.42

We sorted the questions in descending order of their mean score. According to the minimum and maximum scores, there was considerable variation from year to year in perceived instructiveness, due to variability in the availability of faculty, resources and space. The students found that they had learned most from the topic on ethics and research conduct in a cultural context, followed by the topics addressing oral and written communication skills. None of the topics received very weak scores.

Table 6 shows the responses on the satisfaction survey. The mean scores are again the average, minimum and maximum of the yearly group scores. We sorted the questions in descending order of their mean score.

Table 6. Results of the satisfaction survey among summer research participants.

2. How much do you agree with each of the following statements about the Summer Research Course? (1=strongly disagree, to 5=strongly agree)		Mean Score	Min.	Max.
p	The course increased my decision to pursue a Bachelor's degree in Engineering.	4.75	4.43	4.92
j	The lab visits by faculty increased my motivation for engineering.	4.73	4.50	5.00
a	Overall, the course was very interesting.	4.70	4.29	5.00
c	The things that I learned in the course are very useful for my future plans.	4.67	4.27	5.00
b	The course made me understand more about the differences in research projects in the Grove School of Engineering.	4.63	4.36	4.90
o	In general, I was satisfied with the instruction in the course by prof. Doe and the guest lecturers.	4.63	4.15	4.89
k	The instructor was very helpful and available to students.	4.61	4.07	4.89
s	The course increased my knowledge of careers in Engineering	4.61	4.14	4.90
e	The course made me really understand what research in Engineering is about.	4.58	4.21	4.80
f	The instructor of the course was difficult to understand. *(recoded)*	4.58	4.29	4.78
l	I would like to have a research career in Engineering in the future.	4.57	4.18	4.83
r	The guest lecture on ethics made me more aware of the importance of proper research conduct.	4.53	4.25	4.91
d	The course contributed to my plan to study Engineering at the Grove School of Engineering of City College.	4.51	4.14	4.80
q	The library assignments will be useful for assignments in other courses as well.	4.42	4.10	4.80
h	I found the Math tutorials very helpful.	4.19	3.73	4.67
g	The library tour by a librarian gave me helpful information that is useful in my study.	4.15	3.60	4.56
i	The course was well organized.	4.12	3.29	4.60
n	The guest lecture about statistics and methods was boring. *(recoded)*	3.90	3.63	4.20
m	The course was more difficult than I expected. *(recoded)*	3.86	3.70	4.00

Student satisfaction was especially high on the items asking about an increase in achievement motivation, such as choice of an engineering program, motivation, interest and perceived usefulness. The students agreed to strongly agreed with all of the satisfaction statements.
The survey contained three open-ended questions about what the students liked best, did not like, and wanted to see improved in the summer research course. Some representative answers are listed below. These qualitative findings provide important feedback and information for other institutions interested in improving the transfer experience. They confirm what we know from the literature about the importance of opportunities to interact with faculty, older students and peers in a welcoming environment, improving math and research skills and working on socially relevant engineering topics.

- liked best

> "I liked that we visited labs and experienced the lab environment, its work and approach of many engineering disciplines. The mentors were very supportive and informative and helped us prepare for the first semester coming."

> "I worked diligently in a relaxed environment amongst faculty and peers who had my best interest in mind. I was encouraged and motivated to get involved in the many exciting opportunities for research at Grove."

> "I have always been curious about research but never had the opportunity to be in one. This program has been extremely helpful. It showed me how to determine whether something is worth researching, then how to develop the methods to perform the research and use statistical information to show my findings. It showed me how to develop an abstract and present my findings with a visual tool like PowerPoint. The lab visits were very motivating and have convinced me that here is where I want to be."

> "I enjoyed the lab visits. It gave me a chance to speak with PhD students currently conducting research and comprehending the important steps of gathering facts for a research."

> "The best about this program was that now we have a clear idea and understanding of what is expected of an engineer student and what kind of commitment do we have to make to get us to our goal."

> "I liked the videos that they showed about obesity. Looking at these videos made me aware of how important it is to do research."

> "My topic was about "How to build a bridge for many years to avoid incidents". I did the presentation about the safety of the bridge called the "Silver Bridge in West Virginia". Project or predict things. After the presentations I heard that a bridge collapsed in Minnesota. We need to build correct bridges to save people."

> "The environment was very friendly and understanding. The math and physics tutorials were also very helpful."

> "I also enjoyed the review in math & physics, it helps me remember that I have to keep practicing."

- liked least

> "I was somewhat disappointed in the organization - room and time issues."

> "Its length, I would like to spend more than 4 weeks for this course."

> "I think it could be more helpful if there is more time, 6 weeks instead of 4 weeks."

> "At first, I didn't like the class room because it was very cool. It was freezing."

> "I wasn't able to use the Internet in the NAC building. It's only for Grove students who have a user name and password, this was just a slight interruption when I was gathering information."

- suggestions for improvement

> "To have project design presentations based on respective majors."
>
> "I believe that it would be beneficial for previous students in research to come in and talk about their experiences as a transfer student in Grove and how the program affected them. "
>
> "More math tutorial classes."
>
> "Have a session to teach some software."
>
> "A suggestion could be to have more hands-on experience such as help in a lab for a day or something else like that."
>
> "There needs to be a focus on information. It means that transferring students, especially from within the system, did not know about this program. Schedule of the Program: needs organization."

5c. The impact of course harmonization

The harmonization of introductory math, science and some entry level engineering science courses consists of articulating common content and course learning outcomes for equivalent courses across the participating institutions. Faculty from the three institutions who are responsible for coordinating a course met and compared syllabi, textbooks, topics, exams and learning outcomes, to arrive at the harmonized course. The implementation took place in phases, as shown in table 7.

Table 7. Implementation Schedule for Harmonized Courses

Semester	Courses
Fall 2006	Precalculus, Chemistry 1, University Physics 1.
Fall 2007	Calculus 1, University Physics 2, Introduction to Engineering Design
Fall 2008	Remaining courses

We expected a number of positive effects from course harmonization on student outcomes:

- Transfer students to Grove from the partnering community colleges will do better in courses at Grove after harmonization of the prerequisite course. E.g., if they took Calculus 1 in Fall 2007 or later at their community college, transferred to Grove and then took Calculus 2, their first-attempt pass rate in Calculus 2 should be better from Fall 2007 onwards.
- Transfer students from any CUNY community college to Grove should also do better after harmonization than before, in courses requiring a 'harmonized' prerequisite taken at the community college. This is because the Grove faculty now know better what to expect from community college transfer students in general by having worked closely with faculty from the two partner community colleges on aligning their courses.
- Students who started at Grove as freshmen are also expected to benefit from courses in which expectations (i.e., learning outcomes) are explicitly stated, syllabi improved, and course sequences reviewed and better aligned to improve student success.

To verify our expectations we compared transfers from the partnering and from the other system community colleges who entered City College since fall 2000, on their first-attempt pass rates in math and science courses, for which they had taken the prerequisite at their previous college. We distinguished before and after harmonization of the prerequisite course. We also compared pass-rates among native engineering students in math and science courses before and after harmonization.

Table 8 shows the sizes of the groups and the pass-rates before and after harmonization of the prerequisite. The effect size is the difference in pass rate after and before harmonization, and the standardized difference is the difference as a percentage of the pass rate "before". A positive difference indicates an improvement after harmonization. The significance of the differences was evaluated with Fisher's one-sided exact test.

Table 8. Pass rates in introductory courses before and after harmonization of the prerequisite.

				Pass Rate at First Attempt (%)				
Course	partner school	N before	N after	Before	After	Difference	Stand. Difference	Exact Sig. (1-sided)
Chemistry 2	yes	8	6	62.5	83.3	20.8	33.3	0.41
pre: Chem. 1	no	24	27	62.5	74.1	11.6	18.6	0.28
Calculus 1	yes	71	26	53.5	61.5	8.0	15.0	0.32
pre: Precalc	no	198	99	44.9	51.5	6.6	14.7	0.17
Calculus 2	yes	47	22	38.3	45.5	7.2	18.8	0.38
pre: Calc 1	no	186	130	38.2	44.6	6.4	16.8	0.15
Physics 1	yes	101	40	48.5	47.5	-1.0	-2.1	0.53
pre: Calc 1	no	425	183	51.5	50.8	-0.7	-1.4	0.47
Physics 2	yes	22	17	36.4	58.8	22.4	61.5	0.14
pre: Phys 1	no	39	43	46.2	32.6	-13.6	-29.4	0.15

Difference: Pass Rate After - Pass Rate Before. % Difference: (Increase / Pass Rate Before)*100.

Transfers from the two partnering schools have higher pass rates after harmonization of the pre-requisite, except in physics 1 where the difference between before and after harmonization of calculus 1 is negligible. None of the differences is statistically significant but the trend is positive. We see the same, but slightly weaker pattern among the non-partnering community college transfers, except for the physics courses. Physics 2 shows a rather anomalous pattern, with a large improvement for transfers from the partnering schools and a large decrease for transfers from the other community colleges. The numbers are very small though, because most of the transfers who complete physics 1 at their community college also take physics 2 there, before transferring to the GSOE. The calculus sequence looks to be the most relevant in terms of the numbers of students affected by course harmonization.

Table 9 shows increased pass rates at the first attempt in chemistry and math for those starting as freshmen in the Grove School of Engineering, with effect sizes at the higher end of the same range as for transfer students from the partnering schools: 7 to 22% difference between pass rates before and after. Due to the much larger groups any effects are statistically highly significant. The findings among freshmen support our hope that the differences among transfers are real and would have been significant if the groups had been larger. The changes in admissions criteria are accounted for, since eligibility to start in pre-calculus and calculus 1 is based on the results of a placement test. Eligibility to take subsequent courses is dependent on passing the pre-requisite(s). I.e., the admissions criteria may have changed over time, but the criteria for enrolling in a course remained the same.

We see significantly decreased pass rates at the first attempt in physics courses, especially in physics 1. The decreased pass rate at the first attempt in physics 2 is troubling, considering the fact that students taking physics 2 already passed physics 1 at a lower rate as well. It would require further examination of students' records, their backgrounds, and the physics and math alignment and learning environments to gain more understanding of what might have caused the decline. The only group that improved their pass rates in physics consists of transfers from the partnering colleges who took physics 2 at City College, after having taken the harmonized physics 1 prerequisite at their previous school.

Table 9. Pass rates before and after harmonization of the course among students who started as freshmen in the Grove School of Engineering.

Course	N before	N after	Pass Rate at First Attempt (%) Before	After	Difference	Stand. Difference	Exact Sig. (1-sided)
Chemistry 1	1633	1515	56.4	78.0	21.6	38.3	<0 .001
Precalculus	1068	745	45.4	65.8	20.4	44.9	< 0.001
Calculus 1	1475	1123	47.3	61.9	14.6	30.9	< 0.001
Physics 1	826	1088	62.0	50.3	-11.7	-18.9	<0 .001
Physics 2	651	620	72.5	65.8	-6.7	-9.2	< 0.010

6. Discussion

This study is a first exploration of the rich data that the project provided. We could not include all undergraduate and summer research participants yet, or follow up on further efforts and long-term results of course harmonization. Although funding of this project has ended, we hope to continue the activities that have proven valuable in attracting, retaining and graduating students in engineering. The current financial climate poses challenges, as does the increased demand for upper level engineering courses as a result of the improvement in retention rates.

The preliminary findings reported in this paper lead us to believe that undergraduate research is able to increase student motivation, persistence and achievement. This is the case even for the highly selected group of undergraduate research participants that we compared to a similar, if not slightly more accomplished group. The inclusion of a number of students in undergraduate research, who did not quite meet the selection guidelines while the control group contained no exceptions to the guidelines, only confirms our positive findings. Ideally, we would like to provide all motivated students the opportunity to participate in undergraduate research if sufficient resources were available - which unfortunately is not the case. On the contrary, the Grove School of Engineering is facing an increasing pressure on the regular course offerings in the junior and senior years and continuing our undergraduate research efforts at the current level may prove to be challenging. This calls for creative thinking to ensure continuing opportunities for undergraduate research.

The summer research course shows a much weaker impact on persistence and achievement than the undergraduate research course, but the trend is positive and the participants were very satisfied with the course and indicated they learned "something" to 'a lot" from the offerings. The summer research course proved to be a good vehicle to reach out to minorities and women who may be interested in engineering. If it is to be continued, the efforts to reach out to under-represented groups in Engineering should be increased. We should also investigate strategies to maintain the positive momentum created by the summer research course, to improve the rather dismal retention and graduation rates among community college transfers.

Course harmonization proved to be a valuable vehicle for connecting campus cultures and have faculty from senior and community colleges come together to align transferable courses within the engineering curriculum. The effect evaluation found generally positive effects from course harmonization, for transfers as well as students starting as freshmen in the Grove School of Engineering. Continuation of this activity is highly desirable for a number of reasons. Further activities should focus more on interdisciplinary alignment, in particular between the calculus and physics sequences, and on alignment within the physics sequence. Further activities may also benefit from the expertise of learning assessment staff, to formulate measurable learning outcomes at appropriate levels and align assessment processes across participating campuses. Continuing research should also study the effects of course alignment on a number of gateway engineering courses, such as statics.

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Appendices

Appendix 1. Example of an undergraduate research project description

Grove Student Research and Scholarship Center
Project Description and Student Information

Research Project Title:
Student: John Doe, Mechanical Engineering, class of 2015
Contact information:
Email:
Phone:
Faculty Mentor: Professor Jan Anonymous Xu, Electrical Engineering:
Email:

Project description:

I will work in a robotics team under Professor Xu's guidance on a project to design a rescue robot. The function of this robot is to carry out rescue missions at simulated nuclear reactor sites successfully. Through this project we will learn the basic concepts in robotics design, including the heat sensor, radiation detection, mechanics and control, as well as programming skills. In addition, we will learn the hazardous affects that radiation may cause to human health and the environment and the concept of radiation decay half time. We will also learn other safe and renewable forms of energy that may be used instead of nuclear facilities.
After this initial design project, I will work on more advanced robotics project that uses autonomous navigation in the robotics research lab, led by Professor Xu.
To learn how to design robot mechanical parts is one of my main goals in this project. I also plan to use a 3D printer to create these parts. To be able to do this we will have to first create the part on a design software program, we will be using SolidWorks, then export the file to the printer. As a part of our future project, we plan to reach out to high school robotics teams helping them with robotics design, mechanics, programming and all aspects of robotics related STEM education.

Appendix 2. Program description of the summer research course

The objective of this course is to present an introduction to research methodology. The concept of how and why we do research will be presented along with the various methods that researchers use to investigate problems.

It is a 4-5 week summer course that is designed specifically for transfer students with some research experience who may be interested in conducting further independent research. Students are assumed to be familiar with statistics (such as mean, standard deviation, t-test, ANOVA and other such terms).

The daily schedule (Mon-Thurs) will involve a morning and afternoon session.
Morning session: Molecular dynamics training module
Afternoon session: Research Methods

Module Content

Some of the topics to be covered include:

- Introduction to research: Gathering the information necessary to guide you through the research process
- Research methods and theories: How to critically evaluate your research question in relation to current research trends.
- Publishing research: Statistical methods. Presenting scientific results (publications and oral presentations)
- Research project management skills
- Research ethics: Plagiarism and its professional consequences

Course Goals

Students on completing this course should gain understanding of the entire research process, starting from the conceptualization of the "research question" to the publication process. Additional learning sources will include: Formal training by a librarian on how to do literature searches and lab visits (faculty).