Gauging the Effect of Peer Assisted Learning on STEM Course Outcomes Using Propensity Score Matching

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Overview

- Assess whether peer-assisted learning (PAL) increases grades in gateway science and math courses
- Students self-select into PAL, creating potential for bias
- Use propensity score matching to reduce selection bias
  - Compare regression estimates to matching estimates
Project PASS (Peer-Assisted Student Success)

- **Goals**
  - Improve grades in gateway STEM courses
  - Improve student retention

- **Approach**
  - Peer-assisted learning (PAL)
  - Advising

- **Courses**
  - Initially
    - Developmental Chemistry (CHEM 4)
    - Introductory Chemistry (CHEM 1A)
    - Pre-Calculus (MATH 29)
    - Calculus (MATH 30)
  - Additional courses added periodically
Program Structure

Peer-assisted Learning

- Two-hour/week discussion section focused on problem-solving
- Led by a student trained in PAL facilitation
- Faculty create problem worksheets for use in PAL sessions and get feedback from PAL facilitators on where students have difficulties

Advising

- Students who are on academic probation or who are repeating the course are referred to advising before the beginning of the semester
- Students who perform poorly on the first exam are referred to advising during the semester
Data Elements

- All students who took one of four science and math courses during a term when PAL was available
  - Spring 2012 – Spring 2015 or Fall 2012 – Spring 2015
- Covariate data
  - Demographics (age, gender, ethnicity, parents’ education, on-campus housing, Pell grant eligibility)
  - Academics (high school GPA, SAT scores, CSUS GPA, units, class level, major, first-year seminar, AP scores, time between high school and college, remedial status)
- Analysis performed with the R programming language and the Matchit package for propensity score matching
Data include all enrollments during the terms when PAL was available for a given course.

<table>
<thead>
<tr>
<th>Course</th>
<th>Enrollments</th>
<th>Unique</th>
<th>PAL %</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 1A</td>
<td>1712</td>
<td>1418</td>
<td>36.3%</td>
</tr>
<tr>
<td>CHEM 4</td>
<td>1270</td>
<td>1216</td>
<td>37.0%</td>
</tr>
<tr>
<td>MATH 29</td>
<td>1224</td>
<td>1121</td>
<td>25.9%</td>
</tr>
<tr>
<td>MATH 30</td>
<td>1061</td>
<td>971</td>
<td>23.5%</td>
</tr>
<tr>
<td>Total</td>
<td>5267</td>
<td>3336</td>
<td>31.5%</td>
</tr>
</tbody>
</table>
PAL vs. Non-PAL by Remedial Status and PASS Advising Referral
PAL vs. Non-PAL by URM Status and Math SAT

The graph shows the relationship between Math SAT scores and course grades for PAL and Non-PAL students, stratified by URM status. Each cell represents a different course (CHEM 1A, CHEM 4, MATH 29, MATH 30) with lines indicating the trend for PAL and Non-PAL groups. The x-axis represents Math SAT scores, while the y-axis shows course grades from A to F.
PAL vs. Non-PAL by URM Status and High School GPA

<table>
<thead>
<tr>
<th>Course Grade</th>
<th>CHEM 1A</th>
<th>CHEM 4</th>
<th>MATH 29</th>
<th>MATH 30</th>
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<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

High School GPA

2.0 2.5 3.0 3.5 4.0 4.5
Regression Model Predicting Course Grade

- Limit to students...
  - Taking course for the first time
  - No previous PAL participation
  - Non-missing SAT score and high school GPA

- 2322 students and 2909 enrollments, or about 70% of all students who took one or more of the four courses during the study period
Predicting Course Grade vs. PAL Participation

\[ r^2 = 0.33 \]

\[ r^2 = 0.33 \]

\[ r^2 = 0.35 \]

\[ r^2 = 0.27 \]
Summary So Far

- PAL participation and course grades
  - Linear regression of PAL participation vs. course grade suggests, controlling for other factors, PAL students’ grades are, on average, about 0.3 grade points higher, when compared with non-PAL students
  - Models for individual courses suggest PAL students’ grades are 0.24 to 0.45 grade points higher, on average, when compared with non-PAL students (coefficient for MATH 30 (Calculus) was not statistically significant)
- Potential for bias if outcomes are correlated with selection into PAL
Addressing Bias in Observational Studies

- Random assignment usually not possible for ethical and logistical reasons
- Try to reduce selection bias in observational data by accounting for factors that predict selection into the treatment
- Propensity score: Probability of receiving the treatment, given what we know about the study subjects (Rosenbaum and Rubin, 1983)
  - Estimate with logistic regression (or other classification methods)
    - Predictors should be related to PAL participation and should either be fixed or measured prior to treatment
Propensity Score Matching

- Match treated and untreated based on similar propensity scores.
  - Results in treatment and control groups that have, conditional on the observed factors, a similar probability of being in the treatment group
- Check for balance of treatment and control groups on the observed covariates
- Compare means of treated and control subjects (by direct comparison, PS weighting, or regression adjustment)
- Matching is intended to make treated (PAL students) and untreated (non-PAL students) more like what would have happened with randomized selection
- Results in more credible inferences regarding causal effects from observational data
<table>
<thead>
<tr>
<th>Variable</th>
<th>% Improve</th>
<th>PAL</th>
<th>Non-PAL</th>
<th>Diff</th>
<th>PAL</th>
<th>Non-PAL</th>
<th>Diff</th>
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<td>MATH 29</td>
<td>98.70</td>
<td>22.19</td>
<td>22.29</td>
<td>-0.10</td>
<td>22.19</td>
<td>29.72</td>
<td>-7.53</td>
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<td>Major: Science &amp; Math</td>
<td>92.40</td>
<td>41.88</td>
<td>41.34</td>
<td>0.54</td>
<td>41.88</td>
<td>34.81</td>
<td>7.07</td>
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<td>Undeclared</td>
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<td>3.57</td>
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<td>0.22</td>
<td>3.57</td>
<td>5.24</td>
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<td>86.00</td>
<td>46.54</td>
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<td>On-Campus Housing</td>
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<td>25.22</td>
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<td>2.45</td>
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<td>34.74</td>
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<td>79.30</td>
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<td>Propensity Score</td>
<td>78.00</td>
<td>0.41</td>
<td>0.38</td>
<td>0.03</td>
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<td>Pacific Islander</td>
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<td>2.27</td>
<td>1.86</td>
<td>0.41</td>
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<td>MATH 30</td>
<td>71.00</td>
<td>16.45</td>
<td>17.64</td>
<td>-1.19</td>
<td>16.45</td>
<td>20.55</td>
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<td>Units Attempted</td>
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<td>13.80</td>
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<td>Remedial: Math &amp; English</td>
<td>67.90</td>
<td>16.34</td>
<td>14.83</td>
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<td>16.34</td>
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<td>SAT Verbal</td>
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<td>64.20</td>
<td>7.14</td>
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<td>4.74</td>
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<td>Not Remedial</td>
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<td>55.63</td>
<td>57.03</td>
<td>-1.40</td>
<td>55.63</td>
<td>59.35</td>
<td>-3.72</td>
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<td>CHEM 4</td>
<td>60.50</td>
<td>33.44</td>
<td>30.30</td>
<td>3.14</td>
<td>33.44</td>
<td>25.49</td>
<td>7.95</td>
</tr>
<tr>
<td>CHEM 1A</td>
<td>50.10</td>
<td>27.92</td>
<td>29.76</td>
<td>-1.84</td>
<td>27.92</td>
<td>24.23</td>
<td>3.69</td>
</tr>
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<td>HS GPA</td>
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<td>3.36</td>
<td>3.36</td>
<td>-0.01</td>
<td>3.36</td>
<td>3.35</td>
<td>0.01</td>
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<td>SAT Math</td>
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<td>513.58</td>
<td>520.89</td>
<td>-7.31</td>
<td>513.58</td>
<td>526.49</td>
<td>-12.91</td>
</tr>
<tr>
<td>Yrs betw HS and Coll</td>
<td>23.90</td>
<td>0.11</td>
<td>0.09</td>
<td>0.02</td>
<td>0.11</td>
<td>0.13</td>
<td>-0.02</td>
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<tr>
<td>Asian</td>
<td>12.40</td>
<td>30.84</td>
<td>33.66</td>
<td>-2.82</td>
<td>30.84</td>
<td>34.06</td>
<td>-3.22</td>
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<td>Hispanic</td>
<td>11.60</td>
<td>26.41</td>
<td>24.13</td>
<td>2.28</td>
<td>26.41</td>
<td>23.83</td>
<td>2.58</td>
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<tr>
<td>AP Calculus</td>
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<td>2.71</td>
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<td>0.02</td>
<td>2.71</td>
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<td>White</td>
<td>-10.20</td>
<td>25.87</td>
<td>27.06</td>
<td>-1.19</td>
<td>25.87</td>
<td>26.95</td>
<td>-1.08</td>
</tr>
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<td>African American</td>
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<td>5.74</td>
<td>5.52</td>
<td>0.22</td>
<td>5.74</td>
<td>5.79</td>
<td>-0.05</td>
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<td>Freshman</td>
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<td>49.68</td>
<td>48.81</td>
<td>0.87</td>
<td>49.68</td>
<td>49.57</td>
<td>0.11</td>
</tr>
</tbody>
</table>
Visual Balance Check: Continuous Variables

Propensity Score

SAT Math

SAT Verbal

High School GPA

PAL □ Matched Non-PAL □ All Non-PAL
Visual Balance Check: Categorical Variables

- **Visual Balance Check**
  - Categorical Variables

- **Gender Distribution**
  - Male
  - Female

- **Remedial Status**
  - Remedial in Math & English
  - Remedial in Math Only
  - Remedial in English Only
  - Not Remedial

- **Academic Programs**
  - Science & Math
  - Allied Health
  - Business
  - Engineering
  - Other
  - Undeclared

- **Courses**
  - CHEM 1A
  - CHEM 4
  - MATH 29
  - MATH 30

- **Did Not Take AP Calculus**
  - Did Not Take
  - 1
  - 2
  - 3
  - 4
  - 5

- **Graphs**
  - PAL vs. All Non-PAL
  - Matched Non-PAL
Average Course Grade by PAL Participation: Matched Comparison

<table>
<thead>
<tr>
<th>Course</th>
<th>Matching</th>
<th>Regression</th>
<th>Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Courses Combined</td>
<td>0.26</td>
<td>0.30</td>
<td>-0.04</td>
</tr>
<tr>
<td>CHEM 1A</td>
<td>0.46</td>
<td>0.45</td>
<td>0.01</td>
</tr>
<tr>
<td>CHEM 4</td>
<td>0.19</td>
<td>0.27</td>
<td>-0.07</td>
</tr>
<tr>
<td>MATH 29</td>
<td>0.31</td>
<td>0.43</td>
<td>-0.12</td>
</tr>
<tr>
<td>MATH 30</td>
<td>0.11</td>
<td>0.24</td>
<td>-0.13</td>
</tr>
</tbody>
</table>
Matching on the Full Sample of Students

- Same process as before, but including students with course repeats and previous PAL courses
  - Include repeats and previous PAL in the propensity score model
Percent of Students Earning Grade of C or Better

- **CHEM 1A**: Non-PAL 47.4%, PAL 63.0%
- **CHEM 4**: Non-PAL 47.4%, PAL 68.0%
- **MATH 29**: Non-PAL 51.0%, PAL 66.0%
- **MATH 30**: Non-PAL 57.1%, PAL 67.3%
- **All Courses**: Non-PAL 57.1%, PAL 67.3%
Discussion and Conclusions

- PAL participation appears to increase students’ grades in chemistry and pre-calculus. PAL calculus students’ average grade was only slightly higher and difference was not statistically significant.
- Estimated PAL effect is smaller after propensity score matching (although CHEM 1A was an exception) suggesting some bias in selection into PAL.
- No detectable change in overall course grades or pass rates since implementation of PAL.

Potential explanations:
- Too few students in PAL to cause detectable overall change.
- Analysis overstates PAL effect despite matching to control for selection bias.
- Faculty curve grades.
- Faculty increase course rigor when student performance improves.
References
