Service-learning in a precalculus class: Tutoring improves the course performance of the tutor.

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We have introduced an experiment: as part of a Precalculus class, university students have been tutoring algebra prerequisites to students from the community via an academic service-learning program. The goal of the experiment was to improve university students' mastery of basic algebra and to quantitatively describe benefits of service-learning to students' performance in mathematics. At the end of the experiment, we observed 59% decrease of basic algebraic errors between experimental and control sections. The setup and analysis of the study have been informed by the theoretical research on service-learning and peer learning, both grounded in the constructivist theory of John Dewey.

Key words: Precalculus, design experiment, service-learning

Introduction and Research Questions

Academic service-learning consists of two integral components: a useful service to the community, and a meaningful learning opportunity to the students, which is relevant to the material covered in the course (Hadlock, 2013). Astin, Vogelsang, Lori, Ikeda, and Yee (2000) found that service-learning shows positive effects on academic performance (GPA, writing and critical thinking skills) and values of participating students. Service-learning in mathematics courses has recently been gaining prominence (Hadlock, 2005), and our present study was motivated in part by the need for a quantitative analysis of the benefits of service-learning to students' mathematical performance.

Our second motivation was the ever-present need to improve student success and retention in Calculus (Bressoud, Mesa & Rasmussen, 2015). Edge and Friedberg (1984) show that solid algebra skills are one of the main factors determining success in Calculus. Success of the service-learning project raises students' fluency in algebra and leads to a stronger chance of their mastering Calculus, and staying within their chosen technical field.

Our study explored the following research questions:

Question 1: Will students who engage in tutoring algebra pre-requisites to middle-school and returning students demonstrate fewer 'fundamental' mistakes than students from the control section without the tutoring experience? By 'fundamental' mistakes we mean the following:

1. *Mistakes that result from misunderstanding the addition/subtraction algorithm of*
    a. *numerical fractions*
    b. *rational expressions*
2. *Cancellation mistakes in*
    a. *numerical fraction arithmetic*
    b. *rational expressions*
3. *Mistakes in operations on radicals*
4. *Mistakes in operations with exponents.*
5. *Mistakes in basic factoring using formulas.*
6. *Other – may be added after consultations with other mathematics faculty, or after marking the final exam.*

Question 2: What will be the reaction of students to the service-learning experience introduced in a scientific course that has not traditionally been associated with community work at this and other institutions?

Theoretical Perspective

Our framework for the present study follows a standard pseudo-experimental setup as described by McKnight, Magid, Murphy, and McKnight (2000): baseline performance for experimental and control sections is determined via a diagnostic test; the two sections receive equivalent instruction for the duration of the course, except for the difference in the tutoring service-learning component. The two sections are given identical final exam, and their performance is analyzed via a rubric. Qualitative data is also compared. To our knowledge ours is the first study that quantitatively analyses benefit to mathematical performance of service-learning students engaged in tutoring.

Our idea to use tutoring as a means to help student-tutors learn mathematics is rooted in the long-standing theory that underlies Peer Learning in general. From a well-known saying 'I hear and I forget. I see and I remember. I do and I understand', to the theoretical work of Allen and Feldman (1976), tutoring has been shown to benefit the tutor, as well as the tutee.

When designing and implementing the service-learning structure, we closely followed the suggestions and project design outlined in the Special Issue on Service-Learning in Mathematics, PRIMUS: Problems, Resources, and Issues in Mathematics Undergraduate Studies (2013), particularly Schulteis' (2013) experience of building a course with university students' satisfying the tutoring needs of local institutions and non-profit organizations.

In order to fully benefit from the service-learning experience, students must have an opportunity to engage in structured reflection and connect for themselves the tutoring experience with the content of the course (Bringle & Hatcher, 1999). In building the theoretical foundations of service-learning on the basis of the experimentalism of John Dewey, Giles and Eyler (1994) name reflection as the means of converting experience into knowledge. An integral part of the experimental service-learning section was a weekly guided reflective diary of tutoring experiences, helping students analyze mathematical, as well as social and pedagogical, aspects of their work with the students from the community.

Methodology

Our work took place at Seattle University: a medium-sized urban Catholic university in the heart of Seattle, WA, with a long tradition of incorporating service-learning and community work into students' coursework and extra-curricular education. The setting for our study was two sections of a standard Precalculus course that served as a pre-requisite for the science and engineering track Calculus sequence. The course focused on advanced algebra material and served as a mathematics refresher for students whose ACT and SAT scores would not allow them to be placed directly into a Calculus I course. Both sections numbered 21 students each. The experimental section of the Precalculus course involved a service-learning component, while the other section served as control and consisted of standard in-class instruction only.

The students in the experimental section took part in the established university Service Learning program. They spent 2-3 hours per week tutoring basic algebra and sometimes arithmetic to middle school students, students at immigrant assistance centers, as well as adults returning to complete their education at a local community college. The students put in a total of 18-21 hours of tutoring work during the 12-week duration of the quarter.

The control section was identical to the service-learning section in every aspect of the course syllabus, such as the topics covered, the number of exams, attendance and make-up

policy, etc. The only difference was the lack of the tutoring component in the control section, as well as a slight difference in grading weights assigned to exams and homework. The control section also received some amount of extra homework intended to balance the additional workload faced by experimental section.

We established a baseline of the students' prior knowledge and preparation by using a diagnostic pre-test. The pre-test was given to both sections on the first day of class and covered the pre-requisite material including arithmetic with fractions and radicals, basic factoring, and solving basic equations. In order to make sure the task was taken seriously, the students received a small amount of credit for completing the pre-test.

To connect the tutoring experience to the algebra content, the students in the experimental section kept a weekly reflective diary which included mathematical and non-mathematical components. Mathematical reflection helped the students analyze the mathematical component of the tutoring experience and reflect on the following and similar questions:

- What problem did you discuss with your student? What mathematical concept did you address?
- What piece of knowledge was missing from the students' understanding that prevented them from moving forward?
- What method did you use to approach the solution and how did you explain the material?
- Did you discover any gaps in your own mathematical knowledge? What steps did you take to address them?
- Did you discover any parallels between the topics you tutored and our mathematical lectures and problems from class?

The free-form non-mathematical reflection was intended to help the students process the human aspect of their experience with service-learning and tutoring. The following guiding questions were suggested to the students: "What do you think is holding this student back and what can be done to help the student succeed? How was your tutoring week? What non-mathematical problems did you encounter? Any thoughts on what you are seeing and experiencing while tutoring? Any questions you would like to ask me, or your fellow students, or the management of the organizations where you tutor?"

In addition, the experimental section held two in-class reflection meetings, offering the participants an opportunity to discuss the pedagogical issues raised by the students themselves, through the diaries or in class. The students also had a chance to address practical matters of service-learning, such as transportation, time commitment, communication with the community partners.

At the end of the course, the students submitted a typed anonymous reflection where they were free to comment on any aspect of their experience, to offer suggestions for improvement, and to voice any additional concerns regarding the course.

At the end of the quarter, both sections took a standard final exam with identical questions. Relevant statistics were computed and compared for both sections. The number of fundamental mistakes (see Introduction) was determined via a special rubric.

Results

Our diagnostic pre-test indicated that the experimental and control sections were comparable in preparation and abilities and showed similar score distributions, with the experimental section showing a slightly better average, but the difference between the two sections not being statistically significant.

Research question 1 was answered affirmatively. We compared the number of fundamental mistakes in the final exams for both sections: there were only 13 fundamental mistakes made by the 21 students of the experimental section, while the 21 students of the control section made 32 fundamental mistakes. Thus, there were 59% fewer fundamental mistakes in the experimental section than in the control one.

The course average for the experimental section was higher, due to the difference in the weights given to individual course components.

Data from the reflective diaries and the end-of-term anonymous reflection indicate that the answer to the second research question was also positive: out of 21 submitted anonymous reflections, 20 were positive, reflecting a sense of accomplishment and a clear understanding of the privilege of university education, as well as the appreciation of new friendships. Similarly to Butler (2013), we observed a number of service-learning benefits that went far beyond the original goal of the project, including an increased level of confidence in oral communication skills mentioned by the international students. After the quarter ended, several students voluntarily continued their work with the community partners.

In their diaries, the students enthusiastically pointed out multiple connections between the mathematical concepts covered in class and the topics they had explained in the tutoring sessions. Students rediscovered for themselves that the underlying concepts and definitions were in fact the same for the polynomial graphs and the radical equations covered in class, and the basic linear graphs and equations their tutees had studied in middle school. As Roscoe and Chi (2007) point out, peer tutors manifest highest levels of tutor learning as a result of explaining conceptual rather than process-based questions to the tutees. In our case, reflection diaries worked as a tool to reinforce mathematical knowledge gains made by the tutor as a result of the tutoring session.

Conclusions and Implications for Mathematics Education

Our research statistically establishes a number of tangible benefits of service-learning to students' mathematical performance in class. The non-mathematical benefits have been widely explored, and they are confirmed by our study. Our research opens venues to further exploration of the long-term academic and non-academic benefits of service-learning to the university students, as well as to students from the community. Service-learning requires commitment of time and sometimes additional funding: our findings may encourage Mathematics departments and university administration to promote service-learning in mathematics courses.

For discussion

We will be grateful for any comments and ideas regarding the following topics.

- Please suggest additional theoretical frameworks for exploring the setup and results of the experiment.
- Please suggest instruments and experiments to assess changes in students' knowledge and academic performance in Calculus courses, following their service-learning experience in the Precalculus course.

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