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Faculty-Student Partnership in Advanced Undergraduate Mathematics Course Design

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FACULTY-STUDENT PARTNERSHIP IN ADVANCED UNDERGRADUATE MATHEMATICS COURSE DESIGN

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Introduction

In this essay we describe how a faculty-student partnership was created in a UK Higher Education (HE) institution to redesign two undergraduate mathematics courses. Following the description, we discuss the outcomes that accrued from the partnership to the faculty members and the students who were involved in the partnership. Our aim is to describe the ways in which such partnership cultivates a learning community that engenders *identity transformation* in the student partners and creates change in mathematics faculty members' teaching practice.

The partnership that is the focus of this essay was a curriculum development project and the project website, http://sym.lboro.ac.uk, hosts a number of resources and research papers to inform the wider HE sector. The aims of the project were twofold: 1) to enhance the *second year* learning experience of undergraduate mathematics students and 2) to increase student engagement with undergraduate mathematics outside formal lectures and seminars. The acronym, SYMBoL, stands for *Second Year Mathematics Beyond Lectures* and was created to reflect the notion that the project outputs may be used by students independently outside scheduled teaching times. The UK National Higher Education Science, Technology, Engineering, and Mathematics (HE STEM) program funded the project for one year.

The project was based at Loughborough University, UK. The idea behind the project was conceived by two faculty members, Tony Croft and Steven Kenny (Cook-Sather, Bovill, & Felten, 2014) with the support of the teaching and learning committee in the Department of Mathematical Sciences at Loughborough University. The partnership initially lasted one year but its legacy continues today (see above URL). Readers interested in innovative ways to design courses may find the description of how the SYMBoL project came about and the discussion of the key outcomes particularly helpful.

The genesis of the faculty-student partnership

The level of student engagement with the content of their courses is a good predictor of success in the relevant courses. However, some students do not engage with some of their course material and report less than satisfactory learning experiences in their courses, often when the courses have ended. Some students switch courses early on when they find the learning experience demanding from the outset. These issues are not unique to a particular institution or discipline but have been researched in STEM subjects in general (Seymour & Hewitt, 1997) and in mathematics specifically (Brown, Macrae, Rodd, & Wiliam, 2005). From our viewpoint as mathematics education specialists, the issues outlined above provide impetus for innovative and continuous research and development in undergraduate mathematics course design as well as *university mathematics teacher pedagogy*.

In March 2011, recognizing the need to better inspire students to engage with their mathematics courses, a group of faculty members at Loughborough University formed a partnership with students to undertake a redesign of two courses. In this partnership, some faculty members and students worked together to redesign two undergraduate mathematics courses with the support of the academics who had taught the two courses in the three preceding academic years. The two courses were: *Vector Spaces* (an advanced linear algebra course) and *Complex Variables*(an introductory course to Complex Analysis). Both courses are taken by the majority of students in their second year and they are level two courses. The partnership involved eight faculty members and four paid student interns. The four paid student interns had previously taken and passed the two courses: *Vector Spaces* and *Complex Variables*. The role of the four paid student interns was to create learning material for the two courses with a view to increase student engagement with the mathematics content of the courses.

A search of the Higher Education (HE) research literature revealed examples of case studies on faculty-student partnerships in course design (see Bovill, Cook-Sather & Felten, 2010). However, the knowledge base regarding this radical approach to advanced undergraduate mathematics course design was, and still is, limited. Hence we felt there was a need for us to undertake an *empirical study* into the partnership in order to gain insight into the *nature of the partnership* and *its impact* on the existing practice of the faculty members and on the student interns. At the time, Francis Duah had just started his PhD in Mathematics Education at Loughborough University and he made the study of the partnership the focus of his PhD dissertation with Tony Croft as an adviser. Such an empirical study, in our view, calls for the use of a theoretical framework to guide the study and we briefly discuss this framework in the next section.

Theoretical framework and the nature of the partnership

In order to understand the nature of the partnership and its impact on the existing practices of faculty members and on students, we considered two non-competing *socio-cultural theories* to have the explanatory power to help us gain insight into the partnership (see for example, Duah & Croft, 2012; Solomon, Croft, Duah & Lawson, 2014;). These theories were *Activity Theory* (Engeström, 2001) and *Communities of Practice* (CoP) (Lave & Wenger, 1991; Wenger 1998). In this essay we focus on the latter socio-cultural theory. Wenger (1998) points out that CoP is a *social learning theory* that provides a lens for the analysis of learning in social settings. Learning, in this context, refers to *identity transformation* of an individual that emanates from the individual's *participation* in the social practices of a *learning community*. CoP, according to Wenger, is characterized by a *joint enterprise*-goal to be achieved, *a mutual engagement*-regular interaction amongst members of the community, and *shared repertoire of resources*-how members do things.

Lave and Wenger (1991) introduced the concept of *legitimate peripheral participation* (LPP) to describe the trajectory followed by newcomers to a learning community as they engage in the practices of that community: from the *periphery* of the practice to the *center* (see Lave & Wenger, 1991 for information). We see the partnership as consisting of two groups of individuals who belong to different CoP (researcher mathematicians and students) coming together in order to transfer elements of one practice to the other. We applied the two concepts, CoP and LPP, to

analyse a range of data. The data we gathered about the partnership included a *focus group* interview with the student interns, individual *interviews* with faculty and the student interns, *diaries* of the interns, observations of the summer internship, and information gathered from the analysis of documents (artifacts produced by the student interns). So how did the partnership work?

The summer internship lasted for six weeks from early July 2011 to early August 2011. At the start of this period, faculty and students held a meeting in which the four student interns outlined the learning material they were going to produce. The interns, informed by their peers through focus groups, decided to create screencasts, and supplementary problem examples. They also decided to restructure lecture notes (for *Vector Spaces*) and to recommend how lecture notes should be restructured (for *Complex Variables*) in order to increase student engagement with the mathematical content. Faculty trusted the student interns with the responsibility to create learning material that the interns believed would be engaging to future cohorts of students. The interns and the faculty members had what Wenger refers to as a *joint enterprise*-mission that was to enhance the learning experience, increase engagement and hence attainment. This negotiated joint enterprise, was, in our view, a motivating factor that enabled the partnership to be brought to fruition.

Each day, the faculty members and students met up in a neutral place (an office of another faculty member) for an hour break. The break, initially meant to provide the interns with a quiet time away from their desks and computers, developed into sessions in which the faculty members and interns discussed issues ranging from teaching approaches to relationship between university mathematics teachers and students to good and poor teaching of mathematics. In this engagement, the faculty members and student interns discussed mathematical language, symbols, and their meaning and how they are used in different mathematics courses. Thus, the break created space for the faculty members and the student interns to engage in regular *mathematical discourses*. In Wenger's terms, these interactions constituted *mutual engagement* and they were necessary to ensure *community* coherence amongst faculty members and the student interns. The CoP framework helps us to understand not only the nature of the partnership but also the key outcomes for faculty members and the student interns, which we discuss in the next section.

The key outcomes of the partnership

Through qualitative analysis of data obtained via the focus group interview of the interns, individual interviews with faculty and the student interns, diaries of the interns, observations of the summer internship, and documents, we found a number of self-reported and observed outcomes for faculty members and the student interns. The three salient outcomes were: enhanced relationship between the faculty and the student interns, and deeper mathematical understanding for the student interns and faculty member's deeper understanding of learning mathematics from students' perspectives.

Enhanced Relationships

Findings from our coding of observations and interview data showed that faculty and the student interns gained from an *enhanced relationship* that hitherto had not been possible. The enhanced relationship is exemplified by the following two quotations from two student interns:

Meeting up with some of the Faculty for tea and biscuits was a good opportunity to get to know people a bit more, and made me feel much more involved and valued as a member of the project.

It's good to be able to comfortably talk to lecturers about interesting points in mathematics; it's also interesting to hear what they do as mathematicians and how they work together or alone.

The enhanced relationship precipitated *identity* development and change over time in the student interns. As a consequence, the student interns' sense of belonging to the university mathematics community changed.

Deeper Mathematical Understanding

The partnership provided opportunities for the student interns to develop a much deeper understanding of the content of *Vector Spaces* and *Complex Variable*. Consequently, they gained increased confidence in their abilities. We exemplify this outcome with the following two quotations:

Despite all the frustration I feel my knowledge of the eigenvalue equation has improved a lot. My approach to learning will be very different after this internship. I will now get books out, ask lecturers questions and ensure a deeper understanding of my Mathematics. It is actually quite interesting when you understand it all rather than just revise for an exam!

My knowledge of Vector Spaces is also improving, as I discovered an application for a theorem that I had not previously realized was possible.

Faculty Members' Deeper Understanding of Learning

Through their classroom experiences with different faculty members, students in general develop *tacit knowledge* (Polyani, 1967) about good teaching practices. It is from this knowledge base and their *intuition* that students provide feedback on courses to faculty members. The student interns in the partnership we have described in this essay drew on their tacit knowledge and their *perspective* on learning to develop resources (Duah & Croft, 2012) which proved to be useful to their peers. We refer to the student interns' perspective on course design as their *tacit and intuitive pedagogy*. Although they had no educational training, yet they were able to draw on their classroom experiences to inform their own and others' practice-course design.

The faculty members also gained from the student perspective on mathematics course design, teaching, and learning. For example, a faculty member described how this student perspective influenced his practice: "It focused my attention on certain parts of the lecture notes that had deficiency, shall we say, and I was able to improve them." Similarly, another faculty member

described how his involvement in the partnership and the student perspective have influenced his teaching practice: "[They have] made me think about how I present material [in my class]."

The partnership clearly impacted on the faculty members and the student interns. As researchers, we also learned about and gained insight into university mathematics teaching and learning and our own reflections are shared in the next section.

Insights gained into teaching and learning of undergraduate mathematics

As a postgraduate researcher (Francis) in mathematics education and a mathematics educator (Tony), we draw on our experience to make a number of observations on the traditional university teaching practices and how they relate to faculty-student partnership in course design.

First, teaching practices of university faculty members include (but are not limited to) planning their courses, designing the syllabus or specification for their courses, and delivering their courses. Often university faculty design the learning material for their courses either on their own or perhaps with other colleagues. The learning material traditionally includes *lecture notes*, *exercises*, *homework*, and *project work*. These components of course design are typical in many mathematics courses around the world and they have a long history in university mathematics teaching and learning. However, not all students *engage* with all these traditional learning materials.

Second, mathematics courses are typically delivered via *lectures*, *tutorial*s, and/or *seminars*. Some of these methods of delivering mathematics courses, for example lectures and homework, have been subject to criticism in relation to their effectiveness in sustaining student engagement. While many students engage with the delivery methods identified above, some do not. We learned that university mathematics teachers who engage with mathematics education research and curriculum development are likely to enhance the learning experience of their students and increase student engagement and attainment in their courses.

Finally, one *implication* of the insights we gained is that the implementation of faculty-student partnership requires a *cultural shift* on the part of faculty and students regarding: 1) their roles and responsibilities in relation to teaching and learning and 2) their traditional practices in undergraduate mathematics teaching and learning. At Loughborough University in particularly (and some other UK universities), we have shared the evidence gathered in our research on the partnership. Indeed, the evidence we have disseminated so far has caused a cultural shift and is encouraging other faculty to think differently about the ways in which their own courses are developed.

As mathematics education researchers, we have been thinking differently about how we tap the vast potential of the student body; the student interns have clearly shown they have much to offer: there is a valuable resource at our disposal should we want to make use of it. Universities are increasingly recognizing this. For example, a recent development at Loughborough University has been the appointment of a full-time post to develop peer mentoring across the University—another aspect of engaging students in the design and delivery of their courses. The evidence base that was used to convince the university senior management about the value of

this new post included evidence from the SYMBoL project. Staff-student partnership therefore does not only result in the identity transformation of faculty and student partners as we have seen so far, but also has the potential to result in transformation in institutional strategy regarding teaching and learning.

Another implication is that mathematics education specialists and mathematicians need to collaborate in research into learning undergraduate mathematics (Bass, 2005; Nardi & Iannone, 2004). Such collaboration, we believe, could lead to change in teaching practice which might then inspire students to engage more with their learning. As we noted, traditional university mathematics teaching is largely transmissive with content being prepared exclusively by faculty, and it is not unusual to find them doing this alone. The SYMBoL project has perturbed this long-standing arrangement and enabled not only the student voice to be brought to the fore but also encouraged greater dialogue amongst faculty themselves.

Conclusion

The approach to course design described in this essay enabled two Communities of Practice (undergraduate mathematics students and university mathematics teachers) to engage in curriculum development that challenges traditional and enduring university teaching practices. Through their participation in a learning community, student interns, such as those described in this essay, may undergo identity transformation as they import elements of practice from one community to the other. A growing number of disciplines and HE institutions are forming such partnerships and in time there will be a body of knowledge from which readers can draw further evidence to inform their practice in their own institutions.

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