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"No longer a divide between students and staff": Learning through participation in statistics resource development

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In this paper, we analyse the diaries of two intern mathematics undergraduate students who were involved in a project on statistics resource development. Our purpose is to use the theoretical perspective of communities of practice (Wenger, 1998) to investigate how internship functions as a learning environment for these students. The results indicate how the two students shaped their own practice within the internship by establishing a mutual engagement and a shared repertoire and by integrating the joint enterprise of the task to their own work. The overall social environment of the internship, consisting of other students and staff, shaped the practice of the two students and became a learning environment for them.

Keywords: Communities of practice, participation, statistics education, undergraduate mathematics education, learning resource development.

INTRODUCTION

In the last fifteen years higher education has started addressing the demand for statistics professionals in business, economics and research with curricular changes that improve the quality of undergraduate statistics education (Bryce, 2002). These changes demand further development of learning and teaching resources that will cover not only the statistical content but also the contextual needs of a range of disciplines in which statistics is applied (e.g., in engineering, psychology, finance, etc.). In this spirit a team of staff members and students in a UK university has been working since 2012 on the development of resources that can be used in statistical teaching and research with the second author of this paper as a co-ordinator. The students are mathematics un-

dergraduates involved in the resource development either in summer internships or in the context of their final year dissertation project. Although there is little research on student involvement in curricular development in undergraduate mathematics education (Croft, Duah, & Loch, 2013), it appears that there is potential benefit of this involvement to students' learning and to resource development practice (Croft et al., 2013; Biza & Vande Hey, 2014). The study presented in this paper aims to contribute to this area of research by using the theoretical perspective of *communities of practice* (Wenger, 1998) to identify how the internship functions as a learning environment for the involved students. Specifically, we take a case study approach by concentrating on the *Excel Data Generators* (EDGE) project, which is a section of the overall resource development activity we described above, and on two intern students (Beth and Pauline). To this aim we analyse the diaries Beth and Pauline kept across the internship to investigate the following research questions: (a) How do students shape their own practice across the internship? (b) How is this practice related to the overall social environment in which it takes place? (c) How does this practice contribute to students' learning?

THEORETICAL PERSPECTIVE – ELEMENTS FROM THE LITERATURE

In this paper, we see students' learning occurring in the social context of their interaction with staff and other students and we draw on the theoretical perspective of *communities of practice* suggested by Wenger (1998). Communities of practice are formed by people who engage in a process of collective learning in a shared domain of human endeavour. In order to form a *community*, people need to be involved in ac-

tivities with the same objectives, share a concern or a passion for these and learn how to achieve them better as they interact regularly. The *practice* is the source of coherence for the community, and defines the community through three dimensions: *mutual engagement*, *joint enterprise* and *shared repertoire*. Mutual engagement gives substance to the practice that "exists because people are engaged in actions whose meanings they negotiate with one another" (p. 73). The joint enterprise "is the result of a collective process" (p. 77) towards a common understanding of what the aim of the mutual engagement is. Shared repertoire includes resources created and used in a community of practice including "routines, words, tools of doing things, stories, gestures, symbols, genres, actions" (p. 83). Research discusses several communities of practice related to the teaching and learning of mathematics, especially at university level: undergraduate students, mathematicians and mathematics education researchers (e.g., Biza, Jaworski, & Hemmi, 2014). Usually, in this research lecturers reflect on their teaching or/and students participate and potentially shape a learning environment without being involved in its design. In our study students join the resource developers' community of practice: they work closely with members of staff and other students in resource development (e.g., data generator spreadsheets, problem/lab sheets guidance, video demonstrations, etc.) and engage in activities that are not included in their usual university practices. In this sense, students who usually are users of learning resources find themselves on the other side as developers of these resources.

Recently there is a growing interest in students' engagement as partners in course design and its contribution to students' learning. Croft and colleagues (2013), for example, identified several students' benefits from their involvement in producing screencasts for other students: "increased and deeper understanding of mathematical topics, improved technological skills, improved study habits, improved personal and organizational skills, and enhanced communication skills" (p. 1053). On the other hand, although lecturers saw opportunities in this collaboration for their professional development, they expressed reservations regarding students' lack of mathematical maturity and concerns over the mathematical integrity of the produced content. However, the study concluded that collaboration between students and lecturers during the resource design and production "may help lecturers overcome reservations, whilst preserving

the benefits for students" (p. 1045). Solomon, Croft, Duah and Lawson (2014) see undergraduate students' internships as a pathway for improving dialogue between students and staff that challenges traditional hierarchical roles and relationships. They claim that projects that support these internships establish a *boundary-crossing setting* in which there is a "potential for expansive learning to take place" for the students and challenges for "staff perceptions about pedagogy" (p. 332). Similarly, in our evaluation of students' learning through their involvement in resource development projects we have considered not only the learning per-se, but also how and in what extent this learning is a result of students' participation (Biza & Vande Hey, 2014). This evaluation revealed that students explicitly linked their participation to the solidification and organization of their knowledge in terms of statistical thinking and reasoning. Also, this participation contributed to their learning about how statistics is taught and learnt. Students contributed to the whole process by introducing new practices and bringing in 'student' perspective. We also found out how students merged, or sometimes experienced the conflict of, multiple perspectives such as student vs developer and mathematician vs non-mathematician (ibid). In this paper, we pursue this investigation further: we consider the internship as an apprenticeship to the resource developers' community of practice, consisted usually by tutors, and we use the communities of practice theoretical perspective to investigate how this internship functions as a learning environment for the involved students.

THE CASE OF THE STUDY: THE EDGE PROJECT-BETH AND PAULINE

The Excel Data Generators (EDGE) project is the development of an Excel based tool (called the EDGE tool) and materials that support its use in research or teaching and learning (e.g. guidance, online resources, video demonstrations, lab sheets, etc.). The EDGE tool can generate data according to statistical models whose parameters can be set by the user, and perform statistical tests. It can be used for teaching/learning resource development, such as generation of datasets with specific characteristics for problem sheets or assessment; creation of individualised tasks with similar datasets, demonstration of statistical methods with a range of datasets; experimentation with variation and randomness; etc. The instructor can design the context of the problem and use the tool to

generate relevant data. The full EDGE tool includes 19 Excel spread sheets for data generation and statistical tests including: one sample t-test; two sample t-test; chi-square test; tables of t-distribution and chi-square distribution critical values; simple linear regression; one-way ANOVA; etc..

Beth and Pauline are the two intern students involved in the EDGE project. Beth had completed her mathematics degree (BSc with first class honours) just before the internship. Additionally, she was one of the final year students who worked on the development of learning resources for a module on Statistical Modelling in the context of her final year dissertation the preceding academic year. This module was aimed at second-year students in mathematics and Beth produced a lab sheet and three videos on multiple linear regression in R (free software environment for statistical computing and graphics, <http://www.r-project.org/index.html>), together with an assessment tool to evaluate the effectiveness of these resources (Biza & Vande Hey, 2014). With this background Beth entered her internship with prior experience on working with staff on resource development and with skills on R and video creation. Pauline had just completed the second year of undergraduate studies in mathematics and she had attended a module on Introductory Probability and Statistics in her first year and a module on Statistical Modelling in her second year. She did not have any experience on resource development at the time she started the internship, but in her personal statement attached to her internship application she expressed strong interest in Statistics as a subject she wanted to take further.

The internship lasted five weeks during the summer break. Beth and Pauline were mainly working in a study area in which computers, learning resources (books, leaflets, etc.) and specialised software (such as LaTeX, R, Excel, and Camtasia) were available. Elizabeth, the lecturer who coordinated the resource development, visited the study area almost every day and spent some time with Beth and Pauline on their project. Elizabeth, both students and Alicia (researcher in mathematics education with statistical teaching experience) had weekly working meetings (lasting approximately an hour on average) in which the produced materials were discussed. In the same area other intern students (up to 6 in total) were working on statistical and mathematical resource development. Each afternoon the whole group of interns, Elizabeth,

Alicia and other members of staff and PhD students had informal coffee/tea breaks of approximately 45 minutes in which they discussed the progress of their work as well as other topics. This provided an informal context of discussion between students and staff on topics that were very often outside the strict boundaries of the projects. The resources produced by Beth and Pauline included: a fully developed set of Excel spread sheets; four video demonstrations of the use of the EDGE tool made with Camtasia software; and, two lab activities on one-sample and two-sample t-test with their accompanying handouts and EDGE (excel) files.

METHODS

In parallel to the resource development, data were collected for research purposes and towards the evaluation of students' experiences. These data included students' weekly diaries and audiotape of the regular working meetings. Due to space limitations, in this paper, we report outcomes only from Beth's and Pauline's weekly diaries. In these diaries, produced by the end of each week, interns were asked by the first author to include: the activities of the week with some outcomes, if they existed; items that they have learnt or they want to improve (e.g., a statistical concept or method, creation of spreadsheets or videos, use of statistical language, time-management etc.); what went well and what didn't go so well and why; examples in which working together or individually helped them to understand statistics better; contradictions in the collaboration (e.g., cases in which the collaboration didn't work very well) and what they did to overcome them, if they did anything, or why they didn't take any action; and, any other item they want to write down and reflect on it. These diaries, which were each around one A4 page long, were analysed according to how the students collaborated with each other (including the organisation of their work), with other students and with staff; and, how this participation affected their learning.

RESULTS

Beth's and Pauline's collaboration

Beth and Pauline mentioned in their diaries how they organised the work between the two of them as a team and how also they interacted with the other students in the same study area and with the staff members. In terms of the teamwork, early on they decided to work

individually in some parts and together in others but try to be consistent all the time, especially in terms of formatting and symbolisation. As Beth described in her first week's diary:

This week myself and [Pauline] started working on the EDGE generator spread sheet. We focused on the first four sheets (one sample t-test, two sample t-test, simple linear regression and two-way chi-square test) and divided up responsibility for them. [Pauline] worked on the one-sample t-test and I worked on the two-sample t-test sheet. We talked a lot together about how they worked in order to fully understand what we were doing and also to keep each other involved with what the other one was doing. [Beth, W1]

In the above excerpt Beth, who is more experienced, described how they "divided responsibilities" (who was accountable for what) by building a shared understanding of what they "were doing" and what the "other one was doing" (mutual engagement). In other occasions they worked together and helped each other:

After this, we worked together on developing the simple linear regression sheet and the Chi-square sheet. I think we worked very well together on these and both welcomed suggestions from one another. [Beth, W1]

So, from the first week, they both engaged with the resource development and they established the rules of this mutual engagement. They were working individually and together – and at the same time they maintained a consistency in the outputs of their work by using the same formatting and terminology (shared repertoire):

Now, we are creating two lab sheets, one for the one-sample t-test and one for the two-sample t-test. [Pauline] focused on the first lab and I focused on the second lab. [...] We did make sure that the formatting was exactly the same and conferred with each other on specific terminology so that the lab sheets were consistent. [Beth, W1]

This was evident in Pauline's diary as well:

Although we wrote the lab sheets separately, checking with each other periodically has been

important to ensure the layout and terminology within the labs is consistent. [Pauline, W1]

This pattern of work was followed across the internship, as Beth mentions:

We worked separately on these spread sheets, each picking a different one, so that we would not overlap with editing. We still discussed what we were doing with each other and would ask each other questions if we were stuck in order for both of us to understand how each spread sheet works. [Beth, W4]

It seems that this work distribution worked for them as Pauline acknowledged:

I feel we both worked really well together in deciding who would work on which part of the project and ensuring that we both knew exactly where we were at and what needed to be completed in the timeframe. [Pauline, W5]

Beth's and Pauline's collaboration with staff

The role of both Elizabeth and Alicia was to offer feedback and assess students' work. But Elizabeth's role also included the co-ordination and the management of the overall project, its objectives and enterprises. Both Beth and Pauline knew from the very beginning what was the overall aim of this project. However the aim of their task became more evident when Elizabeth informed them that she would use these resources in her module the following year:

[Elizabeth] informed us that she plans to use this lab sheet for her second year statistics students. Even though the lab sheet will be available to other staff throughout the University to use, having a clear audience for the resource made it a lot easier when returning to the lab sheet after the meeting. [Pauline, W2]

Elizabeth was accountable for the establishment of this enterprise and both Beth and Pauline had to align to her plan. It was difficult to them to proceed without a confirmation from her that everything was on the right track. When Elizabeth was busy with other tasks and not available to confirm that everything was alright they "both felt that [they] were lacking a bit of direction" [Beth, W2] and that "[i]t was difficult to know if [they] were covering what she wanted"

[Pauline, W2]. We were interested to see how both students saw their relationship with staff at the end of the internship. Beth, who already had the experience of previous projects, wrote:

The interaction between myself and members of staff has been very positive. I have always felt like I could approach both [Alicia] and [Elizabeth], and am not afraid to ask questions. Also, having lunch and tea breaks with both [Alicia] and [Elizabeth], as well as many other members of staff and PhD students, has made all of us interns feel very comfortable, and I no longer see a divide between students and staff. [Beth, W5].

Whereas, Pauline described how her relationship with staff had developed through the internship and how this can be beneficial for the following year of her studies:

I also feel I have built a good relationship with [Elizabeth] and [Alicia] as this internship has progressed. To begin with it still felt as they were lecturers, and there was a boundary, but as we have been working so closely together I have become more confident in voicing my opinion and feel happy to ask questions whenever I have an issue within my work. This is a skill I aim to take with me into my third year at university and beyond and I believe it will have a positive effect on my module grades and hopefully my dissertation. [Pauline, W5]

Beth's and Pauline's collaboration with others

Throughout the internship Pauline and Beth had many opportunities to receive feedback from other interns and other staff members. Sometimes this was happening informally in the coffee/tea breaks or on purpose. In Week 4, for example, the whole group of interns and supervisors ran a presentation of their projects to three Human Biology lecturers who were interested in using these resources in their teaching. Beth and Pauline were very satisfied by their presentation on the EDGE project and also by the fact that it attracted "some interest from other departments" [Pauline, W4]. This was the first time that they had some formal feedback from outside their team and their department and this was a strong motivation for them.

Additionally, the interns working in the same study area organised between themselves a practice of resource exchange and getting feedback that increased gradually towards the end of the internship. In Week 3, for example, Beth and Pauline shared the resources created by that time with the others. This helped them to make the content user-friendlier. Also, the appreciation of other interns on their work, especially Andy, a very experienced Masters student, encouraged Pauline:

After [Andy] letting us know how impressed he was with the EDGE tool (which uplifted my spirits a lot as it seems to have taken a long time to complete this!) he gave us comments on the lab sheet and ideas for further improvement. [Pauline, W3]

Both students claimed that the overall social interaction in the study area was very positive. In Week 3 the whole team of interns was already getting along and they had started socialising, as Beth mentioned: "We're all getting on very well and were successful in winning a pub quiz last night!" [Beth, W3]. At the end of the internship, Beth acknowledged: "All of the interns have got along very well, and it's much nicer to work in an environment where everyone is happy and having a laugh." [Beth, W5]. Whereas, Pauline concluded:

Overall I have really enjoyed this internship [...] It is definitely interesting how close you can become with a group of people when you are in a fairly small space with them for 40 hours a week! [...]. [Pauline, W5]

Contribution to learning

Both Beth and Pauline found their involvement in the project beneficial to their learning of statistics and other general skills. At the beginning Beth with her experience and her familiarity with this type of projects, worked as a bridge between Pauline and the lecturer (Elizabeth). As Pauline had not attended the module offered by Elizabeth the previous year, she had difficulty putting together the terminology she knew already with this used by Elizabeth. But Beth who had the experience from both modules was able to help Pauline to make the link:

I found [Elizabeth] uses some different terminology to what I am used to in statistical modelling,

however [Beth] has explained the differences to me which has made this clearer [Pauline, W1]

Beth helped Pauline to establish statistical knowledge that was familiar to her:

Although simple linear regression is something I am familiar with, I found working together was the best way to tackle this as I found myself struggling with getting my head around some parts of this process and being able to collaborate with [Beth] helped my understanding. [Pauline, W1]

Or, to expand her knowledge in new items:

I was unfamiliar with the code before doing this, so I am glad we both had a part in the completion of this sheet. It has expanded my knowledge of the different commands available in Excel and I have a good understanding of the calculations carried out throughout this sheet [Pauline, W1]

Pauline was keen on grasping the opportunity to learn new things although there were more experts than her to undertake the tasks. Whereas Beth found that explaining to Pauline (and other students) improved to her own knowledge.

We [Beth and Pauline] have decided to work together on the videos as [Pauline] is very keen to learn how to create them and I have made them before. I think this will be good as I can help [Pauline] if she gets stuck and she may notice new things for us to do when making the videos. Next week I am going to help teach [Pauline] and [other intern] how to make Camtasia videos, which will improve my knowledge and usability with this software even further. [Beth W2]

Both Beth and Pauline acknowledged that their knowledge of statistics improved throughout the internship:

Beth: Throughout this internship I would say my knowledge of statistics as a whole has improved, and through the creation of the EDGE tool, I have become a lot more comfortable with various tests. My understanding of significance and power has increased as we spent a long time creating and editing the lab sheets which involved a lot of interpreting

p-values and manipulating various values to see the effect on significance and power. I have also acquired some knowledge of survival analysis [...] [Beth, W5]

Pauline: [...] I feel as if I have taken a lot of knowledge away from this project. I have basically covered the bulk of [Elizabeth's] Statistical Methods module, learning about multiple statistical tests that I hadn't come across before. [Pauline, W5]

Also, they mentioned how their presentational skills improved alongside other skills:

Beth: This has reassured me that I am capable to present to groups of people, and that I don't need to be nervous about presenting or having an interview. [...] My ability with Excel has naturally improved a lot and I feel these skills will help me in the future. Also, creating the videos has reinforced my understanding of this software [Beth, W5].

Pauline: I really enjoyed learning how to use Camtasia to produce the tutorial videos. [...] It is a skill that I hope will come to use in my final year here [...] I also increased my confidence in using Latex and came across new programs such as GeoGebra. I am able to come away from this internship with a lot more confidence not only in myself, but in my ability to research new areas. [Pauline, W5]

CONCLUSION

In this paper, we analysed the diaries of two intern students who were involved in a project on statistics resource development to our aim to investigate how the internship, in this case, and students' involvement in curricular development, more generally, functions as learning environments. In this study we considered these students entering a resource developers' community of practice and we obtained some insight into how students form their own practice across the internship (research question (a)). Specifically, from early on, both students established a *mutual* engagement: they established a shared understanding and

distribution of responsibilities; they shared their practice with other students and staff; they negotiated the meaning of their work with others and they valued this negotiation. At the same time they established a *shared repertoire* that they maintained later by bringing together different terminologies and being consistent in formatting and symbolisation. Finally, the *joint enterprise*, although among staff's responsibilities, became gradually part of their work. Also, we identified how this practice is related to the overall social environment in which takes place (research question (b)) through the students' regular interaction with each other and with other students and staff. Finally, we have evidence that, according to those students, the working environment of the internship became an environment of learning (research question (c)) through participation and communication. If we draw on the more recent work of Wenger, McDermott and Snyder (2002) on *cultivating communities of practice* – in our case the resource development community of practice Elizabeth aimed to establish – we identified different levels of participation: *core* members were Elizabeth and Alicia who knew the aims of the project and co-ordinated the actions; Beth was an *active* member, who was familiar with this type of work and understood the rules; Pauline started as a *peripheral* member but very keen on drifting to the centre and becoming *active* with Beth's and others' support; other students or staff acted *outside* the community but involved occasionally when the community shifted to their area of interest and expertise and asked for feedback. According to Wenger and colleagues (2002) the quality of a community is established when all its members regardless their level of participation feel *full members*. From Beth's and Pauline's self-reports in their diaries we have evidence of them experiencing this sense of membership. However, we cannot claim that the participation to the project did not have some drawbacks. Students' frustration, for example when Elizabeth was not available to assist them was an indication that the teamwork was not always efficient. From the lecturer's perspective on the other hand several downsides challenge the success of this experiment (see also Croft et al., 2013, about lecturers' resistance), such as disproportionate time investment; integrity of resources; limited contribution to lecturer's professional development; and lack of institutional value on projects like this. The evaluation of the overall experience will be more comprehensive when we combine the students' perspectives with staff views as well and this is the next step of our analysis.

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