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Characteristics of participation - A mathematician and a mathematics educator collaborating on a developmental research project

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In this paper, a developmental research project involving offering mathematical modelling (MM) activities to university biology students is presented, and a particular aspect is studied, namely the project as a collaboration between mathematicians and mathematics educators. The aim of the paper is to investigate what characterizes their participation in the project, and how the characteristics of the project and its development might influence this participation. Interview data as well as observation data from the MM sessions are analysed, and findings show that the mathematics educator served as a broker influencing the practice of the mathematician. It is hoped that the findings of the study can be of use when planning future collaboration between mathematicians and mathematics educators.

Keywords: teaching and learning of mathematics in other fields, teachers' and students practices at university level, cross-disciplinary collaboration, mathematical modelling, communities of practice.

Recent developments in science as well as in higher education have led to a greater need for cross-disciplinary collaboration. For instance, the changing needs of a biological science more and more dependent on mathematical methods has led several authors to suggest a closer integration of mathematics and biology in the education of future biologists (e.g. Brewer & Smith, 2011). This was part of the motivation for a recent collaborative developmental research project between two Norwegian centres of excellence in higher education (The Centre for Research, Innovation and Coordination of Mathematics Teaching, [MatRIC](#); and the Centre for Excellence in Biology Teaching, [bioCEED](#)) in which biology-related mathematical modelling (MM) activities were introduced to undergraduate biology students as a means to increase their appreciation for, and competence in, mathematics. In this paper, however, I will use the project as a case for studying a different kind of cross-disciplinary collaboration, namely between the mathematicians and mathematics educators developing and conducting the project.

MATHEMATICIANS AND MATHEMATICS EDUCATORS

There is a close relationship between mathematics and mathematics education – as remarked by Kilpatrick (1998, p. 36), “neither can exist without the other”. However, collaboration between mathematicians and mathematics educators is still relatively rare, although it has received attention in the literature (e.g. Fried & Dreyfus, 2014), and its importance and relevance to both communities have been emphasized (e.g.

Nardi, 2008). Dörfler (2003) has pointed out several obstacles to collaboration. For instance, the communities of mathematics and mathematics education are often quite separated: mathematicians and mathematics educators work in different departments, teach different subjects and have different educational backgrounds. Furthermore, there are few arenas where they can meet professionally: they mostly publish in different journals and attend different conferences. Dörfler also highlights prejudices about the other field as a possible obstacle to collaboration, something also discussed by other researchers (e.g. Ralston, 2004). On a related note, the mathematician in Nardi's (2008) book states the need for mathematics educators to "be able to talk to mathematicians about mathematics", for there to be a basis for collaboration (p. 270). At the same time, "there is no such thing as *the* mathematician, *the* mathematics educator, or *the* mathematics teacher" (Thompson, 2014, p. 319). What is described above is only the general picture – there are numerous examples of functioning collaborative relationships. Most of these, however, take place on the individual rather than the organizational level. Indeed, the importance of individual relationships and trust is pointed out repeatedly in the literature. As Thompson (2014) puts it: "successful collaboration requires mutual trust and respect among collaborators in the context of a shared commitment to solving a problem" (p. 331).

UNIVERSITY MATHEMATICS TEACHING AS SOCIAL PRACTICE

The MM activities forming the basis of the project were developed and conducted by a MatRIC team consisting of a mathematician and three mathematics education researchers, and in order to study what characterized this collaboration I will adopt a Communities of Practice perspective (Wenger, 1998). A *community* is "a group of individuals identifiable by who they are in terms of how they relate to each other, their common activities and ways of thinking, and their beliefs and values" (Biza, Jaworski & Hemmi, 2014, p. 162), and a *community of practice (CoP)* is a community characterized by *mutual engagement*, *joint enterprise* and *shared repertoire* (Wenger, 1998, p. 73). Mutual engagement concerns, for instance, norms and social relationships within the community; joint enterprise refers to common understandings of the aims and ideals of the practice; and shared repertoire concerns what and how various resources are used in the practice (Biza et al., 2014, p. 163). Participation in a CoP can vary from the central participation of an experienced "old timer" to the more peripheral participation of a newcomer (ibid, p. 162). An individual's sense of belonging to a CoP involves *engagement* – active involvement in mutual negotiation of meaning; *imagination* – extrapolating from your own experiences to form an image of your own place within the CoP; and *alignment* – coordinating your activities to fit within the structures of the CoP and contribute to the enterprise (Wenger, 1998, p. 173-174).

The CoP perspective has been used successfully in research on university mathematics teaching (Biza et al., 2014). For example, Jaworski and Matthews (2011), in a study of university teachers' lecturing, found little indication of a joint

enterprise of teaching. Also originating in research using elements of social practice theory to investigate university mathematics teaching is the Spectrum of Pedagogical Awareness (SPA) (Nardi, Jaworski, & Hegedus, 2005). The SPA provides a means of describing and reflecting upon university mathematics teachers' pedagogical thinking and practices, and consists of four levels ranging from *Naïve and Dismissive*, through *Intuitive and Questioning* and *Reflective and Analytic* to *Confident and Articulate* (ibid, p. 293). There are also several case studies using socio-cultural perspectives to investigate university mathematics teachers' teaching practices (e.g. Treffert-Thomas, 2015). However, there is little research on the type of situation investigated in the present paper. Here, a team of mathematicians and mathematics educators collaborate on developing and conducting teaching activities at the university level, not primarily aimed at introducing new mathematics but rather at getting students to apply the mathematics they already know in new contexts. Of relevance for its focus on the collaborative aspect is the study by Cooper and Zaslavsky (2017), investigating a mathematician/mathematics educator co-teacher partnership in a course on mathematical proof.

The present study seeks to answer the following questions: What characterizes the participation of the mathematician and mathematics educator in the project? How might the characteristics of the project and its development influence this participation?

THE PROJECT – METHODS, DATA AND PARTICIPANTS

As mentioned above, the project involves MM activities aimed at improving biology students' motivation for, interest in, and perceived relevance of mathematics in biological studies. The planning and teaching was carried out by a MatRIC team consisting of one mathematician and three mathematics educators. The mathematician, Yuriy Rogovchenko, is a professor of mathematics with extensive experience of MM both in teaching and in research. He is also coordinator of the MatRIC network on MM. Yuriy had the main responsibility for planning the mathematical content of the sessions and selecting tasks. The mathematics educators were: Simon Goodchild, professor of mathematics education and leader of MatRIC, with extensive experience of teaching mathematics in secondary school, but whose teaching experience at the university level mostly consists of courses in mathematics education; the author, a post-doctoral researcher in mathematics education with a background in mathematics, whose role in the project was mostly data collection and research support to Yuriy; and a doctoral student in mathematics education who was mostly acting as an observer and research assistant in this iteration, in preparation for the second iteration which would form a major part of his doctoral project. Since writing about their collaboration at the level of detail necessary for this paper would make anonymization practically impossible, professors Goodchild and Rogovchenko kindly agreed not only to participate in the research, but also to make their identities known. For simplicity and brevity, however, in what follows they will be referred to

as ME and M, respectively. The project was conducted at a well-regarded Norwegian university where biology students take one compulsory mathematics course, taught in the first semester, designed not specifically for the biology undergraduate program but for students from about twenty different natural science programs. Hence, the course provides little opportunity for focusing on issues specific to biology.

So far, the project has been through two cycles of development; however, in this paper only the first iteration is considered. It consisted of a pilot, where the team met with 10 volunteer students for one three-hour session, a regular sequence of four three-hour sessions with a different group of 11 volunteer students concurrently with their compulsory mathematics course, and a follow-up meeting with the second group of students the following semester. All sessions were taught in English, but student group-work was conducted in Norwegian. The basic structure of the sessions was similar throughout, with an introductory lecture conducted by M introducing some ideas and tools of MM, followed by small-group work on various MM tasks set in a biological context, with whole-group follow-up, led by M but with some input from ME. Examples of tasks included estimating the density of a rabbit population based on the number of roadkill rabbits, and investigating the growth of a yeast culture in a petri dish. All sessions were video recorded. Data analysis is still ongoing, but initial results have been presented elsewhere (Viirman & Nardi, 2017).

The analysis presented in the present paper draws on the video-recorded data from the four regular sessions in the first cycle of the project. To provide further insight into the collaborative process involved in developing the project, after the conclusion of the second iteration of the project the author of the present paper conducted an audio-recorded, semi-structured group interview with the two principal members of the team, M and ME. It was decided not to include the fourth member of the team (the doctoral student) in the interview, since his involvement in the first iteration of the project was peripheral. A thematic content analysis was then conducted, of the interview data and the video data from the whole-class sessions, using the CoP framework as a tool for structuring themes, focusing on signs of mutual engagement, shared enterprise and joint repertoire, central and peripheral participation, and possible obstacles to a CoP developing. For instance, concerning shared enterprise, I looked at what M and ME said about their aims when developing the project, and then examined the video-recordings of the sessions looking at how these aims translated into what was emphasised in their teaching practice, comparing and contrasting the practices of M and ME. Some consideration of my own role in the project is appropriate. Although I was involved in the project from an early stage, and am well acquainted with its aims, my role has been that of the researcher. I did not participate in the planning of the content of the sessions, and my involvement in the sessions was for the most part restricted to data collection.

RESULTS

Looking at the video recordings from the sessions, certain patterns in the behavior of M and ME could be discerned, where M often had a very clear focus on the mathematics and the tasks, while ME assumed responsibility for the students' wellbeing and the nature of their learning. For instance, in the second session work on the first task had taken longer than expected. Still, M, enthusiastic about the mathematics and eager to get through all that he had planned for the session, begins introducing the next task:

M: You will be solving an important medical problem. You are

ME: Yuriy?

M: Yes?

ME: Are you aware of the time?

(...)

ME: I'm talking to our student friends. Are you ready to go on and have a look at this task, or are you saying "Hey, hang on a minute, it's five o'clock?"

Similar situations occurred on several occasions during the sessions, with M getting carried away by the mathematics, and ME intervening on the students' behalf. At the same time, this pattern was not entirely consistent. There were occasions where M showed a clear concern about the students' wellbeing and enjoyment, telling jokes and striving to make the students feel at ease. Similarly, there were occasions where ME got to present his solutions to some of the tasks, displaying an obvious enthusiasm for and a deep engagement with the mathematics. Still, the overall tendency was relatively clear.

Another more distinctive difference between M and ME concerned their engagement with student contributions to the solution of the MM tasks. Again, M had a strong focus on the mathematics, to the extent that he displayed signs of what Ralston (2004) calls the One Right Answer Syndrome, clearly having one particular solution in mind. This affected the way he lead discussions. For instance, when students came up with solutions or suggestions that fit with this expected solution, they were received as being the "correct" ones, as in these examples from sessions 1, 2 and 3, respectively:

M: Any other assumptions you were using in your work?

S: Yeah, that 97 dead rabbits were per 24 hours

M: OK, that's a good one

S: Because it said that they were easily recognizable

M: Correct, you read exactly what was meant there

(...)

M: I will show you how the reasoning goes

M: When we look at the answers, the second group gave the correct one

M: This is the perfect one (...) the only thing we need to check is, how far is this from my computation

Particularly the last quote displays how M used his own solution as the yardstick against which student solutions were measured. On the other hand, when student contributions did not resemble what he had in mind, M often did not comment on them at all, or used a different terminology: “Well, that was a very constructive way to solve the problem.” This contrasts with how ME talked about the students’ work on the tasks, as in this example from session 3:

ME: We really, really, REALLY would like you to share with us solutions that you have worked on within groups on those tasks. Now, it doesn’t matter at all whether they are good or wonderful solutions, perfectly correct solutions, whatever perfectly correct means, whether they look like his [points at M] solutions or look like my solutions, which will be quite different – it really doesn’t matter. What matters is the engagement, and the thinking processes, and sharing with each other, and with us, the thinking processes.

In line with this, on the few occasions during the sessions where ME conducted discussions, he instead let the students lead. He interrupted students’ presentations less frequently, and was not so quick to evaluate their contributions. When presenting solutions to tasks he emphasized the process of doing mathematics over the result, presenting his mistakes and dead-end attempts, seeing these as opportunities for students’ learning.

Still, there were signs of M gaining an increased understanding of students’ needs and potential for contribution as the project progressed. Preparing the last session, he decided to involve the other team members more in the session, providing support to the groups in their work, stating: “We should have done this in the first session”. He also expressed this willingness to reflect on his own practice in the interview:

M: Feedback was essential, so it was like my teaching was shaped during those four sessions towards some goals – I was experimenting, I was changing – partly I was listening to what you [ME and the author] were saying, partly I was trying to do what I felt was appropriate (...) I had very useful advice which might have affected my way of teaching.

Interviewer: In what way?

M: I probably more often look at what I’m doing from the other side. From the students’ perspective.

At this point, ME commented that this was “very much the didactician’s view”, and that it showed “a readiness to reflect” upon his own teaching. This readiness to reflect and change was further emphasized by how M later in the interview talked about his plans for a new course he would be teaching, where he intended to incorporate more student-centred teaching methods.

In the interview, when discussing the collaboration M emphasized the particular qualities of himself and ME: “We are both weird people”. When asked what this “weirdness” consisted in, he alluded to the stereotypical views mentioned by Dörfler (2003), saying that he has a (for mathematicians) uncommon interest in teaching, partly due to the influence of ME, while ME is (for a mathematics educator) uncommonly knowledgeable in mathematics. Furthermore, both M and ME strongly emphasized the value they place on their professional relationship – that two people from adjacent, but still different fields can work so productively together. M added that in no department where he had worked (and he has worked in numerous places, in many different countries) had educational matters been on the agenda. The collaboration was always on the individual level, never on the departmental, and as ME added, this holds true even at their current university, where mathematicians and mathematics educators work in the same department. At the same time, M expressed the view that the differences between mathematicians and mathematics educators had helped improve teamwork within the current project, but emphasized how this was dependent upon all participants being able to engage with the mathematics. Concerning other aspects of successful collaboration, ME highlighted the need for mutual motivation: “Maybe this interdepartmental work has worked so well because bioCEED wants something, and we [MatRIC] want something, and those two wants coincided.” When asked what the mutual motivation was that enabled M and ME to work together, ME highlighted the will to see MatRIC succeed, and how this success was in part dependent on the collaboration between ME and M. M struggled with formulating an answer, but emphasized interest in and curiosity about mathematics.

The main obstacle to collaboration mentioned in the interview was lack of time for preparation:

ME: In terms of preparation, one of the things that I (...) found a bit frustrating, was that the preparation was very often done between three and four o’clock in the morning on the day of the session, and therefore there was very little opportunity for discussion between the three of us [M, ME and the author] about what was going to happen in that session.

ME attributed this to differences in individual styles of working, but still pointed out that because of this and other time constraints, discussions about the mathematical and didactical aspects of the sessions rarely managed to go below the surface level. In response to this, M stated that his initial plan was to have the whole sequence of activities pre-planned, but that the feedback he got while conducting the sessions led to continuous refinement and change. Still, he agreed that providing the rest of the

team with the tasks further in advance would have been preferable. Generally, both M and ME stated that the main difficulty with the project was the lack of time – everyone involved were so busy with other things that they found it difficult to engage with the project as deeply as should have been needed.

CONCLUSIONS AND DISCUSSION

In the findings from the actual teaching sessions, M was seen to a large extent emphasising the mathematics and ME showing more concern with the students, their wellbeing and learning experiences. These characteristics of the participation of M and ME in the sessions align well with observations made by Cooper and Zaslavsky (2017), where a similar pattern could be seen. At the same time, these characteristics were not uniform throughout the sessions, and the overall picture of their engagement with the content and the students is not quite as simplistic as that. Still, the differences are discernible and should not be downplayed.

Furthermore, one might ask whether a CoP developed around the project. From what M and ME expressed in the interview there are definite signs of *mutual engagement* – they both emphasize the close professional relationship, and there is a dedicated support between the members of the project in making it work. There is however, less evidence when it comes to the *joint enterprise* and *shared repertoire*. In particular, practical circumstances regarding the project – the late preparation, the lack of time for discussion and reflection – made the development of a shared repertoire difficult. The responsibility for developing activities and tasks fell mainly on M, and the ways of interacting with students differed quite substantially, as the findings above show. It is also difficult to find evidence of joint enterprise. On a surface level, this could of course be said to be the project itself, but looking at what M and ME say about the aims and motivations behind the project, the existence of a joint enterprise is less clear. For ME, as leader of MatRIC, it is about the success of the centre, whereas for M it has more to do with engagement in mathematics at a personal level. Hence, it is difficult to claim that a CoP has developed.

Rather, what happened was that ME, occupying a more central position within the mathematics education community, acted as a broker (Wenger, 1998, p. 105), introducing elements of mathematics education practice and thereby contributing to changing M's practice. In this way, M displays the beginnings of a trajectory from a peripheral position towards a more central. In the interview, M clearly states how participation in the project has changed the way he views teaching – he talks about “seeing things through students’ eyes”, described by ME as “a didactician’s view”. These changes are perhaps less clearly visible in the video recordings from the sessions, but as mentioned above there are signs of an increased awareness of students’ needs as the project progressed. This could also be understood in terms of the Spectrum of Pedagogical Awareness. When M talked about reflecting about his own practice, and “seeing through students’ eyes”, this fits well with the *Reflective*

and *Analytic* level of the spectrum, which is characterized in part by “awareness in starting to articulate pedagogical approaches and of reflection enabling making strategies explicit” (Nardi, Jaworski & Hegedus, 2005, p. 293). At the same time, much of what M did in the sessions would rather fit with the *Intuitive and Questioning* level of the spectrum, with a less explicitly articulated pedagogical thinking and a more intuitive recognition of students’ difficulties and needs (ibid, p. 293). Hence, a movement along the spectrum could be discerned as the project progressed, and there is some support for claiming that M’s pedagogical awareness has increased as a consequence of the project.

Regarding what factors contribute to functioning collaboration between mathematicians and mathematics educators, what has been reported here is only a single case, and one should be wary of drawing strong conclusions. Still, it is worthy of note how well findings from literature, about mathematicians demanding that mathematics educators know the mathematics (Nardi, 2008) and the need for individual relationships and trust (Thompson, 2014) resonate with what M and ME say in the interview. Both point out these factors as crucial to their collaboration, while lack of time for joint preparation and reflection is pointed out as the main obstacle. An awareness of the importance of these factors will be highly useful when planning and conducting further collaborative efforts involving mathematicians and mathematics educators. Indeed, providing institutional means and resources for preparing and developing projects of the kind discussed in this paper might be one way of moving parts of the responsibility for establishing collaboration from the individual to the institutional level, something which is necessary if such collaboration is to be sustainable.

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