

Improving First Year Mathematics Teaching Through Making Connections: An Action Research Approach

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Four university lecturers at an Australian university have been undertaking an action research project for almost two years to improve first year mathematics teaching. The project is analysed here through the single idea of “connection”. Making new connections or changing the nature of existing connections with colleagues and especially with students is leading to different ways of teaching. Beliefs and practices that had remained, until now, unexamined, are being abandoned, modified, or at the very least, questioned.

In certain traditions, practitioners of meditation believe that focussing exclusively on the breath leads to the centring of the mind and to a better understanding of the interconnectedness of all things. Similarly, in this paper, we focus exclusively on one concept through which to reflect on a complex, collaborative human experience that we have shared for almost two years. The concept is that of “connection” and the experience is that of an action research project in which we have worked at improving the way we teach first year mathematics. At a time in Australia when tertiary mathematics enrolments are not meeting the graduate demand of STEM (Science, Technology, *Engineering*, and *Mathematics*) related professions (Brown, 2009; Dobson, 2007), mathematicians are becoming more aware of how they are teaching (Nardi, 2008; Wood et al, 2011). A review of our experience to date indicates that the quality of “connection” powerfully permeates the ways in which we talk/think, act, and relate (Kemmis, 2009) in our action research group. We argue that “connection” is fundamentally contributing to the changes we are making in the teaching and learning practices of first year mathematics in the lecture theatre and the tutorial room.

The Latin origin of the verb “to connect” means to join or to tie. This meaning has been taken into modern English where “to connect” means to bind or fasten together; or to join or unite (Macquarie Dictionary, 1997). To these meanings, the thesaurus in the WORD software package adds the following synonyms: to relate, to associate, to bring together, to link up, and to network. In our context, connections refer to the links we make in our action research project among people, ideas, and practices.

The human capacity “to connect” is integral to a range of theories that explain how we communicate, build community, and learn. For example, albeit in different ways, the concept of connection is as essential to those learning theories that focus on the cognitive to explain how learners construct and organise knowledge as it is to those theories that view learning as a social activity. Not surprisingly therefore, the element of connectedness appears in pedagogical models (Biggs & Tang, 2007) where connection can refer to how teachers help students develop and make appropriate links among concepts; to how they have students learn from one another; or to how they might encourage students to connect what they are learning in the classroom to the broader social contexts in which they live. While many of these theories would be useful frameworks for analysing the connections discussed in this paper, we use Wenger’s community of practice theory (1998) because its emphasis on the social aligns with the collective nature of action research. Wenger’s (1998) theory is a social theory of learning in which learning is viewed as social participation where identity transformation, practice, and social structure are mutually constitutive.

Lave and Wenger (1991, p. 98) introduced the term “community of practice” in a study of learning through apprenticeships to refer to “a set of relations among persons, activity, and world, over time and in relation with other tangential and overlapping communities of practice”. They then described the connection between the practice of the community and the learning of its members as follows: “The social structure of this practice, its power relations, and its conditions for legitimacy define possibilities for learning”. Learning, they argued, is about participation in social communities and because learning changes who we are and what we can do, it is ultimately to do with transformation of identity. From this perspective, identity, and community membership are interrelated. In a later book, Wenger (1998) details the interconnectedness of identity, community, practice, meaning, and learning, all of which, he explains, are mutually defining.

Wenger (1998) describes practices as the collective learnings of a group or community of people whereby meanings are negotiated and “created over time by the sustained pursuit of a shared enterprise” (p. 45). Communities of practice then are “shared histories of learning” (p. 86) that develop during a time span of indeterminate length, but in which there is sufficient mutual engagement in a common purpose to produce some significant learning. Wenger (1998) argues that practice is a source of community coherence. This comes about in three ways: through the mutual engagement of participants; through the negotiation of a joint enterprise; and through the development of a shared repertoire of resources accumulated over time.

Mutual engagement refers to the interactions and relations built up between community members as they negotiate meanings in pursuit of a common purpose. Mutual engagement requires drawing on one’s own resources as well as drawing on those of others. It involves “defining identities, establishing who is who, who is good at what, who knows what, [and] who is easy or hard to get along with” (p. 95). Negotiating a joint enterprise involves struggling to define the enterprise and reconciling conflicting views and interpretations. Because it is ongoing, the process produces relations of mutual accountability among the community members. These include documented rules, policies, standards, and goals, but they also include norms and values that can go unarticulated. Relations of accountability are central “in defining the circumstances under which, as a community and as individuals, ... they attempt, neglect, or refuse to make sense of events and to seek new meanings” (Wenger, 1998, p. 81). The third element, that of a shared repertoire, refers to the shared resources that the community has developed for negotiating meaning. The repertoire ranges from routines, stories, and symbols to the styles and discourses used in practice. Wenger (1998) uses the term “repertoire” to emphasise that while these resources are made available through a history of mutual engagement, they are also used to create new meanings. Compatible with the idea of communities of practice is the notion of social capital. It, too, has connectedness at its core.

Social capital theory proposes “that networks of relations are a resource that can facilitate access to other resources of value to individuals or groups” (Balatti & Black, 2011, p. 66). According to Coleman (1988), the main aspects of social relations in which the social capital inheres are the obligations, expectations, and trust set up within the relationships; the information channels created in the social structure; and the norms and sanctions operating within the collectivity. In our case, the collectivity is the action research team.

The social relations included in the definitions above have been described in the social capital literature as ties, or more specifically, as bonding, bridging, and linking ties (Gittell & Vidal 1998; Granovetter, 1973). Bonding ties are the ties that build a common purpose and cohesion within groups such as within an action research group. Unlike bonding ties

that are the strong ties within a group, bridging ties are the relatively weaker ties that exist between groups or that an individual has with members of groups that are not his/her main groups. For example, in the university setting, bridging ties may be those ties that exist between schools or between members of different teams within the one school. The third kind of tie is the linking tie. These are the ties that people have with institutions, systems, or “faceless” entities that are important to their capacity to participate more fully in their groups or individually. Linking ties for members in an action research group may include knowing how to communicate with administrators of online databases or software.

To describe the action research team in this study as a community of practice allows us to analyse the connections among its members in terms of Wenger’s (1998) theory of learning. Doing so also provides a framework for discussing the connections among the participants from a social capital perspective thus focussing on the ties and on the resources that are shared and generated by virtue of those ties.

The action research approach adopted in this case follows Kemmis and McTaggart’s (1988, p. 5) model where they describe action research as

a form of collective self-reflective enquiry undertaken by participants in social situations in order to improve the rationality and justice of their own social or educational practices, as well as their understanding of these practices and the situations in which these practices are carried out.

In our project, our purpose is to better understand how first year students experience university mathematics; to reflect on our assumptions and beliefs about what constitutes good teaching; to make considered changes to our practice; and to evaluate the impact of those changes. The repeated action research spiral of plan, act, observe and reflect (Kemmis & McTaggart, 1988, p.11) shapes the interaction among the team members.

Action research as an approach to changing professional practice at the grassroots level has gained currency in a range of professions including mathematics teaching (Atweh, 2004) in the school and university settings. The literature is rich in guidelines on how to undertake action research but much of the research-based literature focuses on the outcomes of the approach rather than on the approach itself. The approach is generally dealt with, sometimes perfunctorily, in the “methods” section of papers which then proceed to report and analyse the results. Hannah, Stewart and Thomas’s study (2011) involving two mathematics educators and one mathematician that reports the development of the mathematician’s lecturing pedagogy is an example of this type. In the smaller body of research that has attended more to the dynamics of the action research approach, Males, Otten and Herbel-Eisenmann (2010) explore the nature of collegiality and “challenging interactions” (p. 461) amongst participants in a long-term action research project of several years involving eight mathematics teachers and three researchers. This paper also contributes to this smaller body of literature by exploring the element of connections in the action research approach adopted by our team.

The Action Research Method

The action research project that this paper draws on is taking place in the Mathematics Discipline in the School of Engineering and Physical Sciences at James Cook University. It began in July 2010 when at a meeting of the six mathematicians in the discipline, staff decided that the fail rate in the two first year mathematics subjects was unacceptable and that changes needed to be made to the teaching and learning in those subjects. The head of discipline called for volunteers who wished to investigate the issues further and improve the learning experience of first year students.

After some early changes, the four member team that continues to the present was established. The three mathematicians in the team are Patrick, the coordinator/lecturer of the first year subject offered in first semester; Shaun, the head of discipline who is also the coordinator/lecturer of the first year subject offered in the second semester; and Wayne, the coordinator/lecturer of the second year subject offered in first semester. Each has extensive experience (over 10, 20 and 30 years respectively) teaching university mathematics including first and second year subjects. Two of the mathematicians completed their undergraduate and postgraduate studies at the university and all three began their professional careers at the university.

Jo, the fourth member of the team is the secondary mathematics educator from the School of Education. She was invited to join the group because of her experience in facilitating action research projects, her knowledge of pedagogy, and her familiarity with conducting education research.

The team continues the practice initiated at the outset of meeting at least weekly during the semester. There is full attendance at almost all meetings. At the beginning of each meeting, an agenda is drawn up from the group. Meetings are audio-recorded and minuted. The minutes document reflections about any actions taken and the results of those actions; issues raised; decisions made and their rationale; and any concerns or insights shared by the members. The recordings and minutes are posted on our community site on the university's Blackboard learning management system.

The online community site also includes other material pertinent to our work. Participants contribute to the research folder that comprises journal articles organised in categories. The material prepared by the high school teacher who delivered professional development in ICTs to the members of the action research team is on the site. Also present are the written reflections that the mathematics lecturers posted in the first twelve months of the project on their experience using unfamiliar teaching strategies in their tutorials.

Most of the "talk" that occurs at our meetings coalesces around two kinds of endeavours. The first is activity at the subject level which impacts the practice of all the teachers in the team. This may include reflecting on student related data such as test results and student feedback or discussing actions taken or actions proposed. The second is activity at the individual level. This may include a tutor's personal attempts at responding more effectively to the different ability levels within his tutorial group or someone else's efforts to collect evidence to support or disconfirm a hunch. In both kinds of endeavour, evidence based decision-making is paramount, a norm that had previously not existed among the mathematicians with regards to their teaching.

It is within the operational framework described above that the action research team members draw on existing connections, modify others, or build new ones. The types of connections and the quality of those connections that the action research team draws on and/or generates are, using Wenger's (1998) terminology, a function of its common purpose, its membership, and its norms of interaction. The rest of this paper discusses three sets of connections in turn, namely those connections forged amongst the members of the action research team; those between the members and people outside the group; and most importantly, those between the members of the group and the students. We place the emphasis on connections among people because as the discussion demonstrates, these connections link to the connections among ideas and practices that the members of the action research team experience.

Making Connections Within the Action Research Team

The common purpose of the team, which connects the participants and shapes the joint enterprise (Wenger, 1998), is shared strongly amongst the four members in different ways. Improving first year mathematics performance is core business for the head of discipline (Shaun) and for the coordinator/lecturer of one of the subjects (Pat). Student performance is also important for Wayne who, as well as tutoring into the first year subjects, teaches mathematics to students who progress to second year and beyond. Although Jo is external to the discipline she, too, is strongly committed to its purpose. Her interest relates to the secondary mathematics preservice teachers. Historically, the fail rate amongst preservice teachers in first year mathematics is much higher than the average fail rate for the whole cohort. The fail rate in these subjects and subsequent ones has consequences for the number of graduates available in a region where many of the teachers teaching mathematics in the junior secondary school are non-specialists. In conclusion, in different but compatible ways the purpose has and continues to be of genuine importance to all members of the group.

The composition of the action research team also influences the links that are made among the members and the nature of their interaction. Arguably the single most important decision made by the three mathematicians was to be involved in first year mathematics as lecturers and/or tutors. This was a shift from the normal practice of having postgraduates as tutors in first year mathematics. Part of the rationale for the change was the need to develop a co-constructed, shared understanding of the first year context (i.e., a new “resource” in the shared repertoire) which, amongst other things, would lead to the development of an induction program for future tutors in the subjects. This shared experience has led to a stronger common purpose.

The membership of the mathematics educator has also brought a particular set of resources to the team. Unlike the longstanding relationships among the mathematicians, Jo had no shared history with any of the team members other than two positive collaborations that had recently commenced with Shaun in a postgraduate supervision and in the development of a mathematics community website. Resources that the team accesses via the mathematics educator include action research know-how, literature, contacts, and research capacity. This is provided by Honours education students who undertake projects to do with the first year mathematics experience.

The third major element of the community’s practice that influences connections is the frequency and nature of the interaction among the members of the team. Although the mathematicians had known one another for a very long time, they had never met deliberately to talk about their pedagogy. In this community of practice, we meet weekly to talk only about pedagogy, student learning, and related topics. This was a new way of interacting which requires deprivatising practice. It requires talking about our practice; inviting others to observe our teaching; learning to talk to others about their practice; and finally, it requires planning and implementing new ways of teaching—together.

To use a social capital term, the connections that have been described above have led to “bonding ties” developing among the members of the group. Bonding ties are important to developing cohesion of purpose, trust, and a sense of commitment, reciprocity, and accountability within the group. These are the strengths of bonding ties. The concomitant risk of strong bonding ties is that the group becomes closed and ultimately stops learning.

Making Connections Between the Action Research Team and Others

As much as bonding ties are important for the mutual engagement of a community of practice to develop, bridging and linking ties are also critical, especially if the common

purpose of the community of practice is to learn. It is through the bridging ties that new resources enter the community, resources including new knowledge, skills, contacts, and even new members. It is through linking ties that we access resources such as expertise and opportunities not immediately available to our members. For our team, attending to bridging and linking ties is also important because of its small size.

Bridging ties that are particularly important are those that we have with practising school teachers of mathematics. As a result of this connection, the mathematicians have more familiarity with the senior syllabus and the assessment regime and thus possess a more informed understanding of the skill base that students bring to first year mathematics. The bridging tie has also brought to the teaching team a high school teacher to tutor the preservice teachers. This same teacher also delivered professional development in ICTs to the action research team members over a period of months. For the first time in semester one, 2012, the mathematics lecturer is having his students use Geogebra as a learning tool in a graphing topic.

Bridging and linking ties are also important for the flow of resources in the opposite direction, i.e., going from the action research team out to other communities of practice within the university or elsewhere in the wider community of mathematics teachers. As well as drawing on or creating new links to share our learning with others, these links, especially in the university context, are important for the sustainability of the project. The team is buried within a discipline, within a school, within a faculty in the University. To ensure that colleagues know what we are doing and achieving we take opportunities to present our work to colleagues.

Making Connections Between the Action Research Team and the Students

Because the connections between the action research team and the student body are core to the purpose of our project they warrant being dealt with separately. An analysis of these connections shows that some can be described usefully in the language of social capital. Most of the connections are at the tutor/tutorial group level.

The formal connections between the action research group as an entity and the student body are limited. One has been the interactions as dictated by the university ethics requirements for seeking consent to use student data in our research. Students also see us together when supervising invigilated assessments. The only other occasion when we have presented ourselves as a group was when we co-delivered a one hour induction to the preservice teachers, an initiative that we may develop and extend to the whole cohort in the future.

The three mathematicians of the team however, do collectively connect face to face with the student body in another very important way. This is via the tutorial representatives meetings which were introduced early in the action research project. Twice a semester, feedback meetings are held with a student representative from each tutorial group (approximately 10 groups each time). The lecturer then reports on these meetings to all the students in the following lecture, thus completing the communication loop.

It is in the context of the tutorial group that the social relations between the mathematician and his students are more complex. The introduction of peer group learning with its emphasis on learning from one another and the accompanying de-emphasis on the tutor as the fount of all knowledge (Belward & Balatti, 2012; Higgins & Read, 2012) has changed the traditional connections between students and students and students and tutor. Establishing peer learning groups for home study and increasing the amount of student-student interaction within tutorials have generated different sets of ties among tutors and students. Tutorials have now primarily become the place where questions that stump the

peer study groups are discussed. Via blogs (previously emails), the peer groups communicate their problems to the tutors (and other students) in advance of their tutorials. Bridging ties are thus created between the community of practice that is the tutorial and the smaller communities of practice that are the peer study groups. In the tutorial context, bonding ties amongst all the participants are forged as students and tutor work together in a joint enterprise that produces identities that are markedly different from those that students and tutors developed in the past.

Discussion and Conclusion

The longevity of the project, the frequency of interaction, the continuity of the main purpose, and the make-up of the team might make this action research project unusual when compared with others in mathematics teaching. The narrative of this particular action research project, including the place that connections have in it, is necessarily unique by virtue of its context and membership. This, however, can be said of all action research projects. While we note the limitations of the single case study, we would argue that the importance of connection is applicable to most, if not all, action research projects because action research, by definition, is a collective enterprise underpinned by learning theories such as Wenger's community of practice (1998) that, in different ways, account for connection.

In this paper, we have provided insights into the workings of an action research team through focussing our reflection using the concept of "connection". In so doing, we have revealed the importance of the bonding, bridging and linking ties we make to the quality of the mutual engagement, joint enterprise and shared repertoire (Wenger, 1998) of the action research community of practice. We have also noted, without being able to elaborate, that the repeated spiral nature of the action research approach makes the transformation of the connections among people, ideas, and practices mutually constitutive in a particular way. By this we mean that the evidence based decision-making characteristic of action research influences how the connections are formed and inter-relate. Furthermore, the inter-related nature of the connections among people, thought, and action makes separating action research into process and outcomes too simplistic.

Although we cannot predict the longevity of this particular project, we are continuing to find value in working together. Student performance has not yet reached what we would like it to be and we realise that much more work needs to be done. For example, we have not yet adequately understood or developed the various facets of connection in the curriculum of first year mathematics. With increasing attention being given to the quality of teaching in the STEM related subjects at universities, action research is likely to become a more utilised way of fostering improvement in how lecturers teach mathematics. Attending to the nature of connections among people is an important element within the action research enterprise.

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