Chapter 3
Building a Network and Finding a Community of Practice for Undergraduate Mathematics Lecturers

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Abstract This case study details the development of a national network for mathematicians teaching undergraduate mathematics in Australian universities and the subsequent emergence of a community of practice. The network was intentionally established to build and support the leadership capacity of mathematicians who coordinate first-year mathematics subjects. To achieve this, events were held that focused on sharing knowledge, experiences, high quality resources and establishing supportive connections with colleagues. In the course of these activities, it became apparent that a fledgling community of practice existed with the development of a strong sense of identity and recognition of common challenges across institutional boundaries. The community leadership evolved over time, taking on roles from facilitation to advocacy on behalf of the network's members, forming a group identity and sense of purpose. This case study illustrates the potential for a discipline-based, cross-institutional community of practice to support individuals in their development as change agents and to provide a platform from which national issues in higher education can be tackled.

Keywords Mathematics · Mathematics education · Scholarship of teaching and learning · Network · Community of practice

3.1 Introduction

The complexity and scale of undergraduate mathematics teaching in Australian universities presents many challenges for mathematics educators as they strive to deliver high quality subjects and required learning outcomes for students. The

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significant diversity in institutional policy, in degree programs, in tertiary mathematics curricula and in student cohorts, all impact on effective approaches to the teaching of mathematics. In recent years, changes to mathematics entry requirements for many mathematics-dependent degrees has added a further complication, which academics are currently attempting to address through a range of institutional and faculty innovations and education-focused research projects. In spite of this, the tertiary mathematics education community in Australia is a small one, with limited influence over common teaching practices.

This case study details how the establishment of an education-focused national network of mathematicians teaching undergraduate mathematics in Australia resulted, unintentionally, in the emergence of a community of practice. The First Year in Mathematics (FYiMaths) network was one of the two main aims of the FYiMaths project.[1] The network was designed to support and enhance the activities of academics involved in teaching first-year mathematics subjects and managing fist-year mathematics programs. The second aim was to examine the nature and challenges inherent in the role of First Year Coordinator in Mathematics. The project involved collection and analysis of data from in-depth interviews with mathematicians in Australian and New Zealand universities and feedback surveys collected at project workshops. The data informed the development of the network by providing evidence of the key challenges facing academics teaching first-year mathematics and identifying areas of need that could be addressed through a supportive network.

The project was conducted by a multi-institutional team from four Australian universities. The project leader, a teaching mathematician engaged in education focused research, and the project manager, an experienced research officer and information manager, are the authors of this chapter.

In this case study we will outline the process of establishing the network and, we will discuss what contributed to the emergence of a fledgling community of practice and identify the key mechanisms necessary to sustain it. This chapter will explore the nature of the community of practice with reference to the original conception by Lave and Wenger 1991,Wenger 2000 and the development of theory and practices in business and educational contexts (Boud and Middleton 2003; Nagy and Burch 2009; Pharo et al. 2014). We will elaborate on our experiences of the differences between a network and a community of practice, how the needs of members determine the form of a community, the importance of leadership and how communities can develop as nodes within a network.

This case study highlights the potential for communities of practice to support academics within a single discipline to develop their teaching practices through information sharing, disseminating innovations, facilitating cross-institutional collaborations and empowering individuals to pursue change. The importance of leadership, belonging and collegiality will be explored to determine how difficult

[1]The project was led by The University of Melbourne and included members from Curtin University, The University of Sydney and The University of Adelaide.

problems in higher education could better be addressed by greater collaboration at a discipline level. Learning is at the core of this community: learning how to deal with difficult challenges, learning to adapt to new teaching practices and technologies, learning where and how to find the information and contacts that can help. This case study will shed light on the conditions and support needed for the development of communities of practice within higher education.

3.2 Literature

The application of the principles and theories of communities of practice to a wide range of environments, has built on Lave and Wenger's original concepts of situated learning and the processes of developing skills and knowledge (1991). The ability of communities of practice to tap into and capture tacit knowledge has been the focus of many intentionally created communities of practice in the fields of business and knowledge management (Boud and Middleton 2003; Wenger et al. 2002). While many organizations see this knowledge as an asset to be managed, there are also significant flow on effects for staff moral and motivation from participating in a community. A number of studies in business have identified that 'knowledge' workers are more motivated by rewards from social interaction than financial gain, because they bring personal validation through recognition of expertise (Cohen and Prusak 2001; Markova and Ford 2011).

Communities of practice have been effective because they shift the focus of learning from formal instruction to a 'social process' involving collaboration, peer support and mentoring on a 'joint enterprise' (Wenger 1998). Communities of practice have been used effectively in higher education as 'top-down' management tools for facilitating staff development and supporting interdisciplinary teaching within single institutions (Cox 2013; Pharo et al. 2014; Warhurst 2008). An important element for their success is the ability of communities of practice to cross the boundaries of disciplines, faculties and work areas and 'provide a valuable corrective to the isolation experienced by many academics' (Pharo et al. 2014). The traditional collegiality within academic disciplines and institutions provides a logical basis for encouraging communities of practice as effective groups for professional learning.

Communities that grow naturally, as well as those formed intentionally, need 'multiple forms of leadership' (Wenger 1998, p. 231). McDonald et al. (2012) identified the role of leader as a 'facilitator' requiring different skills and approaches at different stages of the community's development. Wenger and Wenger-Trayner (2012) identified the importance of a range of leadership roles in supporting the activities of the community 'learning capability inherent in social groups, such as communities of practice, greatly depends on internal leadership. The leadership needs of these groups are diverse—from thought leadership, to social weaving, to facilitation, to logistics, to institutional connections' (Wenger and Wenger-Trayner 2012, p. 3).

Another model of community leadership was identified by Pharo et al. (2014), in a project which facilitated intentional communities of practice to develop interdisciplinary teaching of climate change in four universities. In this instance, the community leadership was divided between 'activator' and 'facilitator', which at times overlapped and worked in response to the needs of the community.

While communities of practice are well established in the corporate sphere as a means of promoting change or supporting staff learning, there are perceived organisational limitations to their adoption within universities (McDonald and Star 2008; Nagy and Burch 2009). These limitations include the commercial pressures on universities, declining collegiality leading to increasing isolation of individual academics within institutions and university accountability and quality assurance processes (Bexley et al. 2011; McDonald and Star 2008; Nagy and Burch 2009). However there are examples of communities of practice in higher education institutions, which have been established to develop teaching practices (with a professional development focus) or to promote engagement with scholarship of teaching and learning (with an innovation focus) (Green and Ruutz 2008; Mann and Chang 2010; Yucel 2009). These examples of communities of practice provide exemplars for assessing the nature of the community identified within the FYiMaths network. While our network was intentionally created and founded on discipline collegiality, the sense of 'joint enterprise', 'mutual engagement' and 'shared repertoire' that emerged was generated from within, by the members shared sense of purpose in tackling the big issues in mathematics education (Wenger 2000, p. 229).

The community of practice framework was adopted to guide the authors in supporting the continued development of the group. This case study will provide insights into the development of a discipline-based, cross-institutional network and community of practice focused on teaching and learning in higher education. Our review of current literature found no further examples of communities of practice quite like this.

3.3 Background

In Australian universities, the teaching of mathematics is, primarily, undertaken by mathematicians and mathematics educators working within a department or school of mathematics. However, staff in learning support units and academics from disciplines such as engineering, economics and physics, also play a key role in the teaching of mathematics within their particular discipline. The organisational structure and number of staff engaged in undergraduate mathematics teaching can vary widely between institutions. The level of interest in educational research and innovation in teaching practices also varies, often being dependent on research priorities, personal interest or on the unique challenges facing students at a particular institution. Consequently, academics often find themselves developing new

programs in isolation with limited input from colleagues or knowledge of successful innovations, which may exist elsewhere (King et al. 2015).

Mathematics is a core component in a wide range of degrees including commerce, science, engineering, health science and education, and is often a compulsory subject for students, at least in their first year of study. The provision of such subjects, known as 'service' teaching, constitutes the majority of first-year teaching in many mathematics departments. As a consequence, lecture class sizes are generally very large, and are comprised of students from many different disciplines who have a wide range of academic backgrounds and interests. The resultant complexities in teaching such a diverse cohort include: determining a starting point for teaching which is suitable for the majority of students' backgrounds and skill levels (Whannell and Allen 2012), and building into each subject, a variety of contexts that are of interest to students from various disciplines. These difficulties can be significantly increased for those students with low levels of motivation to study mathematics or for those who suffer from mathematics anxiety (Gyuris et al. 2012). High failure rates, poor retention to second-year mathematics study, and low student satisfaction are common outcomes and are issues of serious concern for many institutions (Rylands and Coady 2009).

The role of academics managing and teaching first-year programs is often characterised by high workloads which are associated with teaching large cohorts, managing sessional tutors, large scale assessment requirements and student administration (King et al. 2015; Mcinnis 2000). In mathematics departments, these duties are normally the responsibility of a very small team, or in some cases, a single individual (King et al. 2015). In addition, these academics would normally be expected to maintain research activities in mathematics. It is unsurprising then, that academics in such roles generally lack time to explore alternative teaching practices or curriculum change and have limited opportunities for interaction with mathematics colleagues, both from within their institution and cross-institutionally. However, it is precisely these kinds of activities that have been found to be effective in supporting the development of teaching innovations needed to improve student engagement and retention (Kift et al. 2010; Talbert 2014).

The current opportunities for mathematicians to connect with a broad group of colleagues, or access information that supports and encourages innovative teaching, are limited to a small number of annual events across the country. Attendance at, or participation in, such conferences has not broadly been regarded by mathematicians as a way to seek practical solutions to everyday teaching problems. The development of relationships between colleagues teaching mathematics and science in different universities has been impeded, in part, by this lack of participation, and consequently, staff have suffered from isolation and a minimal exchange of ideas.

Although mathematics education is a large field of research in secondary and primary level mathematics, this is not the case for the higher education sector in Australia. At this level, there is limited published scholarship which focuses on practical solutions to common local teaching issues, and this is not widely accessed by mathematicians (Barton et al. 2012). While general advice and information about higher education teaching may provide some guidance for mathematicians,

most find that teaching practices and innovations from other disciplines are either not practical or not possible to implement in the context of a mathematics class (Kahn and Kyle 2003; Neumann 2001). While each discipline has its own specific teaching practices, in mathematics, the level of abstraction, large student cohorts and knowledge dense curriculum all combine to complicate, or limit, the adaptation of pedagogical innovation from other disciplines (Cretchley 2009; Greiffenhagen 2014; Jaworski 2009). This commonly held perception that 'mathematics is different' creates a barrier for mathematicians to access the large body of existing research and practice in higher education teaching. It is more common for mathematics educators to turn to trusted colleagues as a source of information and guidance on teaching issues (Wood et al. 2011).

In summary, the unique disciplinary difficulties in undergraduate mathematics education, the workloads and priorities in academic roles and the pedagogical limitations in mathematics, combine to create a multiplicity of challenges and also combine to present avenues for enquiry which have been largely unaddressed by any existing single group or forum. The establishment of the FYiMaths network provided the ideal environment in which a community of practice could flourish.

3.4 Establishing a Network

The initial objectives of the network were to provide opportunities for interaction between mathematics educators, to build collegiality within the group and to share experiences and resources, with a view to enhancing innovative teaching practices. Although some individual academics had already established their own relationships locally, such opportunities did not exist within institutional or discipline-based groups on a national scale. From within this intentionally established network, a community of practice emerged organically, as members formed relationships with colleagues around shared interests.

The project team addressed both aims of the project simultaneously, using a phenomenological approach to collect qualitative data through an extensive interview program. This approach facilitated engagement with mathematics coordinators as well as with the broader community of mathematics educators right from the project's beginning. The interviews, conducted at 25 of the 39 Australian universities, and one New Zealand university, provided data that helped to direct project activities and established a personal connection between the project team and key academics from these institutions. In retrospect, they were critical components in establishing the network, since they were the first contact between project team members and potential network members; we needed to establish our credentials at this point if we were to be taken seriously. Opportunities to build on and extend these connections were provided by the project's many dissemination activities. These included two workshops, a national forum and numerous presentations and seminars at conferences, workshops and individual institutions and a special issue of a journal. Through these activities contact with mathematics educators was

established in an additional twelve Australian universities. The data collection and engagement activities were interwoven, building the personal connections between individuals needed to establish the network, whilst also providing data and feedback to the project team that shaped the format and agenda of future events.

The full texts of all interviews were analysed and coded using NVivo. The key themes that emerged highlighted the difficulties that staff teaching undergraduate mathematics grapple with, most of which revolve around teaching large and diverse student cohorts, with limited access to collegial networks or professional development (King et al. 2015). These challenges were made worse as a consequence of the many students entering mathematics-dependent degree programs without the expected 'assumed knowledge' in mathematics, creating a multitude of difficulties for curriculum design. Since these students are, often, taught together in large classes, opportunities for innovative teaching techniques are limited. While universities do provide bridging programs, review curricula, and provide mathematics support services, these measures are often not adequate to overcome these challenges and there are high failure rates in first year mathematics at many institutions.

An unexpected finding, for the project team and for participants, was that many of these challenges were common to academics in mathematics departments across most universities in Australia. In this way, the network generated a new level of understanding by providing the 'interpretive support necessary for making sense of its (the community's) heritage (experiences of mathematics education)' (Lave and Wenger 1991, p. 98). Although individual institutions had developed strategies for dealing with these challenges, their responses had not been wholly effective, in part because individuals had limited access to information and guidance about alternatives. The network provided a way of focusing sector-wide attention on resolving some of these issues.

Network membership was informal and grew through targeted publicity, word of mouth and personal recommendations from participants. Membership was open to all mathematicians and mathematics educators in higher education institutions. In the initial 2 years of the network's life, the informal membership reached 170 members, with 52 members choosing to formalise their association, by listing their contact details on the network's website. A member of the network was defined as an academic who:

- attended a number of network events,
- contributed their opinions and expertise to the group and maintained two-way contact with the network leaders,
- encouraged others in their institution to become actively involved in the network,
- made connections with other members of the network and shared information, and
- inspired others to initiate ways of addressing educational concerns through research or activities in their own institutions.

The nature of FYiMaths network activities and the quality of interactions between its members matured gradually during the first year of the network's operation. Initially participation and interactions were tentative as project leaders and participants established a rapport and understanding of the issues and each other's needs and motivations. Over time attendance and participation in events, involvement in interviews, regular email contact by the leadership and sharing of information within the community established a sense of 'trust' and 'social capital' (Wenger 2000, p. 230). This mutual understanding and reciprocity identified by Wenger (2000) is a key element of the network that seeded the community of practice.

The network was not established with reference to any particularly theory or framework relating to social learning or professional development. The simple guiding principle was based on the idea of creating a means for individuals to establish contact with others and share information, with the potential for mentoring and collaboration to occur. However, the shaping of the network was also influenced by the success of a number of discipline-based networks[2] that had been funded by the Office for Learning and Teaching and had resulted in the development of a range of groups that were supporting learning and teaching initiatives through disciplinary connections.

From the outset, the project team decided that the project activities would be determined by the needs of the potential members. To facilitate this, the first workshop held by the team provided an opportunity for participants to share their experience and opinions about what they believed the major issues for teaching undergraduate mathematics at their institution were. This first workshop represented a transformational moment both for the project team, and the participants because it identified that there were unifying issues that would constitute the shared concerns and 'joint enterprise' (Wenger 2000) that would carry the group forward. The participants seized the opportunity to seek information from each other, share problems, work practices and ideas with enthusiasm. This established the shared knowledge, sense of purpose for improving outcomes in teaching mathematics and enthusiasm for learning from others (Wenger 1998).

At the same time the project team began to identify issues emerging from the interview data, which reinforced workshop feedback from network members. The most common challenges identified amongst mathematicians interviewed were:

- Teaching and engaging diverse student cohorts,
- Teaching students who did not have the expected mathematical background, and
- Developing innovative teaching practices under significant institutional constraints.

The establishment of the network, filled a gap within the mathematics community, as it drew together previously disparate and isolated individuals, who strongly identified with each other and shared many common experiences. In

[2]Chemnet, VIBEnet, CUBEnet, AMSLaTNeT.

addition to the shared challenges, the project team realised that each mathematics department was isolated in their attempts to address these issues, often feeling their experiences were unique, or at least not shared by many other institutions.

The network was supported by influential mathematics and science peak bodies through financial sponsorship, through the advertising of events to their membership and by delivery of keynote speeches that endorsed and validated the network's goals. These bodies included the Australian Council of Deans of Science (ACDS), the Australian Mathematical Sciences Institute (AMSI), the Institute of Innovation in Science and Mathematics Education (IISME), the Australian Mathematical Society (AustMS) and the Office of the Chief Scientist. Collectively, these organisations represented the key groups that have an interest in undergraduate mathematics education. Their support was important because it gave the network validity and authority, which in turn provided intrinsic reward to members through recognition of their expertise and contributions to network activities. The peak bodies' involvement also provided members with access to information about the broader government policy and sector priorities. The members' insights and views on important issues, such as the challenges of teaching diverse cohorts, in turn provided these peak bodies with an intimate understanding of the impact that such issues have on the shaping of a mathematics program.

The mechanisms employed for establishing the FYiMaths network laid the foundations for the growth of the community of practice, which became a subset of the network, with many elements of the network's structure, activities and desired outcomes shared by both groups. The initiation of the network exploited much of the groundwork that the project team had completed during the interview phase of the project. The network's establishment was deliberately designed to be inclusive and consultative and this resulted in widespread participation in the network's activities. During this phase, contact was made with each university mathematics department in Australia, with members of the project team visiting two thirds of them, to meet and interview a number of their staff. This process was an effective way to establish personal connections, trust and a shared understanding of the project's intent.

In the course of project evaluation, (mid 2014), it became apparent that a community of practice had emerged within the network and that applying the principles of communities of practice could be useful as a model for supporting and developing it in the future. A literature review was carried out on the development and leadership of communities of practice with a view to developing these aspects of the project.

This case study uses the following definitions as the basis for analysis;

> A community of practice is a 'learning partnership among people who find it useful to learn from and with each other about a particular domain. They use each other's experience of practice as a learning resource. And they join forces in making sense of and addressing challenges they face individually or collectively.'

> A network is a 'set of connections among people, whether or not these connections are mediated by technological networks. They use their connections and relationships as a

> resource in order to quickly solve problems, share knowledge, and make further connections.' (Wenger et al. 2011, p. 9)

Wenger et al. (2011) see networks and communities of practice as being 'two aspects of the social fabric of learning' (p. 9), and while there can be wide variation in the characteristics of both, they are commonly 'intertwined' (p. 10). The FYiMaths network and community of practice are a good example of this 'intertwined' relationship.

3.5 A Community of Practice

The emergence of a community of practice within the FYiMaths network was due, in part, to a confluence of people, events and issues. The network events provided a much needed forum for mathematics educators to connect with others with similar interests, share experiences and learn from each other. The format and coordination of project events fostered trust and personal connections by incorporating substantial periods of discussion time and social interaction, which allowed for both formal and informal exchanges of information and ideas. The timing of the network activities was also significant as it coincided with heightened concerns nationally, regarding mathematics education at both secondary and tertiary level, (Mather and Tadros 2014; Lopresti 2014; Ross 2014) which meant that participants could see that their collective experiences and concerns were reflected at a national level. The key issues raised in the network activities resonated across most universities and had a galvanising effect on the participants, who quickly identified the possibilities for collaboration to develop solutions to these issues and drive an agenda of change.

The main difference between our community of practice and network was the level of engagement by each member in addressing shared concerns. Wenger and Wenger-Trayner have defined a sense of community as 'the development of a shared identity around a topic that represents a collective intention' (2011). The network's focus was broad and members were from a variety of backgrounds in mathematics, science and education. They had different motivations in joining the network, but were chiefly interested in keeping abreast of current research and initiatives in tertiary mathematics, identifying colleagues with similar interests and establishing 'helpful linkages' (Wenger et al. 2011, p. 9). As the community of practice developed within the network, it became apparent that members' activities were 'about something and not just a set of relationships' (Pemberton et al. 2007). The 'something' constituted addressing the challenges in teaching undergraduate mathematics in Australian and New Zealand universities.

The key factors that signified the emergence of the community of practice were:

- The development of a 'joint enterprise' in addressing long-standing problems in teaching mathematics, focused on identifying practical solutions through sharing ideas, experience and collaboration.

- 'Mutual engagement' through making personal contacts, sharing information that could not be easily accessed by other means, mutual support and understanding.
- A 'shared repertoire' of experiences, interests and challenges. Members were like-minded people who were able to establish trust that transcended institutional boundaries because it was rooted in loyalty to a discipline (Wenger 2000, p. 229).

The emergence of a 'joint enterprise' was evident in the strong interest in collaboration and sustained exploration of key issues both through project events, the website and ongoing communication through email. While the network's aim had been to facilitate discussion and information sharing, the emergence of the community of practice was evident in a sustained 'spirit of inquiry' by individuals who wanted to develop practical responses to problems (Wenger 2000, p. 230). For example it was clear that participants wanted to take action over long standing concerns about university entry standards for mathematics and students' mathematical backgrounds. This was identified as a significant challenge shared by most network participants in interviews and workshop feedback. To facilitate further exploration of the issue the project team organised a national forum, which featured presentations and discussion of the evidence and multiple perspectives on the issue. The forum provided a shared learning experience, access to information and individuals not usually available and provided participants with some practical outcomes to progress the debate. The forum received media coverage and a communique was sent to government and peak bodies, taking individual members concerns to a collective concern that has impact sector wide. This contributed significantly to the development of the community's identity and shared sense of purpose, because it recognised their inherent expertise and perspective as necessary to the wider debate.

The project team identified other important areas for community collaboration including, innovative teaching practices to increase student engagement, diagnostic entry testing and assessment practices. These issues generated 'learning projects' within the community, such as mapping sector wide practices and policies, surveys, organising events to showcase expertise and supporting research projects. Involvement in these projects provided opportunities for learning, where the experienced members provided guidance to less experienced members (Wenger 2000). There was active interest in sharing teaching practices, in particular a number of participants inviting others to visit their institutions, present to their colleagues on specific innovations (such as a diagnostic test or sharing resources) as a way of initiating change.

The development of the community of practice showed that many network members wanted to initiate change and sought to develop collaborations as a means of addressing challenges in their own workplace that they did not have the skills, evidence, courage or authority to influence alone. Feedback from participants indicated that they had few contacts within their own department or institutions who shared their interests and concerns related to teaching. In some cases involvement in

the community provided impetus to implement long planned changes, by giving individuals access evidence and expertise that they needed to develop proposals for changes to courses and teaching practices. The continued growth of the community of practice was based on deepening these connections into working collaborations that resulted in research partnerships and local working groups, which could influence change in participants' own local work groups. Further examples of 'joint enterprises' on issues where members of the community have been inspired to undertake and then share research at workshops and conferences, such as implementation a new diagnostic test, assessment framework or mode of instruction.

'Mutual engagement' was evident right from the first project event (i.e. the first workshop) where participants immediately identified 'kindred spirits', with an interest in learning from each other. The workshops provided an opportunity that most participants reported were not available to them in their home institution, such as discussing teaching practice specific to undergraduate mathematics, sharing 'war stories' and building a rapport based on many shared problems. They also shared many common values, such as deep concern for students' learning and welfare and their passion for teaching quality. While some indicate that institutional competition and accountability measures may be an impediment to cross-institutional communities, this was not the case for us (Nagy and Burch 2009). The interaction of individuals at all project events was characterised by openness and trust, indicating the sense of identity through shared interest in mathematics education was stronger than institutional affiliations. It was also clear from the depth of feeling in participant feedback that many had long sought connections with colleagues in other institutions, but had not had been able to establish this on their own. The participants within the community also reported that they appreciated the recognition the group afforded them for their interest and expertise in teaching.

The community of practice allowed for members to participate at different levels according to their particular needs, interests, level of expertise and workplace constraints. Engagement varied from active participants, who attended events, to those who received email and accessed the website only. For the active participants, two levels of membership were identified within the network: 'contributing members', who participated in events, and contributed their experiences and opinions, and 'leading members', who had experience in mathematics education research, shaped discussions, initiated collaborations and who had developed new approaches in teaching. The emergence of these two groups reflects Wenger's idea's relating to the 'trajectory' of community membership that allow for varying levels of involvement and experience (Wenger 2000, p. 241).

A key element of the network that encouraged the development of the community of practice was its provision of an open forum for honest and critical discussion of problems. The social aspect of face-to-face events was highly valued by many and emphasised in participant feedback, with requests for extended free discussion time, sharing of contact details and enthusiasm for follow up events. This collegial approach was founded on a strong discipline connection, which was not limited by institutional or state-based differences. While individuals acknowledged different views, discussions were non-judgemental, confidential and piqued

curiosity, whilst respecting sensitivities about institutional reputations. This was important in developing the familiarity and trust required to encouraging exchange of information, encouraging 'novices' to participate and allowing the breadth of experience within the community to be realised (Wenger 2000). The sense of belonging and shared commitment to improving outcomes for mathematics students, quickly established this trust between members and also between members and the leadership of the group.

The development of a 'shared repertoire' and community 'artefacts' was facilitated by the project team and reflected the activities and interests of the community (Wenger 2000). Artefacts such as the website, reports and presentations supported learning by documenting ideas and knowledge that had not previously been contextualised within undergraduate mathematics or easily accessible. The creation of some artefacts, such as presentations, journal articles or research projects, provided individual members with a tangible outcome of their involvement in the community and validation of their expertise. The community used artefacts in their own work and by sharing them with colleagues in their own institution, for example reporting back on workshops they had attended, referencing FYiMaths reports and using resources on the website in their research and teaching.

The leadership of the community of practice responded to members' feedback and suggestions by tailoring information and its style of delivery to suit their needs. The project team were not attempting to identify best practice or even to champion particular practices. They acknowledged that teaching approaches were highly individual and were informed by academics' experience, institutional requirements, student cohorts and available resources. Feedback on presentations at workshops indicated that members were interested in practical and evidence based information that could inform their own practice, but could also be used as valuable evidence when building a case for local change or innovation. This meant that information in print was brief and to the point on the website and that posts and emails were regular, but not too frequent, with information targeted to key issues and interests. The website was developed to provide access to information and a level of interaction between members and with the leadership. Information was updated regularly and shared through news posts and a newsletter. A webpage directory was established where members were invited to list their contact details and areas of interest to facilitate sharing of information. This was used by individuals to identify possible collaborators for research, inviting members to state based meetings and developing email lists for circulating information about research activities such as surveys. The leadership's attention to its communication strategy was an important factor in ensuring that the momentum achieved through face-to-face activities, did not dissipate in between meetings.

The community of practice developed from within the network with no clearly defined boundaries, membership or leaders and reflected many of the aspects of Lave and Wenger's original descriptions of communities of practice (Lave and Wenger 1991). The feedback from participants in the community did not indicate that its members felt it differed from the network and did not seek to define itself in terms of a community of practice. The leadership, which was originally intended to

facilitate the network, evolved to match the needs of the emerging community of practice. The community of practice members looked for guidance and two individuals from the project team stepped into these roles.

3.6 Leadership Roles

The leadership of the community of practice developed over time and continues to develop as the community evolves its mission and grows in membership. The leadership roles were not formally established, but emerged naturally from the project leader and manager's roles in initiating the FYiMaths network. The original project team was comprised of five members from four universities, with the project leader and project manager as the main drivers. These two individuals operated as 'activator' and 'facilitator', drawing on the advice and guidance of the team (Pharo et al. 2014, p. 344). The nature of their differing responsibilities was largely defined by their particular skills and background and reflects Wenger and Wenger-Trayner's (2012) range of leadership roles.

The project leader (activator), a mathematician in a teaching-focused role, had many existing relationships within the national mathematics community and had connections with key peak bodies in mathematics and science, giving her access to mentors and advisers. This background, together with her recent collaborative projects in mathematics education, gave her an understanding of the broader higher educational landscape and the policy context for science, technology, engineering and mathematics (STEM) education. The project leader's expertise in scholarship of teaching and learning in mathematics lent credibility to her decisions on strategy and community activities. The project leader participated in the majority of interviews conducted by the project team, which allowed her to develop new relationships with potential members and gain important insights into the structures of many mathematics programs.

The project manager (facilitator), an experienced research officer and information manager, had experience researching scholarship of teaching and learning, knowledge of higher education policy and theories of communities of practice. These experiences, combined with her practical skills in communicating and managing information, informed her approach to supporting the network. Her leadership role centered on the management of information, maintenance of two-way communication between the leadership and the network members, and identification of key issues from the collected data and feedback. Her role as the frontline contact for most network activities gave her a personal connection with members, while involvement in interviews and data analysis provided a sound understanding of the issues.

In the design of all the project's activities, the leadership sought to 'reflect member expectations and (be) responsive to changing needs.' (Debowski 2014, p. 3). The leaders did not direct or set the agenda, but provided the opportunity for individuals to talk, to listen to each other's concerns and to explore the issues of

relevance or interest to them. A critical task for the leadership was to analyse and synthesise these contributions, informed by the broader institutional and higher education context and then develop appropriate activities, resources and initiatives. The sensitive and responsive approach taken by the leadership of the project and network facilitated the emergence of the community of practice in a number of ways.

The leadership legitimised members concerns by tailoring project activities to address them. One example of this was that many members experienced similar challenges in dealing with student diversity, but had very limited awareness of the extent of these problems across the sector, nor did they have contact with colleagues in similar roles in other institutions. This was further reinforced during the workshop where it was clear that face-to-face contact and interaction were not only a powerful method of developing an individual's sense of community, but central to the growing sense of shared purpose. The leadership identified the key issues that the community wanted to address and that bringing individuals together to discuss them could provide an effective mechanism for change.

The leadership identified that members of the community of practice had significant concerns about a single issue: the impact of replacing mathematics pre-requisites for entry to mathematics-dependent degree programs, by 'assumed knowledge' entry standards for mathematics. This change, adopted at many universities across the country, meant that many students were commencing their university studies, mathematically underprepared. Although many individuals had voiced their concerns in their respective institutions, it became apparent that their lack of success in effecting change on this matter was shared amongst the group. At the project's workshops, this shared concern began to gather momentum, as members realised that the problem was widespread rather than a local one.

In response to this groundswell of concern, the leadership organised a forum, in conjunction with IISME, to focus on the issue of 'assumed knowledge'. The purpose of the forum was twofold. Firstly, the forum was designed to draw attention to the full range of negative impacts that this under-preparation in mathematics was having on students' progression in this discipline and also the impacts on teaching and staff workloads. However, a second aim was to invite broad participation from science colleagues and the secondary school sector, to assess the impact of assumed knowledge on students' progression through science and engineering degrees and on the choices students make in senior secondary school. By bringing together speakers and participants from across the science disciplines, representatives of peak mathematics and science bodies and curriculum authorities, the leadership provided a link between the community of practice and the wider science and education sectors.

The forum had a galvanizing effect on the community because it demonstrated that the community provided an opportunity for collective action and was a force for change. The event established the credibility of the leadership by demonstrating that they could bring the group's concerns to national attention by issuing a *communique* to the Minister for Education, Universities Australia and Dean's councils, which subsequently received national coverage in the media (McNeilage 2014; Trounson 2014). The national forum proved to be a 'make or break' point in the

development of the community and had a significant impact on participants' enthusiasm. By taking action, the leadership demonstrated the seriousness of their intent to lead change in higher education. The members of the community reported having trust in the leaderships' guidance and initiatives so that the leadership effectively became an advocate for the members. The role of advocate provided a voice for the community that launched their concerns into the public domain in a way that had not been possible for individuals from separate institutions.

3.7 Factors Contributing to Success

The community of practice that emerged from the network has been successful in providing an active learning community for mathematics educators because it:

- recognized and validated the specific expertise of undergraduate mathematics educators,
- had a broad inclusive membership that fostered collegiality,
- identified common concerns and focused on key issues,
- provided access to information through an effective communication strategy, and
- provided leadership that was responsive to members, while also providing strategic guidance and connections with key peak bodies.

The community of practice acknowledged specific skills and perspectives of its members and validated their roles, which they did not receive from their work groups or organisations. The pre-eminence of discipline research in the higher education sector commonly means that academics specializing in teaching practice are not sufficiently recognised within their own institutions or rewarded for their work, despite the substantial contribution their teaching and coordination may make in their departments. The leadership provided events and a website that showcased this expertise by encouraging both experienced and novice members to present their research and teaching practices for discussion and feedback. The key events, the national forum and two workshops, which invited participants to present and facilitate discussion resulted in tangible research and teaching outputs, including publication by several presenters in a special issue of a journal (edited by the project team), two successful collaborations to gain national competitive grants, invitations to individuals to present at other institutions and fora and implementation of numerous teaching innovations in institutions.

The community provided professional development opportunities and access to information, in particular skills related to management roles, undergraduate mathematics pedagogy and scholarship of teaching and learning that most institutions have failed to provide (Wenger 2000). This was identified by the project team as a clear gap in current practice and informed decisions about the types of information provided on the website, the topics for presentations and the format of workshops.

The community included both experts and novices, individuals with diverse backgrounds and career paths and varied experiences of professional development in their own institutions. This diversity ensured a constant 'level of learning energy' (Wenger 2000, p. 230) as individuals with experience became increasingly active in providing guidance and newcomers were encouraged to ask questions and were supported to develop new skills.

In addition, the interwoven relationship between the network and community of practice provided links between mathematics educators (members) and the external institutions and peak bodies with broad sector influence, allowing members a voice in the national conversation on mathematics education. The relationships between the network, community of practice and external bodies contributed to the success of the group in a number of ways. Firstly, at a practical level, the involvement of peak groups extended the reach of activities through increased publicity to wider audiences.[3] Secondly, the expertise of these groups informed discussion and provided access to individuals that members otherwise would have had no contact with. Thirdly, these links also gave credibility to the group by recognising members' expertise and experience and validating their contribution to the debate by raising individual's concerns beyond the walls of their own institutions. These relationships reflect the boundaries of communities of practice defined by Wenger (2000), in that they represented an intersection of expertise and interests that provided learning opportunities.

The newly established connections between the community and peak bodies were based on preexisting connections between the project leader and key members of the reference group, who provided support and mentoring for the project. These relationships enabled the community to 'hit the ground running' by drawing on this expertise early in the planning activities. Throughout the project, the leadership was able to call on these groups for strategic and policy advice. The consultative nature of network activities highlighted the need to bring all interested parties to the table and ensure discussion and debate was informed, balanced and valid. The project leaders' negotiation skills and understanding of the broader educational and political climate were instrumental in guiding the activities of the community. The leadership shaped the focus and direction of community activities by strategically guiding discussion, information gathering through surveys and encouragement of individuals in research and publication.

It was important to participants in the community of practice that their input and time achieved tangible results, both for themselves and others. The leadership was conscious of this and ensured activities were targeted to members' needs, provided access to new information and were timed to make allowances for work schedules (Wenger 2000). To achieve this, the leadership ensured a broad range of topics was covered, representing experiences in a wide range of institutions and varying the

[3]The Australian Association of Mathematics Teachers, the Office of Chief Scientist, Australian Council of Deans of Science, and the Institute of Innovation in Science and Mathematics Education.

format of presentations and interactive sessions. This approach to tailoring activities and information in response to members' input was crucial to building and sustaining membership.

The membership of the network was broad and inclusive, and extended across discipline and faculty boundaries to include educators from mathematics support centres, secondary teachers and other science disciplines. This extension to members outside tertiary mathematics indicated that the boundaries of the community were not defined by profession, role or discipline, but by the shared enterprise. The community countered the isolating influence of discipline silos and faculty structures that exist in many institutions and limit contact between mathematicians and their science colleagues. This is often in spite of mutual interest and the benefit that establishing such contacts would bring. This was a significant part of the success of the community because it brought together the expertise of mathematicians, scientists and teachers, which holds promise for real educational gains for students.

The project team's communication and administration strategy was instrumental in ensuring that members were kept informed and engaged with the project and that it encompassed the breadth of members and interests. The development of the website and use of email provided an important link with the community and source of current information between meetings. It also developed the personal connections between the project manager and network members that enabled her to develop a detailed understanding of issues, be responsive to members' interests and establish trust. The logistics and administration of events was also managed carefully to ensure they were inclusive, welcoming and accessible to as many individuals as possible. This was reflected in the publicity material, website, email invitations and articles posted on third party web sites.[4]

The success of the FYiMaths project in initiating a network and supporting the emerging community of practice was due partly to the serendipitous timing in bringing together individuals and focusing attention on issues that had been long overlooked. It was also fortuitous that mathematics and science education was receiving national attention due to the activities of other groups, such as AMSI and the Office of the Chief Scientist. The leadership of the community of practice was cognizant of these conditions and strategically guided activities to capitalise on these circumstances and achieve significant impact.

3.8 Evaluating Impact

The impact of the network and community of practice were evaluated as part of the formal processes of administration for the project grant and informally through regular reflection on member feedback. The project evaluation process included

[4]Articles reporting on and publicising FYiMaths events appeared in HERDSA news, the AustMS Gazette and Inspiring Australia website.

formative and summative assessments of progress towards the stated goals. The formative evaluation included regular meetings with the team and the project evaluator. Our choice of project evaluator proved to be one of our success factors, since her experienced advice proved invaluable and enabled the network leadership to reflect and adapt their approach. This process of regular re-assessment of project activities and direction became part of the leadership's strategy in supporting and developing the community of practice. In addition to this, the leadership constantly reflected on input and feedback from members when making decisions and following all events. These two factors ensured that the developing community of practice was strongly focused on, and driven by, the interests and needs of members. Community members too were accepting of the breadth of interests and levels of experience within the group.

The qualitative data about the benefits of the network collected from surveys and participant feedback at the three network events, as well as from website comments and emails from members was analysed to identify the major concerns and interests of members. The major themes identified were:

- Establishing contact with colleagues from other institutions,
- Comparing curriculum and teaching practices in mathematics,
- Sharing experiences and problems with others with similar experiences,
- Learning about innovations in teaching and finding out about resources, and
- Finding practical information concerning implementation of teaching innovations.

The feedback from event participants influenced planning for subsequent events, particularly suggestions concerning increased time for informal networking and further topics for presentations and discussion. The following comments from workshop participants reflect the tone of many responses from members:

> I found out that there are more resources out there than I thought… I will use them to promote better practice within my department

> We've got a lot of new ideas, things that were brewing for a while and now we are empowered to make them happen

The formal evaluation report on the project concluded that the project had 'built an effective network for First Year mathematics coordinators' and that the project had made 'a significant contribution to mathematics education in Australia' (King et al. 2015).

The impact of the community of practice is also evident in more quantifiable activities, such as increased research output by members, website hits, and growth in membership. The community has seeded many cross-institutional research collaborations with at least three successfully gaining OLT funding to support projects. The website usage statistics are reviewed regularly to monitor the level of interest in topics and pages used most regularly. The website and social media usage count has steadily grown throughout the project with an average of 51 hits per day in March 2015, four times higher than at the same time the previous year. The response to specific items has given insights into areas of interest to members and influenced

the site's content and format, with new features added in response to demand, such as regular updates on the events, providing information on job vacancies, calls for conference papers and grant application opportunities.

The success of the community is reflected in the increased number of participants in the network as the membership is overlapping and connected. The network membership list has grown to include 180 individuals, who receive regular updates from the website, a quarterly newsletter, invitations to conferences, seminars, optional surveys and requests for information. Whilst it is too early to assess any real impact of the community of practice on learning outcomes for students, or professional practice by educators, it is clear that mathematics educators have become a more noticeable presence in the higher education sector.

3.9 Conclusion, Reflections, Implications

This case study illustrates that academic collegiality can foster naturally occurring communities of practice, given appropriate leadership, resourcing and activities. In particular, discipline based collegiality can be effective in initiating and supporting cross-institutional collaboration to develop teaching practices in higher education. This community grew from the strong sense of identity and shared purpose of members and was not limited by institutional barriers (Nagy and Burch 2009). The emergence of the community of practice was driven by a quest for answers, opportunities to learn from others and recognition of expertise that was not being provided by institutions or professional bodies. In turn the expertise and 'artefacts' developed by the community have been used by to respond to these problems.

The development of the FYiMaths network and community of practice reflect Wenger et al.'s (2011, p. 10) theory of an 'intertwined' relationship, and indicates that a network and community can develop together to meet different needs, particularly in relation to different levels of experience, members availability and motivation for involvement. The early success of the community exemplified the benefits of 'legitimate participation' (Lave and Wenger 1991, p. 111) in encouraging new members, establishing trust and providing a forum for shared experiences. The community's artefacts, such as the website, presentations, surveys and reports provided a tangible resource and point of reference for members, as well as those outside the community.

The leadership of the network and community of practice was responsive and met the diverse needs of the group by fulfilling the range of roles identified by Debowski (2014, p. 7)[5] While the activities of the community were guided by the members interests, it was the leadership that synthesised this input and made effective use of connections outside the network to advance their cause. Leadership

[5]Leaders of networks need to fulfill roles as a; visionary, shepherd, governor, team leader and communicator.

that reflects members' needs and interests is one of the most important aspects of supporting the development of a community (Wenger 2000), which in this case study also included responding strategically to sector wide issues and coordinating community activities.

The FYiMaths network and community of practice are still evolving and both have an enthusiastic and dynamic membership. Our challenge will be to maintain the current momentum, activities and development of artifacts without ongoing funding. Over time the community may develop a shifting membership of 'newcomers' and 'old-timers', experience changes in identity and purpose and mature into a more formalized group (Wenger 2000). The continued involvement of members will depend on maintaining interest and a sense of purpose, by progressing work on key challenges and extending the community's expertise into new areas. Having local state-based nodes could be effective in developing a more distributed leadership and provide busy academics with an accessible forum for continued discussion and development of ideas. However, to be truly successful, we must be able to show that participation in the community of practice translates to tangible outcomes for staff and students.

This community has the potential to achieve significant advancements in student learning in the discipline of mathematics, by harnessing the expertise and 'spirit of inquiry' of academics (Wenger 2000, p. 230). The long term sustainability of the community will rely on building members' current knowledge and experience and supporting projects that can instigate change at institutional and sector level. The community will need to continue to actively explore emerging issues in mathematics education and higher education to extend members knowledge and to make a valuable contribution to the national discussion on them. That the network has already begun to establish itself as a key stakeholder in tertiary mathematics education augurs well for the future, however careful and strategic planning will be critical as we attempt to establish this community's place in the broader mathematics education community.

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