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Chapter 22
The Australian Chemistry Discipline Network: A Supportive Community of Practice in a Hard Science

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Abstract Chemistry is one of the oldest and most traditional of the science disciplines, and there is a long tradition of chemistry research in Australia and worldwide. Within chemistry, groupings are traditionally made around sub-discipline specialties such as inorganic, organic, physical and environmental chemistry, which each have their own journals, conferences, and customs. As a research-intensive discipline, chemistry is competitive rather than cooperative, with appointments and promotions based on publication metrics.

Keywords Chemistry education · Community of practice · Threshold learning outcomes · Gender equity

22.1 Introduction and Context

The importance of chemistry as the foundation to many other sciences means that chemistry is taught in all Australian universities. However, the scholarship of chemistry learning and teaching, including research into effective teaching strategies, has not historically been recognised as an important domain within chemistry in Australia. In 2011, the Australian Learning and Teaching Council (ALTC) funded the Chemistry Discipline Network (ChemNet) with a 2 year, $100,000 grant. The main aims of the project were to form a Community of Practice (CoP) of tertiary chemistry educators from all Australian institutions, and to develop and implement the Chemistry Threshold Learning Outcomes (CTLOs). This shared task

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provided purpose and structure to the network, and the many face-to-face meetings cemented virtual relationships, leading to a multiplicity of indicators of a CoP.

The formation of ChemNet coincided with several other important developments in the science learning and teaching environment in Australia. The timing also paralleled technological developments that make synchronous and asynchronous communication around Australia ever easier. Thus, ChemNet has reduced the isolation of academic staff who may be the only chemist, or only teaching-intensive chemist, at their institution. Members in this category have participated in both the core and active groups of the CoP.

This chapter uses Wenger's conceptual framework and the dimensions he defines for a CoP to analyse the formation, activities and sustainability of ChemNet. Discussion focuses on the challenges and successes in implementing a CoP within a hard science discipline, and the effectiveness of social learning within a particular academic environment where research is emphasised over education.

The principal finding of this case study is that a geographically dispersed but disciplinarily close-knit community can function as a supportive, non-hierarchical CoP based around mentorship, and generate significant social capital. The major pre-requisite is at least one committed person driving the activities and processes of the CoP. Synchronous communication through Skype meetings and asynchronous communication via email, even with a very large group of over 100 people, allow the characteristics of a CoP to develop and evolve as members move between different degrees of participation within different projects.

The richness of Community of Practice (CoP) conceptions, developing and diverging from the seminal writings of Lave and Wenger (Cox 2005; Lave and Wenger 1991; Li et al. 2009; Wenger 1998; Wenger et al. 2002) are enlightening to us as tertiary chemistry educators. They give us tools with which to examine our informal support network, the Chemistry Discipline Network (ChemNet), and the teaching environments in which we work. Although qualitative sociological enquiry is not a common activity for physical scientists, it is important to examine our network in CoP terms in order to understand its development, to identify its strengths and weaknesses, and to ensure its continuation. ChemNet has much to gain from this reflection because one major and critical activity of the Network—the articulation and development of Chemistry Threshold Learning Outcomes (CTLOs)—is drawing to a close and key members are moving on. Further projects, including those evolving out of the CTLO work, will maintain some momentum, but we need to examine the current situation systematically to identify our strengths in terms of what value members derive from the community that will keep them engaged and bring others in. Understanding CoP dynamics found in informally structured and purposed CoPs similar to ours can assist this.

A plethora of CoPs across many sectors and with varied structures, purposes, types of membership and degrees of (in)formality have been reported in the literature. In the corporate world, CoPs are managed and aim to increase productivity (Borzillo et al. 2011; Probst and Borzillo 2008; Wenger et al. 2002). Within academia, CoPs have been formed deliberately (Baker and Beames 2013; Molphy et al. 2007; Pharo et al. 2014; Sánchez-Cardona et al. 2012) as well as incidentally

(Nistor and Fischer 2012). A variety of analyses of these CoPs, both qualitative and quantitative, have been used to investigate their nature, journey, outcomes and successes. There is some literature on CoPs in chemistry for secondary teachers (Santos and Arroio 2013), at the secondary-tertiary interface (Szteinberg et al. 2014), and among tertiary chemistry teachers (Adlong et al. 2004; Baker and Beames 2013) that supports the importance and effectiveness of a CoP in this environment.

Power dynamics exist within Schools of Chemistry (or equivalent institutional units) in Australian Universities around the interplay between research and teaching, and their relative importance. We first examine the evolution of this balance through the history of chemistry research and chemical education. The generally low value placed on teaching led, in the 1990s, to informal groups of chemistry educators coming together for specific cross-institutional projects, subsequently leading to formal annual events and finally to the establishment of ChemNet in 2011, and this history is briefly described. Following this, we give an account of the development, activities, outcomes and artefacts of ChemNet. Then we analyse the characteristics of ChemNet as a CoP and its evolution over time. Wenger et al. (2011) emphasise the importance of both data and narrative in combination to measure value creation in CoPs. Our analysis encompasses these aspects. We reflect on the current state of our CoP and look to sustaining the community into the future.

22.1.1 The Culture of Chemistry

Chemistry is an ancient science with origins in metallurgy and alchemy. Modern chemistry grew out of discoveries and inventions of the seventeenth and eighteenth centuries and remains fundamentally an experimental science that adheres strongly to a positivist philosophy. Chemistry is classified within the hard sciences because of the perceived methodological rigour and objectivity required to report a result in chemistry (Hedges 1987). One characteristic of the discipline that distinguishes it from other fields is the ready reproducibility of results by different research groups and in different laboratories. This is a key part of the culture of chemistry.

The massive amount of factual knowledge and symbolic interpretation required to understand chemistry leads to the general perception that it is difficult (Johnstone 1991). This contributes to a sense of belonging among people expert in chemistry (similar to other specialised academic fields), because they share an uncommon language (Taber 2015b) and have travelled a shared pathway to gain their knowledge. However, there is also a competitive aspect to this culture. Appointments, promotion and prestige within university chemistry departments are largely associated with research success (Coe 2002, p. 28; Fox and McWhinnie 2004), reflected in journal publications and external grants, particularly those from government funding agencies. Because of the high value placed on research publications based on novel results, chemistry academics frequently operate within a rather uncooperative structure and in an atmosphere of competition.

22.1.2 *Tertiary Chemistry Education and the Scholarship of Teaching and Learning in Chemistry*

Education in chemistry includes a combination of theoretical teaching and training in experimental techniques. Although curricular differences exist between countries and institutions, a large body of knowledge is common to any tertiary chemistry degree. This is illustrated by the similarities between available textbooks and curricula, particularly in the first year of undergraduate studies (Hill and Cross 2001; Schultz et al. 2013). Chemistry has expanded over the centuries and is now so broad and diverse that it is impossible to be an expert across the entire discipline. Thus, chemistry education involves sub-discipline specialisation. Sub-disciplines include organic chemistry, inorganic chemistry and physical chemistry, or even more narrow polymer chemistry, organometallic chemistry and carbohydrate chemistry. These sub-discipline groupings are reflected in the structure of professional organisations—not only national bodies such as the Royal Australian Chemical Institute (RACI) and the American Chemical Society (ACS), but also the International Union of Pure and Applied Chemistry (IUPAC) are organised around sub-discipline Divisions. Communications within the sub-disciplines occur at specialised conferences and in specialist journals. In the later years of undergraduate chemistry degrees, academic staff usually teach within their sub-discipline speciality. Teaching methods and research traditions differ between the sub-disciplines, which results in a tribal affiliation of chemists to their sub-discipline speciality (Becher and Trowler 2001). The plethora of sub-disciplines within chemistry means that only very large institutions have more than two or three representatives of each on their staff. Thus, chemistry academics are likely to communicate with chemists from other sub-disciplines in relation to their teaching, whereas they are likely attend conferences with experts in their own sub-discipline. Their affiliation to their sub-discipline means that communication about teaching may be superficial. This dynamic is not unique to chemistry.

There has long been interest in the unique difficulties of teaching and learning chemistry, moving between the macroscopic (observable), microscopic (diagrammatic) and symbolic (using chemical symbols). This was recognised in 1991 by Johnstone, who had been describing learning issues particular to chemical representations since the early 1970s (Johnstone 1983, 1991). In addition, misconceptions regarding physical phenomena are widespread and difficult to combat, which further increases the difficulty of understanding chemistry (Mulford and Robinson 2002; Nakhleh 1992; Taber and Tan 2011). While research into student misconceptions continues (Brandriet and Bretz 2014; Luxford and Bretz 2014; Wolfson et al. 2014; Wren and Barbera 2013), the call has been made to move beyond documenting to attempt to remediate these (Regan et al. 2011; Tippett 2010; Treagust et al. 2011). Pedagogical content knowledge has been suggested as the way forward for chemical education (Bucat 2004), because an intimate understanding of content combined with experience with student difficulties allows optimisation of explanations (Talanquer 2007) and teaching strategies (Davidowitz and Rollnick 2011; Drechsler and van Driel 2008; Green and Rollnick 2006). In addition, the use of sophisticated and careful representations to assist visualisation of chemical processes has been recognised as critical within the pedagogy of chemical education (Tasker 2014). Thus, not only the curriculum but also teaching methods can be optimised for student learning.

These challenges in the teaching and learning of chemistry were recognised over a century ago, and conferences and meetings to share teaching strategies have long been held (Do 2006; Kametaka 1931). Multiple journals specifically dedicated to the scholarship of teaching and learning (SoTL) in chemistry exist. The oldest and one of the most respected journals for SoTL in chemistry, the Journal of Chemical Education (published by ACS, founded 1924), has gradually changed its focus over the past decades. Until the 1990s it primarily reported experiments and other activities for educators to adopt. Since 2000, approximately one third of the articles report the results of primary research in chemistry education, for example concerning characteristics of students and their learning, improved assessment strategies, and methods to probe student understanding. In addition to specialist fora, chemistry is included in a plethora of journals and conferences focused on teaching and learning in science. Both RACI and ACS have Divisions of Chemical Education, and IUPAC has a Committee on Chemical Education, indicating that it is widely recognised as a sub-discipline in its own right (Taber 2015a). In 2014, Monash University in Melbourne appointed Australia's first professor of chemistry education. This marks a turning point in the recognition of chemistry education as a valid field of research in Australia.

22.1.3 The Tension Between Chemistry Research and SoTL in Chemistry

A problem faced by chemical educators is the perception that research in this area is easier and therefore less valid than traditional chemistry research. This stems in part from the misconception that education research is less rigorous than hard science research, because it lies partly within the social sciences. However, high quality education journals have exacting standards for research publications and although the rigour required is different, it is no less (Taber 2015a).

Related to this, the general public holds the perception that social sciences are less important than physical sciences (Bernard 2012), in spite of evidence that advances in the former sphere often lead to improvements in the human condition.

This view also prevails, perhaps even more strongly, among those trained in the physical sciences. Thus, chemists are very likely to see their own work as much more valuable and contributing more to society than research in education. At the same time, a common career track for researchers in science education is to undertake a PhD in the corresponding science, work in the field, then move into education research (Rowland and Myatt 2014). This leads to the situation that science education researchers feel that their own work in science education is less worthy than their own previous (or in some cases concurrent) work in their original science field (Clavert et al. 2014). This is unfortunate because it reduces the likelihood that science education research is conducted by those best placed to perform it within their disciplines.

One of the first papers ever published in the Journal of Chemical Education, over 90 years ago, illustrates precisely the attitude towards those who specialise in teaching over research that prevails to this day:

> The trouble at present is that the teacher is suffering from an inferiority complex. He [sic] sees the prizes in the hands of the "research men" [sic] and when he compares his work with that of the latter he finds that the teacher is usually at a disadvantage… (Patrick 1924, p. 16)

22.1.4 Funding and Conferences in SoTL in Australia

In Australia in 1994, the Committee for the Advancement of University Teaching (CAUT) established UniServe to collect and disseminate teaching materials for multiple disciplines throughout the Australian university system. UniServe focused on computer-based teaching materials, which at that time were just beginning to be widely used. The UniServe Science meetings commenced in 1996 and were established to assist academic staff in using computers in their teaching. Their purpose evolved as computer use became routine and the conference was renamed the Australian Conference on Science and Mathematics Education (ACSME) in 2011. This conference is currently the most important forum for sharing results in chemistry education research in Australia. The number of chemistry presentations in each year since the UniServe meetings commenced is displayed in Fig. 22.1 (light bars) with the percentage of women named on abstracts above the bars in italics. One day of this conference (known as the Discipline Day) has been reserved since 2005 for meetings within disciplines and chemistry educators have used this opportunity to connect each year. In addition to these meetings, the Chemical Education Division of the RACI has been running conferences approximately every 2 years since 1973.

Some funding for research into chemical education has been available for many years through various Australian government funding schemes (McDonald 2011). Figure 22.1 summarises the numbers of Federal teaching and learning grants that

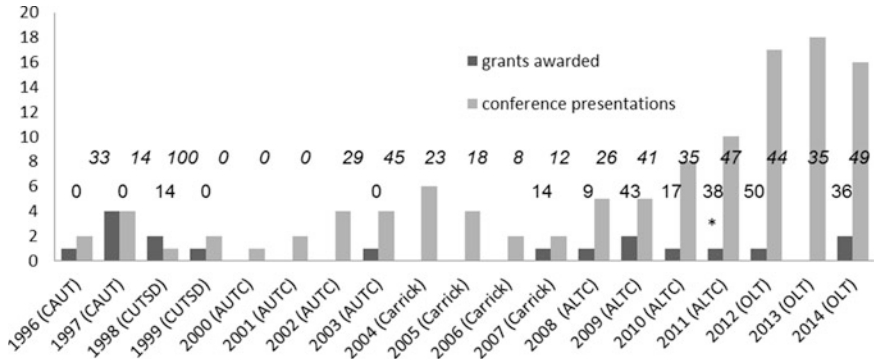

Fig. 22.1 Longitudinal data for numbers of federal grants awarded in chemistry (*dark bars*) and abstracts for chemistry presentations at UniServe/ACSME (*light bars*). The name of the granting agency is in *parentheses*. The percentages of women named on the grants (*regular font*) and named on abstracts (*italics*) are given above or on the corresponding *bars*. * this project's funding

have been awarded for projects in chemistry since 1996 (dark bars), with the percentage of women named among all named grant awardees above each column.

As can be seen from Fig. 22.1, there was a dearth of Federal funding for projects in chemistry education between 1999 and 2007. Although a small number of chemistry projects was funded throughout the 1990s and 2000s, some of which involved groups from multiple institutions working together, until 2010 there was no distinct teaching and learning space for chemistry in Australia. However, research and interest in SoTL in the sciences had been growing. One measure of this increased interest is the annual growth of ACSME, which has grown from 94 attendees at the first UniServe workshop in 1996 to over 250 participants across all science disciplines at the 2014 ACSME. The corresponding recent growth in the number of chemistry presentations at the conference over the past two decades (light bars in Fig. 22.1) contrasts with the relatively stable number of funded projects (dark bars).

An important development within Australian tertiary education from 2009 until 2011 was the ALTC-funded Learning and Teaching Academic Standards (LTAS) project. This arose in response to a Federal publication giving ownership of standards to the individual disciplines (Ewan 2010). For science, an overarching LTAS statement, containing Threshold Learning Outcomes (TLOs), was published in 2011 after extensive consultation across science disciplines (Jones et al. 2011). The chemistry community became heavily involved in the TLO process at this early stage and published a specific set of chemistry TLOs (CTLOs) in parallel with the science process (Buntine et al. 2011).

Within this environment and out of a successful ALTC bid, ChemNet was established. Its primary aims were to connect teaching focused chemistry academics and others with an interest in chemistry teaching and learning in a CoP. As a condition of receiving the funding, ChemNet was tasked with the development and implementation of the recently published CTLOs (Buntine et al. 2011) as agreed thresholds for the bachelor degree in chemistry. This was to prove a major driver for the newly formed Network as described in detail below.

22.2 Formation of ChemNet as a Community of Practice

The theory of CoPs provides a framework within which groups and their activities can be defined and analysed. In outlining the development of ChemNet, we will employ a CoP perspective, using the indicators and the engagement levels from (Wenger 1998, pp. 125–126) as parameters. Then we will appraise the activities and outcomes via descriptors and measures used and reported in the literature. In addition we will consider the various types of knowledge shared in ChemNet, and the links of those knowledge types to social capital and types of learning (Daniel et al. 2003; Preece 2004).

In response to an ALTC call for applications for discipline learning and teaching networks in 2011, we put together an application for the Chemistry Discipline Network and were awarded $100,000. ChemNet aimed to bring together Australian academics with an interest in chemistry education for two main purposes:

1. to connect chemistry educators and those with an interest in SoTL in chemistry in the form of a CoP; and
2. to share our practice and teaching resources in chemistry education at the coalface, often teaching large classes, sometimes in isolated environments.

Other Discipline Learning and Teaching Networks were funded at the same time through this scheme, including several other science networks as well as networks in other fields. There was some communication between all networks during the first year, encouraged and facilitated by the funding agency. The science networks also cooperated and communicated through the Science and Mathematics Network of Australian university educators (SaMnet), and these connections were supported through the Australian Council of Deans of Science (ACDS), leading to the formation of the web based ACDS Teaching and Learning Centre (http://www.acds-tlcc.edu.au). Further inter-Network communication has been facilitated through the Promoting Excellence Networks (PEN), which are OLT-funded Networks in each Australian state.

A guiding principle of ChemNet from its conception has been inclusivity for all interested in tertiary chemistry education. We made explicit attempts to involve people who have not published journal articles or performed well under traditional evaluations of importance within chemistry research. This policy was retained as ChemNet has grown and the effectiveness of our practice in this regard is illustrated by the huge diversity of ChemNet members. Within 6 months of the formation of ChemNet, 87 members had joined of whom 25 had participated in virtual (Skype) meetings. As we write, ChemNet has over 156 members (of whom 54 are women) from 40 Australian and several international institutions, ranging from sessional, part-time staff to professors. Some have no background in SoTL while others are recognised world leaders. Several have made their first forays into publishing educational research through ChemNet. In particular, ChemNet involves many women who historically have been marginalised in chemistry departments (Bell 2009; Mueller et al. 2002; Schultz 2012b; Stevens-Kalceff et al. 2007). The importance of including women in groups for successful team collaboration has been demonstrated (Bear and Woolley 2011). However, our inclusiveness was based on a more fundamental idea of fairness. The impact of ChemNet on women's involvement in SoTL in chemistry is discussed below.

We are aware of the dangers of having the core group too close; as has been recognised

> …tight bonds between members can become exclusive and thus present a major barrier to the integration of newcomers. Without proper monitoring, this closeness can hinder the acceptance of external input and the development of external collaborations (Li et al. 2009, p. 3)

For this reason, we welcomed new participants to every Skype meeting and reached out to new and existing academic staff to invite them into ChemNet. The importance of weak ties in social networks was described over 40 years ago by Granovetter (1973), and changes in communications technology have allowed sophisticated analysis of his concept in the Internet age (Ellison et al. 2014). These and related studies demonstrate that weak ties within social networks facilitate information sharing more effectively than isolated networks of strong ties. This can be understood through the diversity brought into a group that is not already strongly linked. The Internet is particularly effective in facilitating weak ties because of the low cost of maintaining them and the ease of sharing resources (Ellison et al. 2014).

Above all else we wanted to connect people with people to support each other in our work. In Australian universities, Schools of Chemistry or their equivalent typically have one to three teaching intensive staff. Alternatively, depending on institutional structures, chemistry teaching staff may find themselves alone in faculties, departments or schools that are not recognisably chemistry-led. These staff may be teaching over three semesters with little time between. They are often under pressure to produce research outcomes as well as carry heavy teaching and administration loads. They can experience isolation in their day-to-day teaching responsibilities and in any SoTL or development work they plan (Rowland and Myatt 2014). The fundamental aim of ChemNet was to build a group within which a sense of community and support would develop not only to cope with these circumstances, but also to advance participants' expertise. Wenger et al. (2002, p. 4) define CoPs as "groups of people who share a concern, a set of problems, or a passion about a topic… interacting on an ongoing basis." This definition usefully emphasises the common experiences of the participants in particular situations and thus the potential for mutual support and problem solving growing from that shared experience.

ChemNet began with activities centred on communications. We needed to build the membership and provide multiple ways for members to connect to the network and among themselves. The 2011 ACSME was held shortly after the funding was announced and we ran our first face-to-face meeting on the Discipline Day of that conference with over 30 people attending. After extensive discussions during that meeting, we formed working parties for the following tasks:

1. Developing of a website for multiple uses including communication of activities, storage of network meeting artefacts, and an asynchronous discussion platform.
2. Collecting a repository of sharable learning objects to be housed on the website.
3. Articulating and implementing the CTLOs.
4. Mapping of all chemistry subjects (credited units of study making up a degree course) at universities across Australia.

Although we did not refer to any literature at the time, one can easily recognise the development of Wenger's indicators of a CoP (1998, pp. 125–126) within these initial moves to set up and grow ChemNet. In particular, the first few Skype meetings resulted in the following features:

- Shared ways of engaging in doing things together and mutually agreed communication strategies.
- Rapid flow of information, particularly using email.
- Very quick setup of a problem to be discussed—problems in this case included the CTLO process described below, as well as organisational issues and planning.
- Substantial overlap in participants' descriptions of who belongs based on who was involved in meetings.
- Knowing what others know, what they can do, and how they can contribute to ChemNet from past associations—many ChemNet members had worked together or at least met in the past through other chemical education work.
- Mutually defining identities through shared discussions, particularly via Skype but also informal face-to-face meetings of members that occurred.
- Local lore, shared stories, inside jokes, knowing laughter—this was a critical aspect of Skype meetings that was not supported by email or the website.
- Developing or known jargon and shortcuts to communication—again, only live interactions allow this feature.
- A shared discourse about our experience as chemical educators reflecting a certain perspective on the world.

A further set of indicators: specific tools, representations, and other artefacts from chemistry education practice and pedagogy, also became evident early on when members shared published literature of their own or that they had used. This was facilitated by the Skype meetings but also by emails and the website.

Further, one can easily recognise differing levels of engagement or participation of members from the first stages of the CoP. According to Wenger's description, the core group, normally comprising 10–15 % of members, sets the agenda and coordinates activities. In our case this included the members leading the working parties and actively participating (for example attending Skype meetings). The active group is described as participating occasionally rather than regularly and making up a further 15–20 % of CoP membership. ChemNet approximately mirrors these ratios and has done so since the beginning of the project. Peripheral group members (approximately 60–75 % of members) rarely participate and in our case are the majority of members, who receive emails but never engage further. Occasional responses to the email newsletter indicate a transition to more active membership (Borzillo et al. 2011).

22.2.1 Communication: The Key to Connection

Communication within CoPs is critical. Because ChemNet members are spread right across Australia, face-to-face meetings were always going to be infrequent, and so virtual communications were and remain essential to successfully developing the community and producing valuable outcomes. However, to cement the personal relationships necessary for a CoP, face-to-face meetings are invaluable (Preece 2004). Since our first face-to-face gathering at ACSME 2011, we have met on each subsequent annual Discipline Day. Figure 22.2 summarises member participation in the four meetings so far. This is the annual opportunity for members to meet face-to-face and it is always a dynamic and productive meeting.

As can be seen from Fig. 22.2, approximately half of the 39 Australian universities at which chemistry is taught have been represented at each of these meetings. On each occasion, people who were outsiders to the CoP have attended, moving them rapidly through the periphery to the active part of the CoP. Such

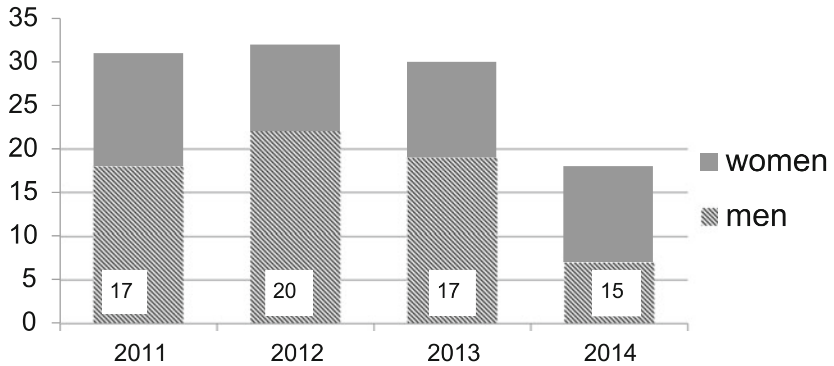

Fig. 22.2 Longitudinal data for attendance at Chemistry Discipline Day of ACSME, *colour-coded* by gender of participants. The number of different institutions represented is given on each *bar*

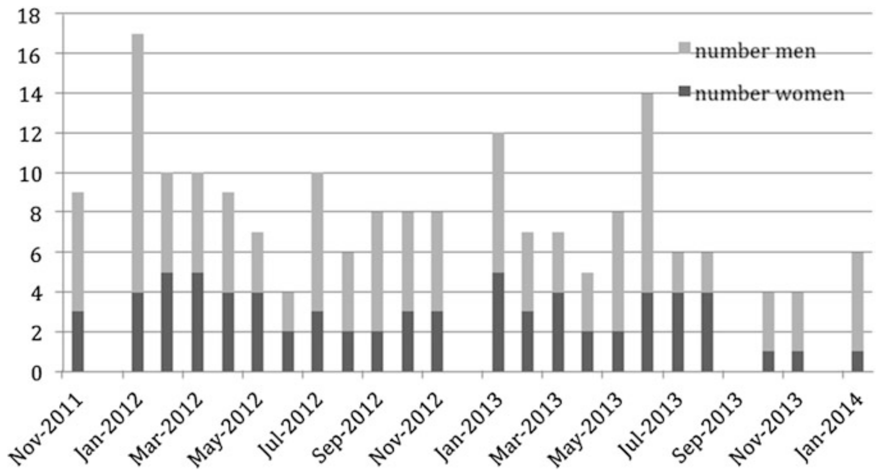

Fig. 22.3 Longitudinal data for attendance at ChemNet Skype meetings, *colour-coded* by gender of participants

participants were in some cases not involved in SoTL, and the ChemNet meeting was their first exposure to chemistry education research.

Monthly Skype meetings were held starting in late 2011. These meetings were well attended, and the active participation of some of the most senior members of the chemistry education community in Australia lent them importance and reassured the ChemNet directors that this was a valuable and valued activity. Figure 22.3 summarises attendance at these meetings over the 2 years during which they were held until early 2014 when, despite efforts of two members to manage the meetings and record notes, attendance dropped to zero. This represented an important dip in the activity of the CoP and can be attributed to the relocation of the person most heavily involved in running the meetings. A group of approximately 20 people regularly attended the Skype meetings over the central part of the project, comprising the core and active members.

Discussions during the Skype meetings were varied, and included the current ChemNet projects such as the mapping exercises, the website and the CTLO project, immediate teaching challenges and resources to support these, upcoming events (funding opportunities, conferences, special issues of journals) and planned grant applications. The rapid flow of information and set-up of problems became more evident over the months, showing strengthening of the CoP characteristics (Wenger 1998, pp. 125–126). Members new to SoTL were assisted in formulating educational research projects, including advice on structuring their research questions, ethics requirements and survey strategies. They were also quickly inculcated into the accepted jargon, lore and jokes of the active and core groups. Conference discussions allowed members to know who else was planning to attend, to arrange travel and to help break the ice in a new environment. Meetings were a very supportive, welcoming environment and also included much humour as members came to know each other better and ties were strengthened.

In addition, ChemNet communicates with all members via a monthly emailed newsletter from one of the authors (MS) with information about upcoming events and deadlines, references of interest, funding opportunities and ChemNet activities. This newsletter is popular and every time it is sent (using mail merge, so is individually addressed), a handful of responses on diverse topics is received. Feedback from members indicates that this is a valuable way of staying in contact, although it lacks the humour and interaction of Skype meetings. The newsletter has continued beyond the funding period and much longer than the Skype meetings. A Twitter account (@chemnet_au) was set up for ChemNet at the time of its formation and has 145 followers, less than half of whom are ChemNet members. This form of communication has led to some important connections outside of Australia and also increased the sense of community among those members who use Twitter. None of the above activities were particularly expensive and in principle the activities could have been conducted without funding. However, the funding opportunity provided a catalyst for the commencement of the activities, paid for the services of administrative support and research assistance, and lent legitimacy to our initial outreach.

Social capital refers to the collective value of social networks associated with their characteristics of trust, cooperation, reciprocity, shared knowledge and understanding, and information and communication flows. Some have referred to social capital as the glue which binds networks together. The link between a community's knowledge and knowledge sharing to social capital in a CoP is multifaceted. Social interaction and social capital support the transmission of the knowledge, while transmission of knowledge further builds up social capital (Abou-Zeid 2007; Preece 2004). Within ChemNet, social capital and knowledge transmission were built through both the Skype meetings and the newsletters, and boosted through face-to-face meetings of members at conferences.

The main challenge to ChemNet has been communication through a website. An enormous amount of time and effort was devoted to designing the website, attempting to find out what would make it useful and popular, and then building the website. This included canvassing views at the first Discipline Day meeting in 2011, an "Ideas Exchange" session at ACSME in 2011 (Schultz 2013), further discussion by email, during Skype meetings and in person when members attended other events together. Many suggestions were received for what would make the website valuable, including sharing resources as exemplified for inorganic chemistry in the US by IonicViper (Interactive Online Network of Inorganic Chemists 2010), with tools for sharing learning objects and fora for discussing all aspects of our shared interest. Originally envisioned as the heart of the network, the website has languished almost unused and is currently a document repository. This continues to be a disappointment given the literature on the success of some virtual CoPs (Johnson 2001; Molphy et al. 2007). Conversely, regular emails and Skype conversations have proven to be the on-going life of ChemNet, supported by annual face-to-face meetings at conferences and informal face-to-face meetings among members who cross paths elsewhere.

As we noticed that people were not sharing learning objects and also not communicating using the discussion fora on the website, we realised that the main resource of the network is the members themselves. To promote people contacting each other directly we generated a spreadsheet with names and contact information as well as some detail about teaching areas of interest of members. However, this was also not used; apparently members prefer not to contact each other directly but prefer the facilitated contact through a Skype or face-to-face meeting.

Thus, ChemNet overcame the double tyrannies of distance and isolation through successful online communications, in the form of the monthly Skype meeting and the monthly email newsletter. In particular the Skype meetings turned out to be far more important that the website, showing that members found value in this form of participation. This may reflect the differences between taking part in the two activities: informal Skype meetings required no preparation, while the value of meeting and talking with others was high and immediately obtained. In contrast, preparing materials to share via a website had a moderate input load, while taking part in asynchronous discussion fora did not give immediate feedback.

22.2.2 Chemistry Threshold Learning Outcomes Project

The articulation of the CTLOs provided impetus for ChemNet and consumed a significant amount of the funds because ChemNet paid travel and accommodation for many attendees across the series of meetings. The working party was reorganised in mid-2012 when it was realised that the task was very large and required multiple meetings with large groups of chemistry academics to ensure that the process would be valid. At that time, few disciplines in Australia had attempted to develop such overarching documents and the task was somewhat intimidating. The ACDS, working with all the science disciplines given the same task, provided leadership and support and facilitated cooperation among the disciplines to make progress on this work.

The main activity over the period October 2012–July 2013 involved the CTLO working party leading and facilitating the development and implementation of the CTLOs by the broader chemistry community. This took the form of four separate, day-long workshops using a process of small group discussions, discussion capture, later distillation, and then sharing for feedback, in addition to two Discipline Day meetings that added to the consultation process. Face-to-face input was gathered from 69 chemists (30 % women) from 25 different institutions, most of whom attended more than one of the workshops (see Table 22.1). Eight of these people had attended the initial CTLO discussion workshop prior to the formation of ChemNet (Buntine et al. 2011).

The meetings included many research-intensive academics not usually directly associated with management of teaching and learning or educational development outside their own sub-discipline area. These meetings, apart from progressing towards the articulation of the CTLOs, greatly enhanced the visibility of ChemNet

Table 22.1 Summary of face to face meetings of ChemNet held to discuss CTLOs

Date of meeting	Number of participants	Main discussion topic
26.09. 2012 Dis Day	32	Assessment of CTLOs on nature of science and concepts of chemistry
12.12.2012	15	Articulate concepts and principles of chemistry
04.02.2013	26	Agreement on statements from 12.12 workshop; how to express these as standards; how to evidence achievement
09.07.2013	20	Laboratory skills and assessment
2013 Dis Day	30	Teaching and assessing ethics, nature of science
05.02.2014	12	Determine extent to which CTLOs are achieved within chemistry majors using a mapping tool

in the whole tertiary chemistry community. Thus the CoP effectively invited non-teaching focused chemistry experts to take part so that all chemistry academics had ownership of the outcome, making use of weak ties (Granovetter 1973) and taking advantage of the group diversity. Degrees of community engagement (Wenger et al. 2002) are represented in Fig. 22.4.

Participants commented that they thoroughly enjoyed and valued the workshops, both the process of gathering commentary and opinion and the shared experience of close conversations about our discipline. The experience of intensive small group discussions to about the TLOs provided time for rich and fulfilling discussions that do not occur at conferences. Furthermore, in these workshops members could find themselves in a small group with senior members of the chemistry community due to the variety of people who took part. The development of the network and its social capital was boosted by the face-to-face meetings, which promoted trust (Daniel et al. 2003) and broke down some of the barriers of online communication (Preece 2004).

The series of CTLO meetings was supported (including financially) by RACI, in part because the Bachelor of Chemistry accreditation standards were undergoing

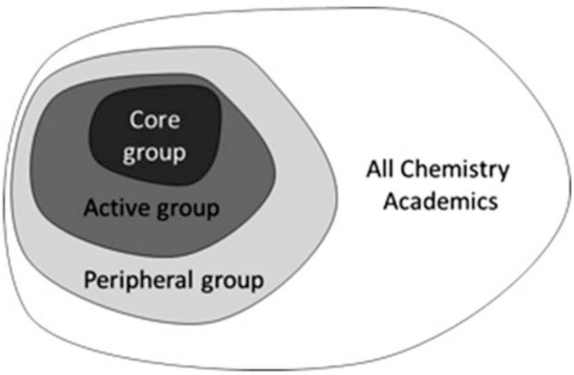

Fig. 22.4 Schematic representation of the participants in the CTLO process within the context of the ChemNet CoP

change from a prescriptive inputs framework to an outcomes based one, and the RACI was considering adoption of the CTLOs for that purpose. During that development period the ACDS teaching and learning community held a 1 day long gathering of the Science discipline networks to feedback their experiences and developments in their respective journeys along the path to TLOs (Yates and Buntine 2012). The CTLO process and outcomes facilitated through ChemNet have been incorporated into the restructuring of the RACI accreditation process for chemistry degree courses, which is a tremendous result and impact for this ChemNet work.

For some individuals in the Australian chemistry education community who originally did not engage with ChemNet, the CTLO process stimulated their engagement. These people could see where they could make a concrete contribution, although they did not engage with the network generally but just with this one activity. Thus, this project led to their movement from the periphery into the core of the CoP (Wenger et al. 2002). Discussion with our counterparts within the UK. Higher Education Academy's Physical Sciences Centre confirm that for a large group, the strategy of forming a smaller group to undertake a specific activity is very effective. Participants know that the group will be closed when their task is complete and the outcomes are shared. The group work may lead to further collaborations or workshops but the group itself is contained. Additional value to the CoP results from the new connections formed during the project, including who has been introduced to whom within their group work, forming new weak ties from previous bridges (Granovetter 1973).

22.2.3 Catalyst Grants

Towards the end of the funding period, it was decided to offer $1000 "Catalyst Grants" to members to help them conduct or conclude a chemistry education project, and ideally to result in publication. Only seven applications were received and all were funded. Applications came from regional, technical and research-intensive universities, and were from early- to mid-career academics. Catalyst grant holders report that receiving the grant was encouraging and a stimulus to their confidence, that reporting back on Discipline Day raised their profile and that they were encouraged to pursue more grants for future projects. Interestingly, these personal outcomes were reported rather than the monetary outcomes of the grant. This illustrates the importance of even very small funding initiatives for education research and the power of a small success to combat disillusionment. At least one Catalyst grant has resulted in publication of results in a recognised journal and continuation of the project through a larger collaboration. This small project of the CoP also drew a new cohort from the periphery into the core (Wenger 1998).

22.2.4 Current Activity

At the annual ACDS Teaching and Learning forum in 2013, the future of the science discipline networks was discussed in terms of possible form and activities. The continuing existence of ChemNet was envisaged to take the shape of an informal CoP, affiliated to both the ACDS TL Centre and the RACI Chemistry Education Division but not embodied within either of these organisations. Since the final report was submitted, the ChemNet monthly newsletter has been the main vehicle for keeping people informed of events and developments. Informal conversations show that members are very pleased to have the continued newsletters. The annual gathering at 2014 ACSME Discipline Day included short reports from several members about their projects and general discussion of teaching issues. Currently activity involving the whole network is low, and we are at a stage of examining our circumstances. Members have voiced a desire to maintain the CoP, reflecting on the connections made and support perceived in various ways during the period November 2011–early 2014. Several members expressed interest in rekindling the Skype meetings. With neither funding nor administrative backing, this will need a champion and some drive on the part of that person to re-establish and maintain the practices and activities. It was attempted during the early part of 2014 but did not gain traction. However the number of projects requiring a way to contact community members is growing, which provides an impetus for maintaining the group and gathering new members.

Outside entities with relationships to ChemNet can affect the sustainability and strength of the community, and understanding how outside institutions influence the community is key to our continuance. These include Schools of Chemistry, the RACI Chemical Education division, the OLT and the ACDS TL centre. These entities are aware of ChemNet and support its existence. We also have relationships with the Science Teachers Associations in some states. These are very active CoPs, more developed and more active than at the tertiary level, and provide sources of bridging social capital (Preece 2004).

22.3 Outcomes of the Chemistry Discipline Network

Measurement of what has come out of a network is not trivial. Publications in the academic literature are valued by the university system, and several papers have resulted from ChemNet activities (Mitchell Crow et al. 2012; Schultz 2014; Schultz et al. 2013). In addition, reports to RACI and ACDS were made, and several articles were published in the RACI magazine (Lim 2013; Schultz 2013; Schultz and Mitchell Crow 2012) as well as one in HERDSA News (Schultz 2012a).

Examining the number of presentations at the UniServe/ACSME conferences longitudinally (Fig. 22.1), it can be seen that there is significantly more engagement with this important meeting since 2011 as the number of chemistry submissions jumps suddenly after the formation of ChemNet. This can be contrasted with the number of presentations at these conferences in physics over the same time period, which has remained static at between 7 and 11 presentations since 2005 with no trend. In addition, the proportion of female authors of chemistry abstracts has increased as shown in Fig. 22.1 (although the numbers prior to 2001 are so small as to make them statistically insignificant). Another example of the impact of ChemNet is that almost all Chemistry Education talks at the 2014 RACI Congress referred to or acknowledged ChemNet in some way.

An early, major activity run under the auspices of ChemNet was a July 2012 symposium held during the RACI Chemical Education Division conference in Adelaide. This symposium included both tertiary and secondary educators discussing standardised assessment, and a speaker was invited from the United States. Again because this was a face-to-face meeting, the connections formed and strengthened continued beyond the meeting itself. Collaborations are continuing as a result of that meeting including with overseas colleagues.

Teaching development other than publishing is difficult to quantify. The percentage of students passing a particular course may change with improved curriculum design or teaching methods, but this is difficult to control or to attribute to a single cause. Among the items shared informally at the Skype meetings were clicker questions that lead to a more active lecture environment, which should improve learning. In addition, discussion about how to introduce conceptually difficult topics may have led to improved teaching strategies among members. Further to this, principles of best practice in chemical representations for visualisation, developed and refined by two senior ChemNet members, have been disseminated through the group and presumably impact the teaching of those who were involved (Tasker 2014). The idea of translating research (our own and that of others) into practice permeated ChemNet, with frequent exchanges of published literature to promote good teaching. This is an example of the importance of weak ties within a diverse group in sharing useful information (Granovetter 1973).

One outcome of ChemNet is that all three OLT funded projects in chemistry since 2011 (Fig. 22.1) have had teams put together through ChemNet. The current large project "Assessing the assessments" is a direct continuation of the CTLO work from ChemNet and involves several members from the core of the CoP as well as others who were active members, already connected through strong ties to the lead applicant (Granovetter 1973). This project involves collecting exemplar assessment items and development of a tool to verify whether a particular assessment item demonstrates achievement of a particular CTLO. Team members are using weak ties within ChemNet to gather assessment items for this project. The smaller 2014 OLT Seed Project involves two core ChemNet members collecting and analysing pedagogical content knowledge, again making substantial use of their weak ties through ChemNet to organise meetings and gather data.

As we wrote in our final report, the Chemistry Discipline Network can be a mentor and matchmaker to people new to educational research. It includes a massive repository of experience in the members who are senior in the Australian chemical education community and who have been publishing in the SoTL for many years. For academics who are new to SoTL and for those who have already been working in the field, the Network has proved to be a way to generate fruitful discussions and to get to know people (in person and virtually). For example, the incoming president of the Chemistry Education Division of the RACI owes many of his ties to the community partly to ChemNet.

The Network also offers a central point of contact to the large group of Australian chemistry academics who are interested in improving their teaching. This group includes research-intensive and teaching focused academics at all levels. Using ChemNet as an organiser has allowed the process of elucidating the CTLOs to be inclusive and representative. ChemNet has been recognised both by the RACI and the ACDS as the key player in establishing standards and assessment of threshold learning outcomes, and helping develop new accreditation standards. It has significant bonding social capital (Preece 2004) through the shared values and goals of many members around improving chemistry education.

22.3.1 ChemNet as a Vehicle for Participation by Women

It is clear from the percentages given in Fig. 22.1 that women were poorly represented in funded chemistry projects until 2009, since when the proportion of women named on grants in chemistry education has increased markedly. The proportion of female chemistry academics in Australia is currently around 15 % (although this figure varies widely between institutions), so women are actually overrepresented in funding for chemistry education research compared to their representation in chemistry departments. This analysis is somewhat complicated by the fact that women are less likely to be research intensive with correspondingly reduced teaching loads, and are therefore more often found with heavy teaching loads, as has been reported for physics (Stevens-Kalceff et al. 2007) and other science faculties (Bailyn 2003). Women are also more likely to teach into service subjects and to large classes in the first half of the degree and are therefore less able to attract postgraduate research students, making educational research in some cases their only option (Stevens-Kalceff et al. 2007). Thus, the proportion of women involved in funded chemical education projects may reflect the proportion of teaching-intensive academic staff who are female, although much finer-grained data collection and analysis is required to verify this.

Examining the data in Figs. 22.2 and 22.3 as well as the numbers involved in the CTLO project shows that women have been heavily involved in ChemNet, constituting 30–50 % of participants in every activity, which is well above our representation within chemistry departments generally. The cross-disciplinary State PENs also involve a disproportionate number of women; in 2015, approximately 90 % of the people in the leadership groups are female. Thus, it seems that the Network structure is particularly appealing to involvement by women. It is difficult to explain this observation without resorting to gender stereotypes; perhaps it is because other avenues to academic leadership are closed to women (Bailyn 2003; Bell 2009; Stevens-Kalceff et al. 2007).

Given the persistent gap between academic status of men and women (Bell 2009), having a CoP that leads to traditionally recognised metrics including publications and grant success (particularly in Category 1) is a positive development. It is particularly heartening that the percentage of women on successful grants is now similar to the percentage of women presenting at ACSME (Fig. 22.1), correcting the previous imbalance that saw women not involved in nationally funded grants in spite of their engagement with the sub-discipline of chemistry education (seen in the years prior to 2009 in Fig. 22.1). Research indicates that mixed gender groups collaborate better (Bear and Woolley 2011) and produce higher-quality science (Campbell et al. 2013), so we hope that our gender mix has a positive effect on ChemNet outcomes as well as improving the careers of the women directly involved.

22.4 ChemNet as a Community of Practice

Wenger's indicators of progress focus on the socialisation aspects of learning leading to three dimensions of interaction within a CoP (Wenger 1998, 2000). These dimensions (or domains as described by Li et al. (2009)) are mutual engagement, joint enterprise and shared or common repertoire. ChemNet activities and outputs give evidence of these dimensions as follows:

1. Mutuality informs us of the depth of social capital in the community.
    a. Sustained mutual relationships: Relationships developed rapidly between members in Schools of Chemistry, or equivalent, which characteristically have few "teaching intensive" or "teaching focused" staff. These relationships, facilitated by the web, developed across the country. The network ensures these members interact informally and more often than just annually at conferences. In addition when they do attend a conference, they now have familiar faces to link up with.
    b. Rapid flow of information: the monthly email newsletter, maintained by one of the directors (MS), the monthly Skype meetings (minutes archived on website) and Twitter.
    c. Conversations and interactions are the continuation of an ongoing process, with members notably aware of bringing newcomers up to date.
    d. A shared discourse reflecting a certain perspective on the world: All members face considerable pressure in terms of workload, research—teaching balance, related career progression, related institutional support.
2. Joint enterprise is a measure of the "communal learning energy":

a. Shared ways of engaging in doing things together: Working parties, new projects, sharing of problems and possible solutions all exemplify the members working towards common goals.
b. Knowing what others know and how they can contribute: As individual members work and projects (inside or outside ChemNet) have become known in the network, others ask for their contributions or suggest their input to particular issues.
c. Mutual support: we have a common perspective as described above, and the most commonly reported value of ChemNet is mutual support in the face of multiple common issues and shared ideas of how to deal with some of them.
d. Projects carried out for the benefit of the community and the discipline as a whole, especially the Chemistry Threshold Learning Outcomes (CTLOs) and the snapshot mapping of chemistry subjects taught across twelve institutions.
e. ChemNet keeps learning at the centre of its enterprise by returning to the questions being asked by members and the challenges members face in their day-to-day teaching. This applies to both types of learning within ChemNet —the learning of our students, based on the learning of members as they improve the effectiveness of their teaching to aid student learning.

3. Shared repertoire (practice) which, as Wenger (2000) points out, is to be reflected upon as part of moving forwards:

   a. Specific tools, representations and other artefacts: There is a well-developed discipline specific pedagogy, and ChemNet members both use and take part in advancing that pedagogy. At the same time members develop their own understanding and usage of that pedagogy.
   b. The Chemistry Threshold Learning Outcomes (CTLOs), generated by the wider Chemistry community including core, active and peripheral members of ChemNet as well as some outsiders.

As we apply the CoP analysis to ChemNet, it is evident that it does not fit the "apprenticeship" model of situated learning (Cox 2005; Lave and Wenger 1991). A better description is a mentorship model. Mentoring has been described within CoP descriptions (Li et al. 2009; Wenger 2000) and a model for mentoring as the basis for a non-hierarchical CoP has been proposed (Smith et al. 2013). ChemNet is not recognisably hierarchical; rather those with experience or expertise in certain areas are known and take part on an equal social footing, with no loss of respect or recognition for their contribution. Social learning occurs informally, usually when one member asks the group for guidance and is connected via weak ties to someone with experience in that particular area of the discipline or other information required.

The knowledge shared within ChemNet can be categorised on the basis of content: discipline specific pedagogical content knowledge, more generic TandL knowledge, practical knowledge about organisational and administrative aspects of tertiary teaching and education research, and sector-wide knowledge (for example, current federal policy). In all of these categories, we find both explicit and tacit

Table 22.2 Comparison of tacit with explicit knowledge (adapted from Daniel et al. 2003)

Tacit knowledge	Explicit knowledge
Drawn from experience and the most powerful form of knowledge	Can become obsolete quickly
Difficult to articulate formally	Can be formally articulated, processed and stored
Difficult to communicate and share	Easily communicated and shared
Includes privately held insights, feelings, culture and values	Can be copied and imitated easily
Shared only when individuals are willing to engage in social interaction	Can be transmitted

knowledge. Daniel et al. (2003) provide a very useful comparison of these two types of knowledge, illustrating their dichotomy, shown in Table 22.2.

The very personal nature of tacit knowledge means it cannot be passed on without contact and rich communication. Thus, transmission of tacit knowledge necessarily occurs in informal settings where exchanges are close and personal, characteristic of CoPs in a mentoring environment. The sharing of valuable tacit experiential knowledge by more experienced chemistry educators with others in the network is the most important outcome of ChemNet and illustrates the powerful social capital generated in the network.

A flexible way to reflect on the value of a CoP is through narrative. Wenger et al. (2011) distinguish two types of narratives: ground narratives which describe the events, activities and interactions of the CoP, and aspirational narratives that describe what the CoP should be. They write

> …the tension between these two narratives creates a space for learning and for deciding what is worth learning. We locate the assessment and promotion of value creation through social learning in the space between the everyday and aspirational narratives. (p. 17)

We find evidence of a successful CoP both in analysis of activities and outcomes and also in the narratives of members reflecting on their experiences of connections made, projects begun, learning materials and practices shared, opinions garnered. We specifically collected narrative reflections from eight ChemNet members ranging from early- through mid- to late-career academics. Many informal comments and observations also indicate a successful and productive community.

The success of the communications put in place is especially illustrated by commentary of members. New entrants to chemistry education who were appointed in teaching focused positions reported that they benefitted greatly because the formation of ChemNet was timely and they quickly made weak and strong ties across the country including introductions to "big names" in the Australian Chemistry education community. Members more established in the chemistry education community reflected on the support and encouragement given to new entrants. Participation in the informal Skype meetings meant that when members new to the chemistry education community did attend a conference or other gathering, they found entering the gathering much more relaxed because familiar faces or voices were present and that easy introductions to others followed.

Generally within face-to-face and online conversations, all members reported that the informality broke down barriers between the newcomers and the old hands and encouraged contributions because opinions were perceived to be valued. Members reported it was very useful to know what others were doing, where the informality permitted airing of problems and discussion of possible solutions. The supportive environment was appreciated and contrasted with the less supportive environment in other sub-disciplines of chemistry.

Informal conversations on chemistry education and general education issues allowed members to develop their understanding of the theories and pedagogy behind the practice. In relaxed multi-faceted discussions, newer members could pick up various aspects of particular concepts where those with more experience offered comments nuanced by their experiences as well as references to important literature in the area. This helped members feel less intimidated by the difficulties of entering the field of education theory and illustrates the trust generated within the CoP (Preece 2004).

Wenger et al. (2011) also provide a useful tool for assessing the value created by the CoP to members and beyond. This tool provides an excellent framework for quantitatively and qualitatively assessing a community's activities, outcomes and outputs. This appraisal is done via five cycles,

1. Immediate value: activities and interactions.
2. Potential value: knowledge capital, yet to be realised, and including personal assets (skills, ideas, abilities), relationships and connections, resources, collective intangible assets such as reputation and status, transformed ability to learn.
3. Applied value: changes in practice
4. Realised value: improved performance
5. Reframing value or redefining success.

Examples of the first four of these cycles are already apparent in the outcomes of ChemNet activities, although we have not enumerated them in detail. The activities described, the quantitative data reported above and the narrative supporting that data all point to the value created by ChemNet for the members and the Chemistry discipline community as a whole. In addition, the impact of our activities extends further via the ACDS and SaMnet. The value created within the ChemNet sphere of influence reflects the potential of CoPs explored in an academic setting by (Sánchez-Cardona et al. 2012). In addition, ChemNet satisfies the 10 'commandments' of a successful CoP developed in a business context (Probst and Borzillo 2008), and importantly does not fulfil any of the rules that lead to failure of a CoP. The significant social capital generated by ChemNet is directly related to its success as a CoP (Abou-Zeid 2007).

It is instructive to view the past 3 years in terms of activities and aspirations—what did we do, what did we intend and how these changed along the way. Among our intentions that did not translate into reality were that we planned and built a website for sharing planned grant applications, teaching resources and general discussion, but ultimately the website was not used except for accessible storage of communication items and reports. A further example of an aspiration that did not translate is that although the working parties were established, by and large the work was not completed by the parties but by individuals. Consultation with the group was sought but the vision of teams working together on the projects completed by ChemNet did not eventuate. In addition, we planned to share assessment items for benchmarking and quality assurance. However, although eight people expressed interest, only three members shared their examination papers from first semester chemistry, so this aspect of the project stalled.

Looking across the CoP elements that Wenger (2000) recommend as "doable" (p. 320), it is evident that ChemNet has acted successfully upon all six. In addition to our outcomes demonstrating events held, connectivity established, membership raised, projects and artefacts in place that we have described, we can also reflect on the leadership developed. The authors of this chapter are co-directors of the Network and have both benefited from the leadership opportunities of the Network. One of us (GOB) also organised and co-directed the CTLO meetings, through which she has expanded her leadership skills and is recognised within the community as a leader. In addition others have come forward in leadership roles from time to time to carry forward particular activities. As co-directors we aim to recognise and encourage members to similarly lead possible projects or activities to help sustain ChemNet.

22.5 The Future of ChemNet and Reflections for Practice

Activity within ChemNet is at a low ebb as we write in early 2015. The current OLT projects based in the discipline of chemistry need the network to provide access to the chemistry education community. However, the driver for action in these cases lies within the project rather than the network. This may indicate that, at the moment, the most valuable ChemNet activities are maintaining and developing the informal and supportive communication channels and maintaining weak ties. The listed outcomes dependent on informal contacts and the narrative from members provide the evidence that this is important and draws members in. As a community of learning, it is within this social context that members advance their own knowledge and expertise in chemistry education. It could be argued that because the social support network appears of primary importance and the learning secondary, we are more like a simple support network. However, the outcomes certainly show that we have much grown and enhanced the community knowledge (for example through the CTLOs) as well as that of individuals informing their own practice. Indeed it would be difficult to disentangle the supportive communications aspect from the learning or expertise development.

Pharo et al. (2014) make relevant points for a science based CoP. Their circumstances, involving the creation of a series of CoPs within institutions but linked together, are different to ChemNet, but their suggestions for conditions of success are pertinent. One such condition is "link participation to a common desire for particular outcomes" (p. 352). This may elucidate the reason for inactivity in ChemNet. One major activity, articulation of the CTLOs, has passed on into other hands, while others such as the mapping exercise have concluded. Perhaps there is a need for a distinct new activity to drive a new round of engagement.

This provides an important direction for the future. It is worth significant effort to rekindle informal meetings and discussions to sustain connections. It may be possible to enhance these discussions in real time meetings by advancing our use of technology for asynchronous communications that is more appealing than a website with log in and password. It may be useful to also promote smaller group collaborations for a specific project or topic over a specific time period. Such groups could form part of a strengthened critical mass to sustain ChemNet. Maintaining such small groups within the CoP as a whole will require commitment and understanding on the part of participants and ChemNet leadership, to avoid splintering and to promote overall growth of the CoP. This dichotomy of outcomes is shown diagrammatically in Fig. 22.5.

Clearly the right hand path is the desired direction. Finding activities or new learning valuable and relevant to ChemNet members needs consideration. This fits with Wenger's (2000) imperative to maintain the learning energy.

One of the key issues highlighted throughout the literature concerns the core group or leading members (Pharo et al. 2014; Probst and Borzillo 2008; Wenger et al. 2002). An issue for those still concerned with maintaining and building ChemNet is lack of time and the need to find ways of engaging other members to commit to more active participation and driving of certain activities. From the substantial literature of CoPs used as a tool for knowledge management in the business world, it is plain that the company or organization has reason to support the CoP, as part of maintenance and building of the corporate knowledge base (Borzillo et al. 2011; Probst and Borzillo 2008). In contrast ChemNet, like many other CoPs based in the tertiary education sector in Australia, has no external support from a larger organization, no external managerial drive, and no funding or

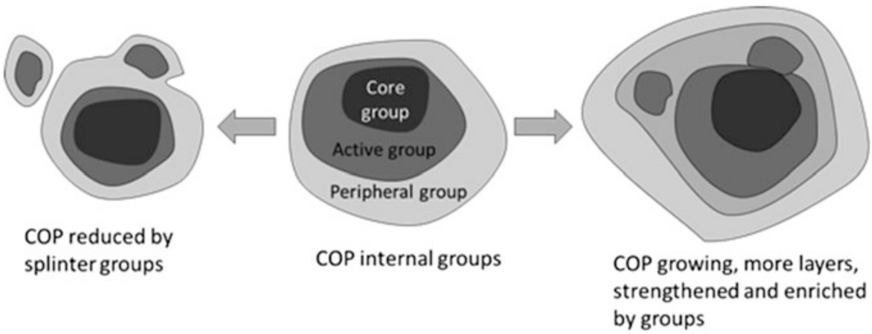

Fig. 22.5 Possible outcomes of growth and development of CoPs

recognition in workload, so it must be self-driving, self-motivated and self-rewarding.

We expect the mutual support and mentoring via informal communication to become more important over the next few years for teaching focused chemistry academics. The Australian Higher Education sector faces considerable uncertainty, pressures from which will impact highly on learning and teaching. With ChemNet as a strong and self-sustaining CoP, teaching staff will find support for maintaining standards and leading developments in both discipline and service teaching. ChemNet provides an invaluable resource in facilitating mentoring for chemistry academics.

Although the term community of practice is somewhat ill defined (Li et al. 2009), this is not a disadvantage but the beauty of the concept. It is open to subtle interpretation, thus allowing consideration of various groups as we have done, to interpret their strengths and weaknesses and to illuminate possible future paths and activities to ensure the long-term sustainability of the network.

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