Australian Journal of Teacher Education

Volume 44 | Issue 7 Article 5

2019

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Recommended Citation

Fraser, S. P., Beswick, K., Penson, M., Seen, A., & Whannell, R. (2019). Cross Faculty Collaboration in the Development of an Integrated Mathematics and Science Initial Teacher Education Program. *Australian Journal of Teacher Education, 44*(7).
http://dx.doi.org/10.14221/ajte.2019v44n7.5

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Abstract: This paper describes a collaborative project involving mathematicians, scientists and educators at an Australian university where an innovative initial teacher education (ITE) degree in mathematics/science was developed. The theoretical frameworks of identity theory and academic brokerage and their use in understanding the challenges associated with the early stages of collaborative projects is described. Data from reflections and interviews of the participants after involvement in the project from one to three years are presented to illustrate these challenges. The paper concludes with a description of the importance of the academic broker in overcoming identity challenges and facilitating cultural change for academics involved in cross-disciplinary collaborations and the time and resource requirements to achieve a successful outcome.

Introduction

Australia, along with many other countries, has experienced a persistent decline in participation in post-compulsory mathematics and science in schools and universities (Ainley, Kos & Nicholas, 2008; Thomas, Muchatuta & Wood, 2009). This trend reduces Australia's research and development capacity in the physical, biological and social sciences, technology, business and industry (Chubb, 2012), and also limits the supply of graduates who are qualified to teach science and mathematics in secondary schools (Marginson, Tytler, Freeman & Roberts, 2013).

In 2014, a 3-year project, Inspiring Mathematics and Science in Teacher Education (IMSITE), was funded by the Office for Learning and Teaching (OLT). The collaboration of six Australian universities aimed to foster collaboration between the mathematicians, scientists, and mathematics/science teacher educators in order to better prepare teachers of secondary school mathematics and science. It considered innovative ways of integrating the content expertise of mathematicians and scientists, and Pedagogical Content Knowledge (PCK) of science and mathematics teacher educators. A range of initiatives were undertaken across the participating universities. All initiatives depended to a greater or lesser extent upon cross-faculty and cross-university collaboration for their collective outputs.

In this paper we describe the initiative of one university that participated in the larger IMSITE project. It relied upon the collaboration of academics from the science, mathematics and education organisational units during the development and implementation of a new and

innovative 4-year ITE degree, the Bachelor of Education (BEd) (Science and Mathematics). Within this course, students engage with mathematics and science content units, simultaneously with the study of pedagogy and science/mathematics PCK units, as they prepare to teach in secondary schools. Through the use of the theoretical frameworks of academic identity and brokerage, the paper describes the way the project leaders made sense of, and sought to understand the challenges, that underpin any collaboration between members of different academic disciplines. Project leaders and discipline collaborators responded to questions designed to prompt reflection during the project, and these reflections and interviews form the data referred to here. These data demonstrate the continued existence of identity and communication challenges 12 months from the commencement of IMSITE, and after 3 years of collaborative effort. We use identity theory and the concept of academic brokerage to interrogate the data. The paper concludes with a discussion of the implications for practice that relies upon multi-disciplinary collaborations and the importance of the academic broker role in progressing the IMSITE project.

The Need for Collaboration

Historically, in Australian tertiary education, there have been two approaches to the initial education of secondary science and mathematics teachers. The first, involves students completing a 3-year undergraduate science and/or mathematics program of study that results in the award of a degree, e.g. Bachelor of Science, followed by a shorter postgraduate qualification in education; usually a Masters of Teaching of 2 years duration. A second, less common model also exists, where students study dual degrees concurrently, that is a mathematics or science undergraduate degree is completed at the same time as an undergraduate education degree. Both of these approaches involve the completion of independent qualifications, with little or no overlap of content or assessment between the two degrees.

During mid-2014 until late-2017, scientists and mathematicians, mainly from a chemistry, physics or biology background, and science and mathematics educators, worked in a collaborative project team on the development of the BEd (Science and Mathematics) in order to contribute to a third model of ITE. The course was designed to enable prospective science and mathematics teachers to make links between their discipline content, pedagogy and PCK units. The creation of the course structure relied upon the expertise, leadership and collaboration of academics from diverse disciplinary research and teaching backgrounds to ensure an effective course scope and sequence which would also qualify for accreditation through the national body, the Australian Institute for Teaching and School Leadership (AITSL). Participating academics collaborated from the beginning and throughout the project in the design of the qualification, the writing of units and assessment, and the delivery of units - a process which remains ongoing.

Academic Cultures

Although it might be thought that academics from science/mathematics disciplines, and science/mathematics education, working within the same university would share a relatively common background in terms of their study and life experiences, research has found that this may not be the case. A study conducted in 2008 (Bush, Pelaez, Rudd, Stevens, Tanner & Williams) investigating the experiences of discipline education specialists employed within science faculties at the University of California established that 95% of the

science education academics hired for the purpose of improving the quality of teaching and learning were considering leaving their current positions. The primary reason offered for this consideration was that "their science education efforts were not valued or understood" by discipline experts in the faculty (Bush, Pelaez, Rudd, Stevens, Tanner & Williams, 2008, p. 1796). The impact of disciplinary status has been identified in other studies, with Amey and Brown (2004, p. 2) describing interdisciplinary collaborations as "most often characterized by dominance of a single disciplinary change paradigm, mixed perceptions of improvement or goal attainment, and poorly resolved group tension". Even within interdisciplinary research collaborations between scientists, the collaboration process has been described as a "risky undertaking as it challenges prevailing organization, social and political structures and traditions" (Gardner, 2013, p. 250). Gardner (2014, p. 70) further argued that the challenges to collaboration arise from "issues involving disciplinary status, power and hierarchy". Earlier research conducted by Franks, Dale, Hindmarsh, Fellows, Buckridge and Cybinski (2007) resonates with these conclusions. They identified that associated with disciplinary status and power, failure to acknowledge interdisciplinary success stories was also a barrier to collaboration.

These studies point to a cultural divide both between closely related disciplines (i.e. among science disciplines), and between academics who conduct research in their discipline and those who research the education of the same discipline. It is also apparent that there is a cultural divide between these closely related disciplines, even within a single university. The divide appears to exist at a variety of levels, including at the institutional level where institutional leaders must provide the funds and resources to support collaboration (Pharo et al., 2012), encourage a supportive culture to complement collaborative priorities and goals (Harris, 2010), and encourage changes in work practices in the institutional culture related to interdisciplinary endeavours (Holley, 2009). The different academic disciplines within a single university appear to be separate communities of practice, each with its own values, beliefs and (academic) identity (Wenger, 1998).

Identity and the Academic Identity

Our identity is thought to change in the context of our past, present and future experiences (Geijsel & Meijers, 2005); it is dynamic and influences the way in which we manage both our personal and working lives (Henkel, 2000). Proponents of identity theory (Burke, 2006; Gee, 2001; Stryker & Burke, 2000; Terry, Hogg & White, 1999) have argued that each individual possesses a number of identities that reflect the roles that the person plays within their social context. These roles may or may not be complementary, depending on the individual's particular situation. Stryker and Burke (2000) argued that where an individual's identities or roles do not complement each other, competition and conflict arises such that the person may question their commitment, identity, and self-perceptions in particular situations. Burke (2006, p. 93) described a "dynamic view of identities as always changing (though slowly) in response to the exigencies of the situation. Insofar as an identity cannot change the situation…it adapts slowly, gaining control where it can, and adapting where it must".

Similarly, what is referred to as an academic identity is not seen as fixed, but rather dynamic, changing and evolving over time in response to university and external changes (Clegg, 2008). Lingard, Schryer, Spafford & Campbell (2007) described the situation of a research team that collaborated over a 5-year period as characterized by tensions that arose from the researchers' multiple identities. They proposed that, where university researchers work in multidisciplinary teams, each researcher may experience frustration and a feeling of

being alien, not yet belonging to the multidisciplinary research team, and no longer feeling as belonging to their scholarly discipline. These findings describe the potential for angst when the individual is required to make a psychological movement, from a position where identity is familiar and known, to an identity which is, perhaps, unfamiliar and may not at the outset be understood or valued. However, Lingard, Schryer, Spafford and Campbell (2007) argued that when the associated emotions arise they should not be ignored, but rather be made explicit and support provided appropriately, because it is at this point that true breakthroughs may occur.

Academic Identity and its Relationship to Emotions and Behaviour

Identity is connected with emotions and long-term behavior. Based on the work of Burke (2006), Burke and Reitzes (1981), and Stets and Serpe (2006), the relationship between identity, the role associated with that identity, and emotions that may arise can be modelled as shown in Figure 1. In this model, Whannell and Whannell (2015) highlighted identity as the driver of ongoing behaviours, based upon the individual's understanding of the role that is associated with a particular identity. The manner of performance of this role gives rise to short-term emotional responses, both positive and negative, which in turn influence the emotional commitment to the identity. This process is represented cyclically to illustrate the dynamic nature of identity. Whannell and Whannell (2015) posited that social context is key as it influences all aspects of the process.

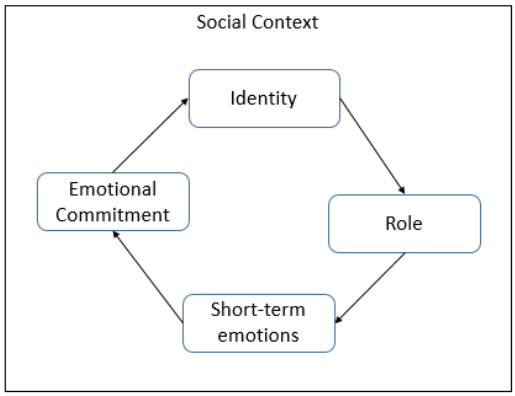

Figure 1: Model of the relationship between identity, role, and emotions, taken from Whannell and Whannell (2015)

The examination of identity, and its associations with emotions and role, suggest a number of possible challenges that might arise for scientists, mathematicians and educators engaged in collaboration in the development of a teaching and learning program such as that being described in this paper.

Academic Identity and Challenges for Cross-Disciplinary Collaboration

In recent decades, universities have experienced massification, whereby the system has expanded to cater for increasing numbers of students (Dobson, 2001). This has resulted in significant changes and challenges in higher education, with the expectation that universities produce graduates who are job ready. At the same time there has been an increasing focus on excellence in research, and increasing accountability aimed at ensuring university learning and teaching meets expected quality standards (Giannakis and Bullivant, 2015; Smeby,

2003). Academic identities and work roles have, therefore, had to evolve as institutional expectations have evolved.

In the 'new' universities (i.e. those universities that were previously focused on professional education) there is an expectation that teaching-focused academics become research active, whilst at the research-intensive universities, academics are expected to increase the quality and quantity of their teaching and research. In their work at a Dutch 'new' university, van Winkel, van der Rijst, Poell and van Driel (2017, p. 6) identified six identities ("continuous learner", "disciplinary expert", "skilled researcher", "evidence-based teacher", "guardian of the research work process", "liaison officer") which reflected the academics' personal scholarly objectives in the context of university expectations.

Because of this, academics, even within the same discipline may have diverse identities. This diversity of identities and the differing personal aspirations to which they lead, must be acknowledged when academics are brought together in any collaborative endeavour. In particular, academics from different disciplines may be more inclined to adopt particular identities from among those identified by van Winkel, van der Rijst, Poell and van Driel (2017) as a result of differing discipline expectations for research and teaching.

Tensions may also exist between teaching and research within many universities as university rankings and funding are heavily associated with research outputs. Within research-intensive universities, for example, the development of an academic's identity as a teacher can be at odds with the institutional focus on research outputs. Despite the fact that a wide range of initiatives have been introduced to promote teaching in these contexts "…these initiatives have met with limited success in terms of changing predominant values and culture" (Skelton, 2013, p. 23). As academics take their lead from institutional priorities and values, it is not surprising that there is resistance to change. Jain, George and Maltarich (2007) reported that even research-active academics, challenged to engage in commercialisation activities, resist a role change and only modify their identity, prioritising their existing research identity and minimally developing an identity associated with commercialisation.

In a recent review of the literature on 'teacher identity' of university academics, van Lankveld, Schoonenboom, Volman, Croiset and Beishuizen (2017, p. 328) indicated that its development "…during the transition to teaching proceeds differently for teachers who entered university from a professional background (e.g., music, nursing, primary education) than for those making the transition from PhD student to lecturer". Van Lankveld, Schoonenboom, Volman, Croiset and Beishuizen also found that participation in staff development programmes alongside contact with students assisted academics to develop their teacher identity, while a 'neoliberal management culture' and teaching – research tensions constrained its development. Even in a research-intensive university, providing academics with a supportive environment in which to develop their teacher identity has been found to have positive outcomes for teaching and potentially student learning, as their "teacher identity develops through dynamic interaction between a reflection of teaching practice and a deepening knowledge of theoretical pedagogical constructs" (Nevgi & Löfström, 2015, p. 53).

Because identity changes slowly (Burke, 2006), efforts required to incorporate changes in academics' practice that will be evidenced in long-term behavior must be continued for a substantial period of time. Targeted interventions must also be appropriately resourced, emotionally supported, and publicly recognised. In the case of the IMSITE project and its collaborative development of the BEd (Science and Mathematics), this meant a continuance of the cross disciplinary efforts in everyday behaviour and beyond the availability of funding as recommended by Pharo et al. (2012). In the absence of such efforts, little long-term change is likely in either the identities of the academics or their understanding

of their associated roles in cross disciplinary activity and/or engagement. In this circumstance the individual is likely to return to his/her original identity and role performance such that continued involvement in collaborative activities ceases and the benefits to the individual and the organisation are lost.

The change to online and blended delivery by educational institutions worldwide has been growing, in part due to its potential to provide student-centred, inclusive and equitable education for all (Garrison & Kanuka, 2004). Moving from a traditional to a blended approach to providing education, however, is not always easy. A study of the transition to blended delivery at the University of Glasgow identified time management, reduced face-to-face contact, technical issues and quality of learning materials as challenges for students, whilst staff conservatism, workload issues and digital literacies were the challenges identified by staff (Adekola, Dale, & Gardiner, 2017). As has been described previously, significant changes to both the development of educational outputs and academic teacher identity do not always occur, due to a variety of challenges, particularly those related to emotions that manifest within the individuals, when involved in the collaborative endeavour.

The Academic Broker

The model of identity construction, which has been described to this point and illustrated in Figure 1, highlights the importance of social relationships in the development of identity and its associated role(s), and in the drivers and emotional responses that arise in relation to role performance. Although the model describes the process of identity and role development for an individual, for us to understand how an individual with a well-defined academic identity within a particular discipline is able to participate successfully within an interdisciplinary collaboration required us to access other theoretical notions, and particularly that of academic broker.

Burt (2005, p. 3) informed our understanding of social interactions, through his consideration of organisational networks which he defined as comprising "clusters of dense connections linked by occasional bridge relations between clusters" where connections signify exchanges of information or knowledge. He argued that communication within networks is hindered by the existence of structural holes – that is, clusters of actors between which there are no connections – within these communication networks, which reduce the flow of information and impede work performance and output from the organisation. Burt (2005, p. 9) posited the notion of brokerage was a way of addressing such holes, defining it as "the action of coordinating across the hole with bridges between people on opposite sides of the hole, and … brokers, are the people who build the bridges". Fleming, Mingo & Chen (2007, p. 443) defined the broker as someone who "occupies the sole intermediate position between others, such that others can interact only through the broker". Such people display crucial characteristics, "(a) they bridge a gap in social structure and (b) they help goods, information, opportunities, or knowledge flow across that gap" (Stovel & Shaw, 2012, p. 141). It is important to note at this point that a broker plays more than a purely social role in facilitating improved communication. The role requires the enhancement of the flow of the relevant factor(s), for example information or goods, which will result in enhanced functioning and output from the organization (Haas, 2015).

There are a number of different types of broker described in the literature. One is a knowledge broker described as "an actor who uses his/her in-between vantage position to support innovation through connecting, recombining and transferring to new contexts otherwise disconnected pools of ideas" (Burgess & Currie, 2013, p. S132). A knowledge broker belongs to multiple groups and can thereby facilitate the exchange of information

between them (Haas, 2015). Brokers are also positioned to use their membership of multiple groups to promote innovation because they have access to ideas from otherwise disconnected groups and can see ways in which they can be through connected, recombined or transferred from one context to another (Burgess & Currie, 2013, p. S132). Where knowledge is shared across boundaries within the collaboration, substantial improvements in work performance have been achieved (Di Marco, Taylor & Alin, 2010).

The term 'cultural brokerage' is generally used to describe brokerage situations which involve people of different ethnic cultures in a variety of contexts (Kitchen, Cherubini, Trudeau & Hodson, 2009; Lo, 2010). The ability to undertake cultural brokerage requires cultural competence, which has been defined in part, as "the mutual inclusion of seemingly incongruent sets of schemas or orientations with which people organize their meanings and information" (Lo, 2010, p.7). It can also be seen as "the act of bridging, linking, or mediating between groups or persons of differing cultural backgrounds, for the purpose of reducing conflict or producing change" (Jack, Hlombe & Mars, 2014, p.15). Cultural differences within a collaborative team represents a "boundary that needs to be spanned in order to increase understanding and team performance" (Long, Cunningham & Braithwaite, 2013, p.9). Although university academics from different disciplines may or may not be separated by ethnic boundaries, they do differ in terms of their discipline cultures and the associated schemas, values and beliefs, which means that the brokerage that is required, draws upon more than simply knowledge brokerage.

In a multi-disciplinary collaboration within a university, an academic broker, or brokers, needs to exercise both knowledge and cultural brokerage roles.

Cultural Divides and the Process of Cross-Disciplinary Collaboration

In this section we describe relevant aspects of the context in which the BEd (Science and Mathematics) was developed and then present data that illustrates the impacts of academic identities and cultures on the collaboration, and the role played by brokers in its facilitation.

The Collaborative Context of the Study

The University of Tasmania where this study occurred is a medium sized Australian university that operates across three campuses. The Faculty of Education has a presence on all three but is based in Launceston, whereas the Faculty of Science, Engineering and Technology (SET) is predominantly based in Hobart. The Australian Maritime College (AMC), where some of the participating mathematics and science academics worked operates only in Launceston. The three academic leaders of the project – a science educator, mathematics educator and chemist – were all located in Launceston. Other participants from both Education and SET were located in Hobart.

The collaboration thus involved the engagement of multiple groups of scientists, mathematicians and education discipline experts. These clusters were also comprised of further divisions based on disciplines and geography, for example, between the biological sciences and the physical sciences. Some bridges already existed between these groups due to the members working within the same university. Those on the same campus were in relatively close physical proximity that may have facilitated chance encounters. In other instances, connections had been made due to involvement in the same work activity. For example, one of the science academics and the science education academic had served or

were serving as Associate Dean (Learning and Teaching) in their respective faculties. The fact that one of the mathematics education academics and the science education academic had PhDs in mathematics and science rather than in mathematics education or science education facilitated their understanding of the culture of the mathematics and science disciplines. One of the science academics had also been involved in professional learning for science teachers and had collaborated with science education academics to this end.

Sharing knowledge across these groups was essential to the development of a high quality program, and to ensure that the units making up the course were consistent with the delivery options for other BEd courses, which are offered to both on-campus, and off-campus students. This required the team to create a course, which enabled blended delivery, that is, online delivery of theoretical content, complemented with intensive on-campus practical components where necessary. Through such collaboration and sharing of knowledge, it was expected that high quality units demonstrating clear and valid science and mathematical content and concepts combined with current, high quality educational theory and pedagogy would maximise the educational outcomes for students. The new course required that science and mathematics academics changed their mode of delivery of their units from exclusively face-to-face to blended delivery. The process was viewed as an opportunity by the science and mathematics faculty management team as a catalyst for more widespread change to increased flexible delivery of courses.

Together, knowledge and cultural brokerage, and identity theory, appeared to provide a useful lens through which to understand the processes involved in multi-disciplinary collaboration within a single university.

Evidence of Cultural Tensions, Identity Shifts and Brokerage Activity

In order to explore how, and the extent to which, knowledge and cultural brokerage, and change or enhancement of individual academic identity contributed to the processes involved in multi-disciplinary collaboration, the academics involved in leading the project and/or in the development of units for the course, were asked to reflect on a set of prompts and respond by email, along with an interview which used a different set of prompts, during the course of the project.

The reflective activity was undertaken twice over the course of the project, in May 2015 and October 2017. In both instances participants were provided with the following prompts for reflection, adapted to their specific discipline, and email responses were sought.

- What aspects of the project are in your current thinking and why?
- As an academic in the Faculty of [participant's discipline area] what have you learned recently about [other disciplinary areas] as a discipline area?
- What value do you see in working with colleagues in the Faculty of [other disciplinary areas]?
- What in your experience are the main barriers to working with colleagues in the Faculty of [other disciplinary areas]?
- What could make it easier to work with colleagues in the Faculty [other disciplinary areas]?
- What has contributed to and what is contributing to the effective working of the project team?

Participants were also invited to make comments about their experience in the project up to that time. Responses were received from seven academics in May 2015 (three science/mathematics educators, two scientists, and two mathematicians) and six academics in October 2017 (two science/mathematics educators, three scientists, and one mathematician).

The comments are identified with the prefixes ED, SC or MA to indicate the academic discipline of the science/mathematics educator academics, science academics and mathematics academics, respectively, with the same identifiers used across both reflective activities and the interviews.

Interviews were conducted in April 2016 with 10 science, mathematics and education academics (one science/mathematics educator, seven scientists, and two mathematicians) and the project manager using the prompts below.

- The scope at which a participant (list provided of participants involved in the project) may have been involved could be described as follows:
  - Peripheral involvement in collaboration
  - Development of a specific course unit
  - Involvement across a single discipline e.g. across maths, science OR education.
  - Involvement across all disciplines
- How would you describe your involvement in the project so far?
- Considering the list from prompt 1, who would you go to if you had a question about the project that you wanted answered? Also nominate what the question would be about.
- What do you think have been the strengths of the collaboration in the development of the Bachelor of Education (Science and Mathematics)?
- What do you think have been the challenges involved in the collaboration up to this point?
- How have these challenges been overcome?
- What gaps do you think still exist within the collaborative structure for the project?
- Why do you think these gaps still exist?
- What do you think still needs to be done to improve the collaboration process so that the degree program includes the integrated science, mathematics and education approach that is intended?
- Is there anything else that you would like to say at this time about your involvement in the collaboration?

Phase 1: May 2015 Reflective Data Generation

In May 2015, after the project had been running for 12 months, a number of comments were made that indicated that the divisions between the different academic disciplines, described previously in relation to identity and culture, were still evident after 12 months of working together, and that ongoing efforts were required to bridge cultural divides; as an education academic described:

> *I think there is goodwill amongst the group, but a certain naivety about the time it takes to redevelop curriculum for online delivery. I am also very interested in ensuring that each 'silo' of the course maintains communication and actually explicitly refers to the learning that is being undertaken in each others' units. I don't want the course to become a double degree. (ED1)*

Rather than a focus on social or communication bridges that we expected would have been required for effective collaboration, the challenge highlighted by both education and science academics related to bridging disciplinary boundaries:

> *We have made progress on developing cross-disciplinary relationships but less on how we might be involved in each others' units within the project period, let alone beyond. How will we maintain the coherence of the BEd secondary and*

prevent it degenerating into the more usual model of joint degrees where the education and science elements do not articulate at all. (ED2)
I think we have worked well together to "collaboratively" develop the BEd, but to be honest I think it is still a degree of 2 halves - Education and Maths/Science. It is not so much what I have learnt about Science Education and/or Mathematics Education as disciplines, but the fact that we are still struggling to bridge the gap between Education and Maths/Science disciplines. (SC2)

These quotations illustrate that, although the participants had managed to achieve a measure of trust and developed a relationship across disciplinary boundaries, the relationship was not sufficiently strong to allow for the merging of academic practice in an integrated and ongoing way, highlighting their concerns about not achieving the shared goal of a coherent course structure.

Even though the project had been running for 12 months at the time that these data were generated, a number of comments were made that identified continuing communication challenges. Of particular relevance was the recognition that to bridge structural holes within the organisation, the academic broker(s) must take a proactive approach, as one education academic reported:

We need to maintain our lines of communication and help proactively rather than waiting for them to ask and that is what we are doing at the moment. (ED1)

One participant highlighted the potential for university level culture to interfere with the goals of the collaboration, specifically the ways in which the university rewarded teaching endeavours (e.g., through which school the individual units are delivered and financed):

A potential impediment is perceived ownership of the degree (and this does not necessarily mean by project members) (SC2)

Phase 2: April 2016 Interview Data Generation

A further 12 months on in April 2016 it was apparent from interviews that facilitated interactions between science, mathematics and education academics were appreciated by staff, with comments such as:

It was just quite enjoyable to be able to talk with colleagues who are in the same boat and just hear their opinions on things or get feedback. ... I found it overall, after a bit of an initial fear, an enjoyable process overall. (MA2)
... as scientists, we're not education people, understanding how the education units and the science units should kind of connect; we wouldn't be able to understand that if we hadn't had those meetings through the project. (SC7)

And science and mathematics academics felt at ease to progress at their own pace:

... I think what they've done a particularly good job of is basically bringing people along at their own pace and being encouraging and supportive, rather than demanding and requiring people to do it. So, there's a fair bit of flexibility in what we're allowed to do. (SC8)

The project manager role was regarded as an important role for project management, and at least one academic broker was identified with a critical role in engaging science and mathematics academics in the project:

If it was just the mechanics of what's being done and how things are to be done, the running of the project, it would be [project manager name], the project manager. If it was actually more conceptual and theoretical about why are we doing what we're doing and how does everything fit together, it would be

certainly [academic broker name] would be the first one. … I know her the most and she's pretty heavily invested in this process. … the other thing that she has, of course, is a science degree. So she's actually a good person to straddle that gap. (SC6)

So there's been lots of different models, but there's never been an integrated model that brings in the aspects of what's being done currently in education, and then brings together the aspects as what's being done in science … so that's something that [academic broker name] has been able to bring to this project that other people would not have been able to bring to this project (MA3)

Phase 3: October 2017 Reflective Data Generation

After three years of the project running, in October 2017, the academics involved in the project were again asked to reflect on the reflective prompts. Much progress had been made in the development and implementation of the BEd (Science and Mathematics) since the time of the first round of reflection, with chemistry, physics and mathematics units having moved into a blended delivery mode to facilitate delivery to off-campus students. Science and mathematics staff viewed the development of the BEd (Science and Mathematics) as a catalyst for change, and participants were pleased with this:

I have been pretty pleased with how [unit name] went being moved into blended mode. Our next challenge is to take what we learned from that and roll it out across other units. (MA2)

… it was a catalyst to how we deliver a flexible degree program to all students in Chemistry. … the cohort of students in the BEd is only a very small percentage but we have considered more widely how can we deliver flexible programs to all Chemistry students. (SC3)

While the goal of changing unit delivery was to facilitate enrolment by off-campus students, science academics perceived there to be potential benefits for on-campus students:

It is not clear if there is a correlation to providing the extra on-line materials but student feedback for these has been very positive (SC3)

However, while progress had been made with the development of blended units in chemistry, physics and mathematics, concerns about the sustainability of the degree post-project were raised by one science academic:

Ensuring that we have a coherent and viable suite of science units available for the students in off-campus mode, particularly the biology units. (SC2)

The reference to biology units in this quotation, related to uncertainties at that time, regarding the future of these units due to institutional restructuring and reluctance of academics to commit to the extra work in developing the blended delivery mode.

Participants were in no doubt, however, that collaboration had increased across the disciplinary boundaries as a result of the project, with staff reflecting on the value they saw in working with staff across the education and science/mathematics faculties. Education staff were aware of, and grateful for the manner in which their discipline colleagues participated in curriculum development:

I value the trust they have placed in me/us in education and their willingness to work with us to explore their teaching and curriculum development in a blended environment. (ED1)

While the benefits of working with academics from education with pedagogical expertise were evident to science staff:

Developing a greater understanding of the pedagogical issues with respect to effective teaching in scientific disciplines; to utilise their expertise on the 'how' of teaching with the local discipline expertise. (SC1)

Participants noted that they would value further inter-disciplinary relationships, with one staff member reflecting that they would benefit from further collaborative teaching and research:

It would be great if Mathematics and Mathematics Education worked together more both on Teaching (via courses like the BEd (Science and Mathematics) and individual units like Thinking Mathematically) and on Research. (MA2)

Future co-teaching of units by science and/or mathematics academics and their education colleagues was highlighted as being beneficial:

Definitely need to work towards some co-taught units between science, maths and education staff. (SC2)

Although again, a lack of opportunity to collaborate across faculty boundaries such as in co-teaching or assessing units was raised:

Greater involvement in units probably. We have talked at the course level but the action is at the unit level and there is limited opportunity. (SC3)

Crossing faculty boundaries was not seen as insurmountable, but inevitably time and distance were seen as the main barriers to working with colleagues in the other faculty. There was also a sensitivity to the demands on the time of colleagues that the collaboration involved, that is, perhaps, indicative of awareness of cultural differences and the tensions that focusing on curriculum development and teaching and learning in general might cause for academics whose research was focused elsewhere:

The main barriers would be time-related and process-related. Our colleagues in SET and the AMC are busy people, and the work we are asking them to undertake is in addition to their already busy work schedules. (ED1)

As highlighted previously, funded projects such as IMSITE provide the incentive for and resourcing in support of collaboration across faculties, but without it, even close physical location is not enough to make it happen:

Seems silly but location is part of it, even though Hytten Hall isn't that far away it does need a project like this one to bring you together. (MA2)

Even with the support for collaboration, not being physically co-located was highlighted as being enough of an impediment to prevent meaningful interaction:

having most science and maths staff on the Hobart campus and engaged Education staff on the Launceston campus limits interaction. (SC2)

Finally, while project funding enabled collaboration, limited institutional support or prioritisation of the initiative was viewed by one participant as limiting progress:

Lack of support for program from Faculty of [Faculty name] leadership doesn't necessarily encourage engagement (SC2).

The comments made by the participants after more than three years of involvement in the ongoing collaboration confirm the challenges described previously in the literature, particularly the continuing divide between the academic disciplines, the limited time academics have to build relationships and reshape their academic identities, and insufficient support or guidance at the institutional level to facilitate these changes.

Discussion and Implications for Practice

Cross-disciplinary collaborations are funded with the expectation that high quality outputs will be produced, which will benefit the organisation. Other than these outputs, one

of the perhaps unarticulated, long-term goals for such funding, is the expected benefits to the individuals involved, in terms of their personal development through the broadening of their academic identity and role. At the commencement of the cross-disciplinary collaboration aimed at producing the BEd (Science and Mathematics) in blended mode, it was clear that a focus on bringing academics from different discipline backgrounds, academic cultures and identities was essential. In order for the project goals to be achieved and be sustained beyond the life of the project, it was necessary to have at least one, or preferably a number of academics, who had the capacity to undertake the academic broker role. As mentioned, a multi-disciplinary collaboration in a university such as ours requires both knowledge and cultural brokerage between the different groups involved. The academic broker(s) would be expected to be in a position of influence within the institution, and have an appropriate background in terms of their qualifications and/or work experience to support multiple group membership (Stovel & Shaw, 2012), and be able to support/lead the cultural change.

For the BEd (Science and Mathematics) collaboration, the broker characteristics included the capacity to bridge the mathematics and/or science discipline and education clusters, with the ability to understand and be able to contribute to and translate cultural traditions. Their role was to bridge that gap in social structure between the faculties and disparate disciplines and academic identities, to build trust and relationships, and to create opportunities for knowledge to be shared. The broker role was essential, therefore, to supporting those involved in the project as they negotiated knowledge (discipline and pedagogical) and cultural differences, and engaged in the challenging process of developing their academic identity.

Not unexpectedly, reluctance to engage in the project, particularly by some biology academics, could be accounted for by a reluctance to change teaching practice from a traditional to a blended approach, consistent with staff challenges (conservatism, workload issues, digital literacies) identified by Adekola, Dale & Gardiner (2017).

Conclusions

In this paper we have examined literature pertinent to understanding the challenges of cross-disciplinary university collaborations at both the individual and group level. The model represented in Figure 1 and based on Identity Theory (Clegg, 2008; Gee, 2001; Lingard, Schryer, Spafford & Campbell, 2007; Stets & Serpe, 2006; Stryker & Burke, 2000), offers insight into the process of identity and role development that would be involved for an individual participating in cross-disciplinary collaborations. In particular, it offers an explanation for the source of the strong emotional consequences that may arise from participation in such a collaboration. The theory of knowledge and cultural brokerage appears to provide a sound basis for understanding what must be achieved in order for the different groups involved in the collaboration to work successfully together, to produce an innovative and creative science and mathematics education outcome. If an academic broker (or brokers) was not actively involved in the project from its commencement, we consider it unlikely that the collaboration would have lasted as long as it has. Nor, we believe, would the perceived changes to project participants' academic identity and role (e.g., from discipline researcher to curriculum designer) have resulted due to the time it takes for such changes to happen.

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