An exploration of cross-disciplinary engineering education research collaborations

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***Abstract**: At a time when an increasing number of engineering academics are conducting research in the engineering education field it is important for them to recognise when they should collaborate with researchers from other disciplines. There is a growing body of literature that can be used as a guide to support the establishment and structure of cross-disciplinary groups and the approaches and processes that may be used to successfully achieve the research goals. This paper draws on this literature, and the author's experiences in cross-disciplinary research collaborations, to provide readers with an understanding of some of the key learnings in this field. It begins with a story about a successful cross-disciplinary engineering education research collaboration that the author has been involved in for more than five years. The paper then discusses how cross-disciplinary engineering education research projects may be established and describes some of the structures and processes collaborators can use to facilitate quality research outcomes.*

Introduction

The aim of this paper is to address two questions that many engineering academics face when they begin a research project in the engineering education field: '*What knowledge and expertise do I require to undertake research in this field?*' and '*If I don't have the required knowledge and expertise, how do I collaborate with someone from another discipline who does have the required knowledge and expertise?*'. Many researchers have found that these questions are resolved when they work with people from other disciplines in a cross-disciplinary research collaboration. Thus, they 'buy-in' the expertise that is required to undertake the research.

To avoid re-inventing the wheel researchers should draw on the growing body of literature about establishing cross-disciplinary research projects and the structures and processes collaborators can use to facilitate quality research outcomes. The cross-disciplinary research collaboration described in the next section is typical of the successful collaborations that have occurred in the engineering education field in Australia.

In the beginning…

At the end of a staff development planning meeting I asked a Psychologist colleague, "Who should I talk to about spatial ability?" "Me", Lorelle replied, 'It was the topic of my PhD". This simple enquiry, on 10th February 2004, led to the development of a cross-disciplinary research collaboration that continues to this day. The size and make-up of the research team has changed over the years as we undertook different projects, but Dr Lorelle Burton and I are the core members of the collaboration.

My question followed a period of study leave where I had researched, among other factors, the influence of students' spatial abilities on their achievements in first year engineering studies. Many engineering educators have reported on this phenomenon (for example, Potter et al., 2004; Magin & Churches, 1996; and Gradinscak & Lewis, 1995), and there is normally at least one paper on this topic at Australasian Association for Engineering Education (AaeE) conferences. But, of course, researchers in other fields have also written on this subject, particularly Psychologists. For example, Kosslyn (2002, cited in OECD, 2002, p59) reported that '*it is known that the level of the hormone testosterone affects spatial ability*'. It was during my reading in this section of the literature on spatial ability that I concluded that I needed advice from a discipline expert before I embarked on research in this field.

The research

Initially the collaboration was centred on assessing the spatial abilities of the on-campus cohort of first year engineering and spatial science students and then tracking their progress through to graduation or departure from the university. We restricted the research to on-campus students at this time as we recognised that we did not have the capability or resources to enable the Faculty's distance education students to participate in the project, even though this cohort includes 80% of the Faculty's undergraduate students.

Within a couple of weeks, however, the project had expanded and a battery of tests was developed to create a "learning profile" for each student by identifying students' learning preferences, cognitive abilities (e.g., general reasoning, verbal, and spatial abilities), major personality traits, high school outcomes (e.g. tertiary entrance score, and subject grades), as well as cultural, demographic and socio-economic characteristics. The battery was developed for use in a longitudinal study of individual differences and their impact on student achievement.

The battery was administered to the on-campus students via paper-and-pencil over a three week period in Semester 1, 2004, with 132 students undertaking all of the tests. The progress of these students was tracked through to their departure from the university. To date three conference papers have reported on different aspects of the project (Burton & Dowling, 2009; Dowling & Burton 2005; and Burton & Dowling, 2005) and the final data is currently being analysed. The outcomes will be used to inform teaching and learning practices at the University of Southern Queensland (USQ) and reported in one or more journal articles.

In late 2004 the team was expanded to write a book chapter about the aims of the project, with Lyn Brodie contributing to the women in engineering section and Marilyn Dorman to the cultural diversity section (Burton et al., 2005). Once the chapter was completed the research team reverted to its original membership.

In 2006 a refined test battery was administered online, providing a more efficient data collection process and enabling distance education students to also participate in the project. The progress of this cohort of students is still being monitored as most of them are yet to complete their program because they study part-time.

Later that year two new researchers were added to the team to undertake a university wide research project to explore the learning patterns and concepts of knowledge of both on-campus and distance undergraduate students from across the university. Dr Janet Taylor, a mathematics educator, led the quantitative research components of the project while Dr Jill Lawrence, a cross-cultural communication educator, led the qualitative components of the project. Both also contributed to the project through their considerable expertise, and research experience, in the student 'transition to university' field. To date only a preliminary analysis has been undertaken of the data collected from the 1089 students who participated in the study, with the results being reported in a journal article (Burton et al., 2009).

Our experience

Overall, our cross-disciplinary research collaboration has been a richly rewarding and enjoyable experience. We have learnt about ourselves, our disciplines, and our students, and applied that knowledge to enhance learning and teaching at USQ. The research has also been an important addition to the collaborators' CVs, as all have been promoted since the project began.

However, like all collaborations, it has not always been easy. Because the projects have been in the engineering education and general higher education fields, we had to acknowledge that we were working in a field that is a second profession for each of us, i.e. higher education. This meant that we had to engage with the relevant literature in the scholarship of teaching and learning (SOTL) field so that our work was grounded in relevant theories and practices, and so that we could confidently develop recommendations for change.

Like all collaborative activities, working with others often meant we had to learn to meet deadlines imposed by other members of the team, and to compromise and do it 'their' way. Each of us had to learn some of the basics of the disciplines of the other collaborators, and also about some more complex topics in those disciplines. In addition, we had to learn about the research methods and publishing conventions associated with those disciplines. While these activities took time and energy, and added to our already busy schedules, they were necessary to build our cross-disciplinary skills and sustain the collaboration.

Why collaborate on engineering education research projects?

When engineers begin work as academics they enter a new profession, a second discipline: higher education. To enhance their teaching, and student learning, some engineering academics apply the methods, principles, and theories associated with the Scholarship of Learning and Teaching (SOTL). Some engineering academics engage in this field by reviewing relevant sections of the SOTL literature, and through staff development activities. Others engage by undertaking formal studies, such as a Certificate in Tertiary Education, which provides them with a good introduction to the field.

When they engage in scholarly activities in this new field it is important that engineering academics recognise that they may be novices in the field, and may need to build their expertise before undertaking research in an unfamiliar area. This is an important consideration at a time when an increasing number of engineering academics are conducting research in the engineering education field and contributing to the body of knowledge in the SOTL field.

Understanding the research context

Many engineering education research projects are aimed at discerning the changes in student learning, understanding, knowledge, or behaviour, which may result from a change in one or more factors, for example: teaching, assessment, learning environments, or the definition of learning outcomes. To do this successfully, the researchers try to eliminate, minimise, or keep constant, the impacts of other factors that may influence the changes in student learning or behaviours being studied.

Figure 1 is designed to illustrate the context in which students learn throughout a semester, and some of the factors that may influence student learning or behaviour. The vertical lines indicate the learning that occurs in each of the four subjects a typical student may study through the semester, with the rectangular box at the bottom of the figure representing the learning that occurred in the four subjects.

It should be noted that student learning over the period is broader than that shown for the four subjects. This is because the students learn from a range of other activities they participate in such as work, sport, and recreational activities.

A black square has been drawn at each of the intersections of a subject line and a factor line to illustrate how a factor may impact on student learning in that subject. It should be noted that the figure does not show the impact of the learning (or lack thereof) students achieve in one subject on the learning that occurs in the other subjects.

The number of factors that may influence student learning may initially appear to be overwhelming and could lead researchers to conclude that it is impossible to rigorously and thoroughly research anything! But, by considering all of the relevant factors when designing a research project, the outcomes are more likely to be rigorous and authentic. To do this, researchers need to carefully identify the factors that might be important in shaping students' learning or affecting the teaching and learning environment. Having done that, they are better positioned to evaluate the impact and significance of those factors, consider how the impacts may be addressed, and determine what, if any, expertise is required to understand and measure the impact of those factors.

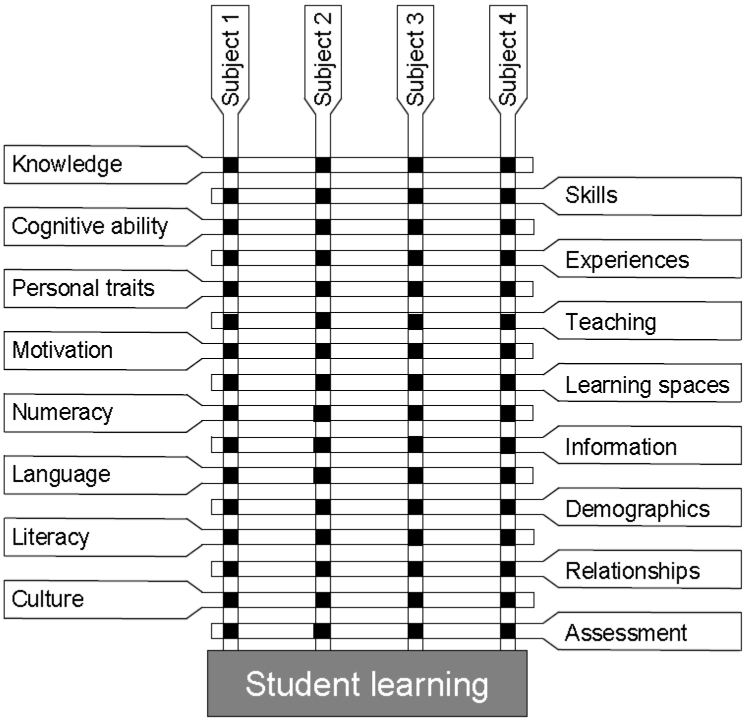

Figure 1: An illustration of how a range of factors may influence student learning

There are a number of options that researchers can use. For example, they can:

- Try to eliminate or minimise the impact of a factor by careful design of the research method. For example, the timing of research activities should be planned so that student engagement in those activities is not compromised by their commitment to activities in other subjects, such as a large assignment.
- Ensure the number of participants is sufficient to minimise the impact of factors that may only influence the learning or behaviour of a small number of students.
- Incorporate one or more additional factors in the study. When this occurs it is important that the research team includes people with expertise, and preferably research experience, in each of the fields associated with those factors.

A cross-disciplinary research collaboration begins when a researcher(s) decides that additional expertise is required and plans to invite people from other disciplines to be involved in the project.

Theoretical frameworks for cross-disciplinary research

Since the 1970's there has been a growing emphasis on the need to conduct cross-disciplinary research, particularly in the biological and health science fields. The trend towards cross-disciplinarity arose because of the complexity of the problems being addressed and the fact that such problems could not be resolved by a single discipline or practice constituency (Abrams, 2006). In addition, researchers often found rigid discipline-based approaches proved inadequate to address such problems.

Many of the major issues facing contemporary societies, such as climate change and sustainability, have multiple dimensions and cross many disciplines. The transdisciplinary approach has great potential to resolve these environmental problems (Russell et al., 2008) and researchers with transdisciplinary capabilities are well placed to conduct research in these areas (Abrams, 2006).

Definitions

Rosenfield (1992) suggested a typology of research practice that covered the continuum from *uni*disciplinary research to *trans*disciplinary research. This typology was later adapted by Stokols (2006) and Abrams (2006) and reported by Neuhauser et al. (2007). The generally agreed categories in the typology are:

- *Unidisciplinary*: Researchers from the same discipline work independently or collaboratively to address a problem in their discipline.
- *Multidisciplinary*: Researchers from different disciplines work in their field independently, in parallel or sequentially, and with little interaction, to address a common problem.
- *Interdisciplinary*: Researchers work jointly, but in their own fields, to address a common problem. There work is more closely coordinated and entails greater sharing of information.
- *Transdisciplinary*: Researchers work together to address a specific research problem and from the outset develop appropriate and shared conceptual frameworks that integrate and extend relevant discipline-based concepts, theories, and/or methods.

Wickson et al. (2006) further differentiated transdisciplinary research (TD) by stating that transdisciplinarity is characterized by a specific problem focus, an evolving methodology, and a collaborative effort. Stokols (2006) extends the *TD Science* approach to form a *TD action research* model that includes members of the community and practitioners as well as academic researchers. He suggests that the addition of these groups in a coalition facilitates the translation of the research recommendations into policy changes and community action. This theme is picked up by Russell et al. (2008) who suggest that an engaged community that collaborates to seek new knowledge is a driver for transdisciplinary action research.

When undertaking TD research there must be a balance between the depth within each of the participating disciplines, and the breadth across those disciplines; the role of the leader is critical in achieving this balance (Abrams, 2006). Abrams also suggests the TD approach is itself a bold experiment, and it is unclear what metrics will be used to evaluate the success of a TD community.

While discussing the work reported in Fuqua et al (2004) and Klein (1996) Stokols (2006, p68) described two important outcomes of transdisciplinary research: '*Transdisciplinary collaborations, thus, are more likely to force participants out of their disciplinary "comfort zones" and require their unwavering commitment to sustained and mutually respectful communications. An advantage of transdiscipinlary collaborations is that they often lead to fundamentally new conceptualizations of scientific and societal phenomena and transcend traditional disciplinary boundaries that frame multi- and interdisciplinary boundaries.*'

Cross-disciplinary research collaborations can be rewarding from a number of perspectives, for example: "Our experience of transdisciplinarity has shaped us for the work we do, demonstrating the transformative power of successful transdisciplinary collaboration" (Wall & Shankar 2008, p563).

Beginning a collaboration

Once the need for a cross-disciplinary approach has been identified the search begins for people with the required expertise, and a willingness (and passion!) to be involved in the project. It should be recognised from the outset that the search may not be successful, and the project may have to begin with one or more empty chairs at the research table. In this case, the researchers should remember to acknowledge the empty chair(s) at their meetings. This should act as a constant reminder that the team may lack the expertise it represents, and alert them to the pitfalls of working and publishing in an unfamiliar field.

Opportunities and constraints

Universities have well defined, but seemingly ever-changing research policies and protocols to facilitate and grow the research quantum. In some cases, however, the policies can inhibit cross-disciplinary research. For example, the way research output is measured and rewarded may not consider the number of researchers involved in a project, or the number of authors who contributed to a publication. Thus, a researcher may restrict the size of a research group if, for example, the reward for a publication has to be divided amongst all of the authors. Of course, a research group should see this as an opportunity, and balance the ledger by writing additional papers that can be published in the range of journals associated with the different disciplines involved in the collaboration.

Dyer (2003) lists some of the factors that may inhibit cross-disciplinary research: competition for organisational resources; academic staff workloads; disciplinary turf wars; and differences in practices and pedagogical approaches.

Some guiding principles

Research collaborators should be carefully chosen and the following factors should be considered: interest in the field; expertise; passion about the proposed project; personality; values; integrity; work ethic; and the ability to meet deadlines. Interest in the field, and passion for the research proposal, are important criteria as they are likely to drive motivation. Of course, those recruited to the project are unlikely to satisfy all of the criteria, and the collaborators will have to learn to work around any weaknesses.

The following principles for successful cross-disciplinary research, particularly transdisciplinary research, have been synthesised from Wall and Shankar (2008) and Kahn and Prager (1994, cited in Abrams 2006, p516)

- Come with an open attitude and ready to engage with people from other disciplines;
- Listen across the gulfs that separate the disciplines involved in the collaboration;
- Learn the language and methods of other disciplines at sufficient depth for a meaningful exchange of ideas to occur;
- Recognise that innovation, learning and growth can stem from personal relationships;
- Develop a common language for conceptual translation among researchers;
- Jointly develop new measures and methods;
- Conduct research that reflects an integration that generates rich new hypotheses, perhaps resolves prior anomalies or counterintuitive results; and adds explanatory power;
- Ensure there are adequate resources to support the cross-discipline collaboration; and
- Hold regular meetings to build relationships and momentum.

The collaborators should prepare a covenant that describes the way the collaboration will function, the roles of each of the collaborators, and the expected behaviours. This is particularly important if the team approach is adopted.

The approach

Having decided to undertake a cross-disciplinary research project, the collaborators should then consider how the collaboration will function, i.e. as a research group or a research team. For many people the terms ‘team’ and ‘group’ are interchangeable and they often use the terms ‘team’ and ‘teamwork’ when they are really talking about a ‘group’ and ‘group work’.

‘A **group** is a collection of two or more people who work with one another regularly to achieve one or more common goals’ (Wood et al., 2006, p193). When a group is established within an organisation the leader is often appointed by the organisation, and would normally be a manager or supervisor. For example, a formal group established to design a new high rise building may be led by an architect, and include a landscape architect, civil engineer, electrical engineer, mechanical engineer and a structural engineer.

‘A **team** is a small group of people with complimentary skills, who work together as a unit to achieve a common purpose for which they hold themselves collectively accountable’ (Wood et al., 2006, p228).

Some of the key differences between groups and teams are shown in Table 1. The decision about whether research collaborators should function as a single-leader group or as a team should be based on the way the collaboration was established and the type of collaboration being undertaken.

‘*Whenever a small group can deliver performance through the combined sum of individual contributions then the single leader discipline is the most effective choice. This choice is fast, efficient, and comfortable, since most organisational units have followed the single-leader model for decades. However, if there must be collective contributions in addition to individual efforts then the group should apply the team discipline’* (Katzenbach & Smith 2001, p.13).

Thus, it is likely that *Multidisciplinary* and *Interdisciplinary* collaborators would operate as single leader groups while *Transdisciplinary* collaborators are more likely to operate using the team discipline. *Unidisciplinary* collaborators may, however, decide to operate as a group or as a team.

Table 1: Differences between groups and teams

Working Group	Team
Strong, clearly focussed leader	Shared leadership roles
Individual accountability	Individual and mutual accountability
The group's purpose is the same as the broader organisation mission	Specific team purpose that the team itself delivers
Individuals produce work-products	The team collectively produces work-products
Runs efficient meetings	Encourages open-ended discussion and active problem solving meetings
Measures its effectiveness indirectly by influence on others	Measures performance directly by assessing collective work-products
Discusses, decides and delegates	Discusses, decides and does real work together

Source: Katzenbach & Smith (2005, p. 214)

Conclusion

At a time when an increasing number of engineering academics are building their research profiles, and skills, in the engineering education field it is important that they recognise the pitfalls of researching in new fields. Where appropriate, they should consider collaborating with researchers from other disciplines so that the required expertise is harnessed for the research project. Cross-disciplinary research collaborations can produce high quality research outcomes that build on the knowledge bases of the relevant disciplines and create new knowledge that may transcend discipline boundaries. To achieve these outcomes the collaborators should be carefully selected and the structure and approach the collaborators use should be clearly defined. The researchers are then likely to find the collaboration to be a rich and rewarding experience.

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