Barriers and Levers Driving Change in a STEM Science Subject in the
Australian Higher Education Sector: A Focused Study

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Abstract

Background: This study explored the challenges around enacting change in a STEM (Science, Technology, Engineering and Mathematics) subject at an Australian higher education institution and examined key elements required to ensure change. Purpose: The purpose of the study was to examine the barriers and levers driving change during the collaboration of discipline experts, in both science and education disciplines and professional staff across education and science faculties to change the delivery of an existing subject within a science faculty, from traditional lectures to an active learning approach. Sample: Participants from the education faculty and science faculty formed the participant interview pool of five academics for this study. Design and Methods: Research design of semi-structured interviews of participants was conducted to answer the research questions. Instruments were used to test the research questions, such as factors to facilitate and support change to teaching a science subject and the elements required for successful interdisciplinary collaboration for bringing about change to the teaching of a science subject. Thematic analyses were conducted on the data responses to answer the research questions. Results: The findings revealed that participants found that factors such as time, resources, understanding of and commitment to the proposed change represented potential barriers to change in the subject. The existence of multiple, time sensitive champions, additional human resources and a collaborative network of participants, however, were identified as some of the key elements that supported enacting changes to a science subject. Conclusions: The findings of the study provide insights to interdisciplinary collaborations enacting changes to the teaching of a science subject. For instance, the need for establishment of a dynamic network of participants engendered with multiple interdisciplinary expertise, as well as the need for a change champion and
implementation champion, throughout the curriculum re-design, planning and implementation phases of the change.

Keywords: collaborative work; interdisciplinary projects; change; science education; university teaching

Introduction

Interdisciplinary approaches drawing on the knowledge, skills and commitments of academic staff in both Education and the Science disciplines, as well as on the knowledge and abilities of professional staff, have the potential to facilitate positive changes in the teaching of broader STEM subjects. Creating sustainable change in the higher education sector remains a fundamental difficulty in the context of rapid and continuous changes to transfer of knowledge and information, and of an increasingly dynamic, digital and global society in the 21st century (Lane 2007; Menzies and Newson, 2007, Pucciarelli and Kaplan 2016).

Changes for university STEM education have generally focused on developing reflective teachers, disseminating curricula and pedagogy, or enacting institutional policy (Reinholz et al. 2014). Recent models for systemic cultural changes in STEM departments, however, are broader in their approach and have attempted to address the university system at multiple levels (Reinholz et al. 2014), and to change faculty teaching methods (Chasteen et al. 2015).

Broader change theories (Hiatt 2006; Kotter 1996) and a range of theories and frameworks for understanding and facilitating change (Kezar 2001; Lueddeke, 1999; Henderson et al. 2011) have identified the individual, the group, the organization (as a complex system) and time as key enablers for change. Change theories are applied throughout a variety of sectors, however due to contextual factors around higher education, it is important to focus on theories that align with the higher education sector. Effective change
strategies typically support proactive approaches that align with the beliefs of an individual, involve long-term interventions, and provide a strategy that aligns with universities complex systems (Henderson et al. 2011; Kezar 2001; Lueddeke 1999) and disciplinary communities (Henderson et al. 2012).

Connections between disciplinary communities within a university are rare, even though different individuals and groups have complementary strengths in disciplinary knowledge and research (Henderson et al. 2012). The contextual issues that exist in a university’s external and internal environments may precipitate change, but change can only happen when university teachers and students look beyond the information and individuals that populate a discipline and engage with the intricacies of learning: for example, the discourse practices of those communities (e.g., teachers), organisations (e.g., professions) and institutions (e.g., universities) that influence a discipline (Becher and Trowler 2001).

Theoretical Framing

The proposed change in the teaching of the science subject referred to in this paper was a shift from traditional lectures to an active learning approach, in line with a sociocultural approach to teaching and learning. The teaching approach employed social interaction through participation in group work, whole class discussion, hands-on activities, the use of learning materials derived from professional publications, and problem-based learning activities.

The practices of active learning are designed to foster students’ higher order thinking through argumentation and value-based decision-making. This requires that students collaborate in problem solving situations that require them to represent, compare, explain and justify ideas within a learning culture that promotes what Bereiter (1994) refers to as the quasi-moral commitments of a scientific community to work toward a common
understanding, frame questions and propositions, expand the body of collectively valid propositions, and to allow ideas to be subjected to constructive criticism

One theory of change that directs attention to students’ and the teacher’s discursive practices such as argumentation can be attributed to the work of Vygotsky. Vygotsky (1987), in his theory of learning and development, emphasised the centrality of communicative tools (such as comparing, explaining and justifying) and cultural tools (such as commitments to discourse) in weaving everyday forms of thinking and understanding with more abstract, scientific understandings. The process by which the transformation of the everyday into the scientific occurs, that is, the process upon which more abstract and general understanding of scientific concepts emerge (John-Steiner et al., 1998) is dynamic and interactive requiring learners to engage in joint tasks, for the purpose of linking their lived experiences of the world to established cultural frameworks such as those represented in scientific and mathematics curricula (see Renshaw and Brown, 2007 for an elaboration of this process). As such, through the use of active learning practices (Tal and Kedmi, 2006), mediational means, such as language and other symbolic systems, may transformed into internal tools of thinking and problem solving.

**Barriers Confronting STEM Education**

A heightened focus on the STEM agenda in Australian education has arisen in response to reports and statements from the Office of the Chief Scientist (2013), Australian Government (2017), Australian Council of Deans of Science (Harris et al. 2005) and learned institutes within Australia (Australian Academy of Technological Sciences and Engineering 2013; Wienk 2017). A growing concern in Australia over the decline in the number of high school students studying maths and science (Kennedy et al. 2014) has led to calls for more time to be spent on teaching science and mathematics at all levels of education.
National analyses (see for example Wilson and Mack, 2014; Marginson et al. 2013) have shown declines in the number of students studying maths and science in the senior years of high school and there is concern over participation in STEM education. For example, between 2001 and 2013 the proportion of students in senior high school studying the Higher School Certificate in the Australian state of New South Wales (NSW) without any mathematics tripled (from 3.2 to 9.7%) (Wilson and Mack, 2014). For students receiving Initial Teacher Education university offers in NSW between 2001 and 2013 there was a tripling in the proportion of students with no mathematics at Senior High School level (4.8 to 15.6). Wilson and Mack (2014) go on to state that these analyses raise serious concerns for mathematics and for STEM education.

This trend in the lack of participation in Mathematics and Science at the senior high school levels continues and when considered in terms of the declining participation rates in Mathematics and Science among prospective teachers is deeply concerning. Consequently the reduction of out-of-field science and mathematics teaching (i.e. teaching by teachers without formal teacher education preparation and advanced content knowledge in a particular subject area) in the secondary school system, and an increase in the preparation of specialist science and mathematics teachers along with the professional development of practicing science and mathematics teachers becomes a priority for STEM education (Prinsley and Johnston 2015; Australian Academy of Technological Sciences and Engineering 2013). As such, the slow adoption of transformative learning practices, that is, those referred to earlier that utilise problem solving situations to encourage the critical use of argumentation and value based decision making particularly in university science, technology, engineering and mathematics (STEM) education (Weaver et al. 2015; Wieman et al. 2010), remains a challenge for the development of change strategies and models of systematic change for STEM education.
Barriers Confronting Interdisciplinary Learning

Review of the STEM education area identifies the need to place an emphasis on science and mathematics learning for K-12 students (Becker and Park 2011; Blackley and Howell 2015; Brown 2012; Freeman et al. 2014), the development of science and mathematics skills in practicing teachers (Baumert et al. 2010; Hill et al. 2004; Lee and Luft 2008), and research into the preparation of science and mathematics pre-service teachers (Eckmann et al. 2016; Loughran et al. 2008; Rinke et al. 2016) as important priorities for the teaching of STEM subjects. A successful science and mathematics teacher must have deep content knowledge (Blackley and Howell 2015; Munby et al. 2001; van Driel et al. 2001) articulated with knowledge of how to effectively teach content to students (Grossman et al. 2009; Shulman 1987). In essence, science and mathematics teacher preparation is an interdisciplinary challenge, which should integrate the disciplines of education and science in the tertiary education sector.

In general, the discipline of education focuses on questions of curriculum (what should be taught to students), pedagogy (how the curriculum should be taught) and on what other goals should be pursued when teaching knowledge and skills (Krishnan 2009). On the other hand, the discipline of science, in general, is focused on what knowledge and skills from the discipline should be taught to students for the purpose of improving their chances of finding suitable employment and pursuing a career (Krishnan 2009). As such the interdisciplinary challenge for education and science in tertiary education requires both disciplines to incorporate pedagogies that not only privilege content (knowledge and skills) but also promote commitments to engaging in the discourse practices of science such as those enunciated by Bereiter (1994) and promoted by Holbrook (2013): commitments to pursue ‘mutual understanding’, ‘empirical testability’, ‘openness’ and to ‘expand the knowledge of
the discipline’.

**Barriers Confronting Active Learning**

In a report grounded in 22 commissioned studies into STEM around the world, Marginson, Simon, Tytler, Russell, Freeman, Brigid, Roberts and Kelly (2013) found that even though the STEM disciplines are seen as essential for work, citizenship, the economy and social creativity, the participation of Australian students enrolled in higher level STEM disciplines has been declining for decades and runs the risk of falling behind international counterparts. To combat this declining participation Marginson et al (2013) advocate that methods of problem solving, inquiry, critical thinking and creativity should be at the core of our pedagogy in the STEM discipline classrooms. This requires pedagogical change from the traditional lecture format employed by many in the teaching and learning of the STEM disciplines. However pedagogical change is challenging to enact in the tertiary sector. Teaching strategies are intricately linked to subject requirements, ensuring simultaneous evolution. This takes time and university resources, with one-off and short-term workshops not consistent with change (Davidovitch and Soen 2006; Walczyk and Ramsey 2003). Semester-long changes are more likely to lead to success (McShannon et al. 2006), however such changes have additional requirements.

Academic educator time, already strained with other faculty commitments, is at the forefront of successful pedagogical change. Meaningful educational change of any kind requires a change in beliefs. This is difficult, as new beliefs challenge core values (Fullan 2001). In addition, pedagogical change must adapt to content breakthroughs and evolved teaching strategies (National Research Council of the National Academies, 2011). It is accepted that the activity of teaching science content must be learning- or student-centred (e.g., Barr and Tagg 1995), however it is the shift to this approach from teacher to student
centred that is complex, especially in the tertiary education context. Regardless of their intent to change, faculty often discontinue innovations (Dancy and Henderson 2010; Henderson et al. 2012), mostly due to lack of support and structure for innovation.

In the present study, issues that drove change included a desire to respond to some of the challenges that face STEM Education, for example, declining enrolments in science and mathematics subjects, which are at a 20 year low (Kennedy et al. 2014); the decline in Australia’s performance in school level mathematics and science as reported by the Programme for International Student Assessment (PISA) (Thomson et al. 2017), along with the emergence of position statements calling for the transformation of STEM teaching (Harris et al. 2014; Prinsley and Johnston 2015). The impetus for the project also included a desire to respond to a challenge to incorporate Interdisciplinary Learning in the teaching of science through from government initiatives (e.g., Step Up;) to enhance the pre-service training of science and mathematics teachers by exploring the effects of adopting an active approach to learning in a university Bachelor of Science subject.

The proposed change in the teaching of the science subject was a shift from traditional lectures to an active learning approach, in line with a sociocultural approach to teaching and learning. An approach that employed social interaction through participation in group work, whole class discussion, hands-on activities, the use of learning materials derived from professional publications, and problem-based learning activities. During the implementation of this change and the associated study we sought to explore some of the barriers to changing approaches to teaching science encountered in a discipline-focussed university.

In summary, the barriers and levers presented in this paper are not particular to one university but are experienced by universities both nationally and internationally as educational authorities attempt to address the inadequacies in the mathematical and scientific
literacies (see for example the work of Boaler, 2002, 2008 for mathematics education and the work of Bereiter, 1994 and Roth and Barton, 2004 for science education) of their populations as revealed by internationally comparable data such as that provided by the Programme for International Student Assessment (PISA) (see Grek, 2009).

As such, this paper aims to address the following questions:

(1) What factors facilitate and support change to teaching a science subject in an Australian higher education sector?

(2) What are the elements required for successful interdisciplinary collaboration between science educators, mathematics educators, and technical engineers to take place for bringing about change to the teaching of a science subject?

**Method**

**Research Design**

This research adopted a generic qualitative design to explore academic educator (academic staff with a 20-60% teaching allocation in their work profile) experiences and perspectives on pedagogical change at a tertiary institution (Caelli et al. 2003). This type of design aims “to discover and understand a phenomenon, a process, or the perspectives and world views of the people involved” (Merriam 2009). Generic qualitative designs do not declare loyalty to any particular approach, however take a more general approach to the issue (Kahlke 2014) and can stand alone as a researcher’s articulated approach (Merriam 2009). This approach was chosen for this study because an aim of the project was to understand the perspectives and lived experiences of academic educators through their own descriptions (e.g., Caelli et al. 2003).
Participants

The interdisciplinary collaboration within the one university was established through the
common goal of the *Step Up* project (see earlier description of this project). Two sets of
participants from the collaboration, one from a science faculty the other from an education
faculty, formed the participant pool for this study and were invited to voluntarily take part in
interviews. These educators (ranging from Lecturer B to Lecturer D) occupied positions of
power neutral to the influence of the academic educators directly involved with designing and
enacting the pedagogical change for a science subject to be delivered during a 13 week
semester. From the Science Faculties, three academic educators (from a total of five)
responded, referred to as I1, I2 or I3. Two additional participants, (from a total of three) from
the Education and Science faculties (referred to as P1 and P2), were invited to participate
based on their involvement with non-teaching stages of the change (e.g., design) providing
additional information at an administrative level. To support the anonymity of the
participants, demographic information is deliberately minimal. Informed consent was
obtained from all participants.

Data Instrument and Collection

Data were collected from participants through semi-structured interviews. Examples of
questions used to elicit experiences included:

- How was learning organised in this science course?
- What assisted the organisation of the science course at this stage?
- What assisted with the interdisciplinary collaboration at this stage?
- In your own words, list the factors required for a successful inter-disciplinary
collaboration.
Interview questions were informed by the literature on interdisciplinary approaches to teaching science in the higher education sector and focused on the primary purpose of the data collection, that is, to explore the perspectives and lived experiences of academic educators through their own descriptions.

Interviews with academic educators (I1-I3) were conducted face-to-face by an independent Research Assistant, as a single instance during the semester following delivery of the change to teaching. Interviews were audio-recorded and transcribed, with identifying information removed. Post-interview meetings were held with participants and the interviewer to member check the de-identified data. To ensure the integrity of responses, interviews with other participants (P1, P2) were conducted online due to work commitments.

**Data Analysis**

Data were analysed using a thematic approach (Creswell 2008). Data were examined for emergent themes and coded accordingly. Themes emerged during the data analysis through a process of discussion and consensus and were clustered into categories, such as, people, curriculum, administration. These categories remained unchanged during the analysis. To ensure the reliability and validity of coding, two researchers independently reviewed the transcripts in their entirety and codes were compared. Comparison indicated a very high level of consistency between the researchers’ interpretation of the data.

Member checking was used to ensure the credibility and validity of the findings (Guba and Lincoln 1989). Checks occurred after initial coding of the data to verify whether the thoughts of the two researchers had been accurately captured. Triangulation occurred through the use of a wide range of informants (Shenton 2004), which included intra- and inter-institutional members of the Step Up project team, not involved in delivery of the
project change. This allowed for individual viewpoints and experiences to be verified against those of others and provided a richer picture of the attitudes and needs of participants.

**Limitations**

The project team acknowledges limitations in the present study. Although qualitative research generally draws upon a small number of participants, it must be noted the small number of interviewees ($n=5$) is a limitation of this work. In addition, the study only drew upon data from a staff perspective, excluding student and institutional perspectives that may influence change in higher education. It is useful to note that the interview process intentionally did not include students or institutional authorities in order to focus on the purpose of the research, namely, to understand the perspectives and lived experiences of academic educators through their own descriptions.

**Findings**

In this study the barriers and levers for driving change in a Science university subject relate to two main aspects, challenges and levers for design and challenges and levers for implementation. The first of those aspects focused on evaluating the successes (levers) and challenges (barriers) encountered in seeking to foster change in a STEM subject in the Australian higher education sector. The second aspect sought to identify the main elements required for a successful interdisciplinary approach. With regard to design, the findings relate to communication and co-ordination factors such as time, understanding and commitment, resourcing, networking, sharing and championing change. With regard to implementation the findings relate to curriculum and human resourcing factors such as the sourcing and creation of resources, student interaction, communication with students and teaching delivery.
The key challenges that emerged for curriculum design and planning were: co-ordination and communication between team members; time pressures; participant commitment, involvement and understanding of the changes involved in the curriculum re-design.

**Time a barrier to designing change**

It became apparent that creation of a change in the curriculum from traditional lectures to more active teaching and learning was ambitious in an environment where people were time poor and had other workload pressures such as discipline research and extended teaching responsibilities. Time issues, which led to difficulties in organizing interdisciplinary meetings, were a major obstacle for all participant interviewees.

A challenge for collaboration was …getting people together to meet i.e., finding suitable days, times, venues (P2)

Certain members were very keen to be on board but also said there wasn’t enough time (I2)

Time pressures extended beyond the individual. The institutional requirements to publish a subject profile months in advance created a lack of flexibility in timing for curriculum change and teaching delivery.

One big change we made is that…because we have [subject] profiles which … set in stone what we can assess down to ‘nitty gritty’ details [and published months in advance], that caused us real problems …because it set things which were unfeasible within the [new] model of delivery (I1)
Understanding and commitment barriers to designing change

However, curriculum issues provided greater challenges. There was the requirement for a clear understanding of the proposed changes.

A requirement for collaboration was a…clear understanding of what [the pedagogical change] meant and how to deliver it (P2).

Some members needed more time to gain this understanding.

For me there would have been value in getting a clearer sense, earlier, of the [subject] itself in terms of its content and Learning Outcomes, so that I could better contribute (P1)

A strong issue was that the teaching team’s commitment and involvement varied during the curriculum re-design.

Getting the coordination between all the people involved and getting them to understand the importance of … the project (I2).

I…again go back to the philosophy of staff members. There was definitely a divide among the teachers on the value of something like the [curriculum change] …I think that there was - probably needed to be more education between - or dissemination of the value of this teaching style (I2).
Not all those who were involved in the delivery were on board (P2)

…there were some people involved in the project who clearly were not particularly interested in contributing (P1)

An issue that was raised was the perception of extra workload for subject development that had not been incorporated into the normal academic workload allocation process:

I think also to have been asked to do work that’s outside of their regular workload felt like it was [compulsory] (I2)

Curriculum Re-design and Planning Levers – Resourcing and championing the cause

Human resources were the crucial element that facilitated the curriculum re-design and planning.

A ‘change champion’ as an intended adopter, in a senior position, such as a science discipline head or Learning and Teaching leader at a Head of School or Dean level, was needed to engage other science discipline participants in the importance of the curriculum re-design and manage institutional issues (e.g. teaching workload) to facilitate the change being achieved. The ‘change champion’ took in this role as part of their existing senior leadership role. It was noted by participants that, for successful collaboration to occur, it was necessary to have an,

…active champion to lead the science curriculum change (P2)

Curriculum Re-design and Planning Levers – Networking and resource sharing
Curriculum re-design occurred with the active involvement of participants with discipline expertise, both from education and science, for the organization of content, selection and organization of learning experiences and changes to assessment that were made in order to include formative assessment. The content of the curriculum and overarching learning objectives remained unchanged. The engagement of participants was enhanced by in-person meetings and their buy-in was identified as necessary, as noted:

People attending the meetings. People being engaged with the idea and actively working for the change… (P2)

I think face-to-face meetings were crucial in building relationships and respect and drawing together expertise. Some video conferenced meetings occurred later and were effective, but the face-to-face ones had paved the way for them to work (P1)

Interdisciplinary relationships were of central importance and facilitated success in the curriculum re-design and planning stage. During the collegial interdisciplinary meetings, it was indicated that it was necessary to have all participants on the same page and to create a shared understanding of the change between discipline experts from education and science,

…get all the teachers together to understand what the [change] … was for starters (I2).
Having had multiple meetings by this stage, the interdisciplinary collaborative relationship was established and communication between disciplines was open. (P2)

During this phase, sharing of educational resource materials to inform the curriculum redesign process included items such as references for teaching science concepts using interactive simulations (Hennessey et al. 2007; Moore et al. 2014). This exchange was an enabler for the discipline academic educators, who recognised that during curriculum delivery, a key aim was to achieve an increased level of active teaching and learning,

You provide the videos for the students to watch, …some questions in a quiz, …a mastery question and also a task - an experiential learning tasks within the face to face …. From a staff perspective you need a bit more of a close working relationship than you would in a standard delivery (I1)

Then there is the faculty members as resources and how they’re supposed to interact with students (I3)

…tried to give [the students] a more interactive session that would basically spark their interest (I1)

The strengths of the interdisciplinary relationships provided a foundation for curriculum redesign and participants described the benefits of a successful interdisciplinary collaboration:
I think mutual respect is the key; if all collaborators have appropriate respect for the knowledge, skills and experience of all other collaborators, the process can be effective. In this process I felt it was very much present in both directions (P2)

[Successful interdisciplinary collaboration] provides a variety of perspectives which distil to a clear way forward [and] can value add by using the expertise of more than one discipline (P2)

Upon completion of the curriculum re-design, implementation of the change to meet the timing required for successful delivery and assessment during semester was facilitated and challenged by a number of factors.

**Barriers to implementation change**

Implementation of the curriculum changes was principally comprised of a pre-teaching phase and a teaching delivery phase. The pre-teaching phase included sourcing and creation of digital resources for content, development of frequently asked questions for students and staff explaining the curriculum approach and development of staff support resources for teaching delivery. The teaching delivery phase involved enacting the curriculum with students during the weeks of semester. These two phases were implemented for each module in the curriculum (total of 5 topic modules) leading to staggered implementation of the curriculum changes. As with curriculum design and planning, time was a considerable pressure for the implementation phase:

[Interdisciplinary] meeting times were difficult to find due to the demands of semester for staff who were involved in [teaching] more than one [subject] (P2)
The time scale required to develop [the curriculum change] was very compressed and put pressure on staff (P2).

[Implementation of the curriculum change was] a little bit rushed in how it was organised (I2)

**Barriers to implementing change - the sourcing and creation of resources, student interaction, communication with students and teaching delivery.**

Sourcing of digital resources for content, with concomitant curation for quality assurance, was a lengthy commitment for academic educators and, in the current study, a discipline area research assistant became involved, through the support of the Step Up Project. In addition, professional staff with digital learning \expertise became essential for the technical upskilling of academic educators to create digital resources for subject content.

The content involved online lectures which were produced with the [digital] learning team (I2)

Perspectives on the teaching delivery phase displayed the emergence of bidirectional relationships between students and staff.

I think it [the curriculum change] was a good first try, but it needs ongoing work… It changes the role of the lecturer and the students quite a lot in the sense that it becomes more of a collaborative process to try to get through the material (I1).
The variable interaction levels on the part of students towards the change away from traditional lectures to active learning was a challenge for the initial delivery by the teaching staff:

We had some students who were quite lackadaisical (I3)

The thing is, some of the students who wouldn’t turn up, when they did turn up they would absolutely interact. They were perfectly good and you could see that they were learning and actually helping the other students too. (I1)

In addition, some staff identified the need for self-professional development for teaching delivery:

‘I tried to do a little bit of research online…of what was supposed to be going on’ (I3)

Those teachers who were reflective recognised the challenges of delivering the teaching in a way that enabled the active learning approach to be effective.

It's a delicate balance there to draw students into, first, a conversation at all, and then into, I want to say, a good productive conversation, and then to get that flowing in the correct direction and achieve some educational goals. (I3)
Levers to facilitate the implementation of change – human and curriculum resourcing

Implementation of the curriculum changes was facilitated by an ‘implementation champion’ (an academic with expertise in the field of science education) who assumed leadership from the ‘change champion’ during the pre-teaching phase and the teaching delivery phase, along with involvement of other non-teaching staff for sourcing resources and providing skills training. In the pre-teaching phase additional human resources were identified as one facilitator of the change. A discipline content assistant who provided time relief to academic educators to carry out the sourcing of quality content resources (digital and hard copy) that could be embedded in the curriculum change, assisted with the implementation stage:

Research Assistant worked with staff to find resources for [change] (P2)

Despite the need for extra support, there was a clear understanding on the part of teaching staff of the need to meet the requirement for sufficient appropriate curriculum resources to enact the curriculum change and to provide flexibility for student active learning to take place.

We tried to accommodate all preferences…so we gave [the students notes] and then the main delivery mode was video, plus clips, plus online content, plus textbook access for each thing (I1)

Sufficient resources [were required for success] to be able to provide a stimulating and engaged learning on-line environment (P2)
A primary facilitator for implementation of the change in the pre-teaching and teaching delivery phases was the involvement of professional staff with digital learning expertise, who advanced the digital skills of the academic educators and provided in-situ training. This in turn allowed the teachers to become more independent over the duration of the project in aspects such as the studio production of the lecture content mini-videos resources. Initiatives to support the teaching team to develop their skills included a peer-academic educator showcase of mini-videos at the beginning of the delivery phase. Having participants with multiple expertise was important to ensure change.

Have the [digital] learning team who were the backbone of getting the online material… there was certainly several stages so there was the roles based around getting the online material (I2)

It was interesting to note the unexpected engagement by some academic educators with the video digital resources produced.

I love to be able to use them [the videos] to see how my teaching style evolve[s] (I3)

As with the curriculum re-design and planning phase, it was noted that it was not only buy-in on the part of the participants that was required, it was also necessary to have an ‘implementation champion’. As noted by participants:

One key factor that's not often mentioned is a 'champion' to carry forward the project. While there were other instructors and others involved, without [the
champions] enthusiasm, focus and work, it's my view that this project would not
have succeeded. [Name removed] was the one person who took ownership and
made it happen. (P1)

The strength of the interdisciplinary relationships extended into the implementation
phase. Once teaching (delivery of the change) commenced in Semester Week 1, an
interdisciplinary meeting between education and science discipline experts, including the
broader teaching team, lead to the development by the education experts of guidelines (key
principles for group work and ideas for discussion classes) for the teaching team. This
meeting between education and science also provided cross-validation of the curriculum
changes during the implementation phase.

Conversations about [teaching delivery] problems arising and how to address
them were very valuable (P1)

If the [teaching activity guideline] was followed, then it would be well organised.
(I1)

Discussion

Models and concepts for change, in response to the challenges experienced in higher
education in the last 20 years, have focussed on the cultural realities of academic leadership
and decision making at the institutional level (Kezar 2001; Lueddeke 1999; Pucciarelli and
Kaplan 2016). When attention is turned to change in university STEM education subjects,
ineffective practices have been identified to include: (1) developing and testing ‘‘best
practice’’ curricular materials, then making these materials available to other faculty and (2)
“top-down” policy-making meant to influence instructional practices (Henderson et al. 2011). Change efforts for university STEM education have generally focused on one of three areas: developing reflective teachers, disseminating curricula and pedagogy, or enacting institutional policy (Reinholz et al. 2014). Recent models for systemic cultural changes in STEM departments, however, are holistic in their approach and have evolved to address the university system at multiple levels, such as the ‘6 core commitments’ approach (Reinholz et al. 2014), along with changes to faculty teaching methods (Chasteen et al. 2015).

In this study the barriers and levers for driving change in a Science university subject, without the context of a systemic faculty approach, were organised into two main aspects. The first of those aspects focused on evaluating the successes (levers) and challenges (barriers) encountered in seeking to foster change in a STEM subject in the Australian higher education sector. The second aspect sought to identify the main elements required for a successful interdisciplinary approach.

Overall factors that were barriers for change (Research Question 1) were (1) ‘time’, (2) a shared understanding for and about the change and (3) the level of commitment of the staff involved in the change. Time pressures were singled out as a constant barrier for all participants. Time is well known as an impediment to implementing instructional changes (Dancy and Henderson 2010). In this study, time pressures were associated with the individual academic educators, whose professional pressure on timely preparation for implementation of the curriculum re-design had potential to negatively impact on the change. Other time issues emerged, such as the longitudinal institutional time requirements for subject documentation and the increased time required for sourcing and quality assurance of new digital resources for the curriculum re-design.

It is no surprise that one challenge faced by academics implementing change in this science class was identified as ‘time’. Since the latter years of the 20th Century when the new
knowledge economy promoted organisational shifts in universities, academics’ ‘job stress’ has increased, with some academics adopting standardised practices that promote knowledge delivery at the expense of temporal practices that promote reflection and dialogue, in order to manage this stress. It is through the ways that academics participate in change that they may co-produce practices that promote reflection and dialogue (Menzies and Newson 2007).

Working from an interdisciplinary perspective, Holbook (2013) suggests that if change is to occur in an interdisciplinary endeavour then the practices employed need to privilege ‘consensus’, ‘incommensurability’ and ‘invention’. That is, effective practices are based on (a) a common understanding of the task at hand, (b) interpretation of the concepts and skills being presented and (c) invention of a discourse genre accessible to all stakeholders – an invention driven by commitments to progress the discourse of the discipline. The need for this commonality of purpose is reflected in the second challenge identified in the data analysis which we have summarised as ‘collaboration’.

A noteworthy challenge was the need for a shared understanding of the need for change and re-design of the curriculum. This was influenced by the stages of adoption that the participants were at: pre-adoption, early use, or established users (Greenhalgh et al. 2004; Hall and Hord 2006) and the level of commitment and involvement of the staff involved in the change. Specific challenges that arose included ensuring that all participants were: aware of the change innovation; had sufficient information about what impact the change was likely to have; knew how to carry out the changed teaching delivery and had sufficient training and support on delivery (Greenhalgh et al. 2004).

Overall levers for success for change (Research Question 1) included (1) availability of resources, (2) the establishment of a dynamic network of participants (Figure 1) who had multiple interdisciplinary expertise [in all there were a dozen academics and professional staff involved in the different phases of this study] and (3) a synergy of more than one
champion through the different phases of the change. Studies mention the fundamental
importance of resourcing in terms of financial and human resources, along with the obvious
requirement for curriculum and content resources for student learning to occur (Stoddart
2015).

This project identified the need for curriculum and content resources to enable the
change for an active approach to student learning as well as scholarly resources regarding
delivery of the change that were shared between the participants, in the implementation stage.
In this study, it is important to recognise that change was enabled by interdisciplinary (Klein
2013) academic educator interactions and through successful collaboration (Research
Question 2) that involved a mutual respect for and understanding of the knowledge, skills and
experience of collaborators from both science and education faculties. In addition, human
resources extended to the involvement of professional staff with specific skills in digital
educational design and learning. A key outcome of this change, therefore, was an
understanding of the value and power of a dynamic network of participants with multiple
expertise. As such, the project has identified a particular need for the harnessing of human
resources (academic experts and professional staff), driven by an interdisciplinary
commitment to ‘consensus’, ‘incommensurability’ and ‘invention’ and the need to progress
the discourse of the discipline.

Another key finding was that multiple champions working in synergy played a critical
role within the interdisciplinary collaboration and change journey. The roles of ‘change
champion’ and ‘implementation champion’ emerged during the phases of change in response
to a ‘sense of purpose’ for the change, which was triggered by an external imperative:
improving STEM education in Australia. In the curriculum re-design and planning stage, the
need and importance for change became a pivotal part of the role of ‘change champion’ and
necessarily this person was a senior staff member who was able to lead the other participants
and address concerns in the pre-adoption and early use stages. The implementation stage, however, required an ‘implementation champion’; an academic educator practitioner, involved in the delivery of the change. In this study the champions were different participants who were direct colleagues and responded to key triggers during the change.

**Implications and future research**

Findings from our research have a number of implications for theory, policy and practice. At the theoretical level it provides an example of implementing an active approach to learning in an institutional context. Although findings support existing theories regarding certain stressors encountered when implementing change, including time stressors and institutional requirements, this study draws attention to implementing change in a manner that respects the past (for example traditional approaches to teaching science), but enacts the present with confidence in the affordances of an active approach to teaching and learning. At the policy and practice levels, the literature reveals barriers towards change in general and identifies elements such as time as of concern. For example, a major barrier to the implementation of active learning approaches in the classroom is the time teachers and students need to devote to group and whole-class discussion (Brown, 2017). However, this research, was not, in general, based in Australian higher educational institutions with a specific focus on change within STEM subjects. As such, the present study makes a major contribution to exploring an active approach to learning within the higher education context.

In Summary, findings from this study:

- give insight into challenges faced by STEM educators as they attempt to implement change in the Higher Education sector.
- provide perspectives valuable for administrators when considering change for STEM subjects within their environments.
• provide important information on supports required and factors of success.
• highlight the important role of interdisciplinary collaboration and a synergy of
  more than one champion throughout the phases of change.

Further research is required in this area. It is important to ask for student perspectives in order
to understand the pressures they experience during times of change in the university sector.
Further, gathering data on policy around change in these institutions and comparing this with
lived experiences would provide interesting data for the sector.

Conclusions

We have explored the challenges around enacting change in a STEM subject at an Australian
higher education institution and found that these include ‘time’, a shared understanding for
and about the change, and the level of commitment of the staff involved in the change. The
study involved the collaboration of discipline experts and professional staff across faculties
and offers a modest, but valuable contribution to exploring change in the science disciplines.
Success factors and key elements, levers that may support a more integrated interdisciplinary
approach to change were identified. The importance of resources including human (staff),
digital content and curriculum as well as scholarly resources for academic educators
delivering the change were highlighted. The benefits of bringing education and science staff
together were identified as key elements for change in the STEM sector. Interdisciplinary
collaboration was seen to be necessary for the establishment of a dynamic network of
participants engendered with multiple interdisciplinary expertise, along with a mutual respect
for and a common understanding of the knowledge, skills and experience of the collaborators.
Finally, a key element for bringing about change in STEM education is the synergy which
may arise from having more than one champion (change champion and implementation
champion) throughout the curriculum re-design, planning and implementation phases of the
change. This, along with the other findings as outlined above hopefully will influence practice for higher education institutions wishing to enact changes at a subject level.

**Ethical Approval**

All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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**Conflict of Interest**

The authors declare that they have no conflict of interest.
References


Figure Captions

Figure 1. Dynamic network of participants across the phases of the change process.