ADDRESSING DISCREPANCIES BETWEEN ASSUMED, EXPECTED AND ACTUAL MATHEMATICAL COMPETENCIES: A LEARNING DESIGN MODEL OF NETWORKED PARTNERSHIPS

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KEYWORDS: curriculum design and learning design, microcultures, networked partnerships, preparedness levels in mathematics, STEM in higher education, learning design model, networked partnerships

ABSTRACT
Curriculum design in higher education is facing the challenge of satisfying increasing industry demands while preparing commencing students to become content specialists and autonomous learners. First-year curriculum design is a pivotal point for the entire degree and issues encountered there impact throughout the degree. A key issue at the first year level is commencing students' perceived low levels of preparedness in mathematical knowledge. However, this raises a question of whether a gap exists between levels of knowledge formally assumed, expected by academics, and actually held by students.

This exploratory study investigated academics' perceptions of commencing students' mathematics preparedness for studying a Science degree. Single-case study methodology was applied and focus groups were conducted with academics teaching a first year mathematics unit. The data, through inductive content analysis, revealed important discrepancies between assumed, expected and actual knowledge of commencing students. Analysis of the data through a theoretical lenses of *learning networks* and *microcultures* then led us to develop a learning design model of networked partnerships between academics, industry, students and teachers.

We argue that our model, through collaboration between the above-mentioned stakeholders, and based on the principle of networked partnerships, has the potential to effectively influence the learning outcomes throughout the degree.

Proceedings of the Australian Conference on Science and Mathematics Education, The University of Sydney and University of Technology Sydney, 2 - 4 October 2019, pages 127-133, ISBN Number 978-0-9871834-8-4

BACKGROUND
The importance of STEM education has been acknowledged and discussed for some time now. The Australian Government has recognised STEM education as a priority for research, industry and education (ATSE, 2016; Finkel, 2016; Norton, 2016; Prince, 2016) and continues efforts to promote STEM education across all levels of the education system, including Higher Education. Australia's Chief Scientist (Finkel, 2016) has called for closer collaboration between industry, schools and universities to promote STEM education that nurtures "creativity and rigorous critical enquiry conducive to scientific progress and technological innovation" (Finkel, 2016, p. 2). Universities are expected to develop curricula that would assist their graduates in becoming analytical, critical, collaborative knowledge workers (Markauskaite & Goodyear, 2017a, 2017b), who have achieved either "broad and coherent knowledge and skills" (AQF, 2013), or "advanced knowledge and skills" in their chosen disciplines (AQF, 2013), depending on their qualification level.

With these requirements in mind, universities develop their curriculum design frameworks, write policies and clarify procedures to ensure the requirements are satisfied and students' learning experiences promote deep rather than surface learning (Clarke, Johal, Sharp & Quinn, 2016). However, curriculum design is a complex process and necessitates a balance between formal (i.e. learning and teaching approaches applied to content-specific activities) and informal (i.e. extra-curricular activities) curriculum design (Green & Whitsed, 2015; Leask & Bridge, 2013). Over the years, we have observed a certain imbalance with regards to the ways design teams are formed and curriculum design is approached. In addition to the above-mentioned formal and informal curriculum, Leask and Bridge (2013) identified a third type: “a hidden curriculum” (p. 82). The often overlooked hidden curriculum, formed by power and authority struggles within an institution (e.g. faculty, school, or discipline) (Green & Whitsed, 2015), appears to be the actual driving force behind the decisions made about content knowledge, learning outcomes, preferred learning approaches and relevant assessment strategies (Leask & Bridge, 2013, p. 82). The hidden curriculum may also influence the composition of the curriculum design team, which may not include academic teaching staff who have relevant knowledge of high school curricula and/or of the academic profiles of enrolling students. Moreover, workload allocations often make it difficult for some academic teaching team members to be included in the design teams (e.g. lecturers as opposed to Unit/Course Coordinators). Finally, the tutors are often not included in the curriculum design teams, which contributes to them being “disconnected from organizational values” (Kahu & Picton, 2019, p. 24) and might result in their low awareness of curriculum design principles and familiarity with recommended pedagogical approaches, as this group of academic teachers also often lack professional development (Kahu & Picton, 2019). In summary, the combination of above-described factors may result in an imbalance in the process of curriculum design, which can impede the quality of the curriculum design, as it contradicts calls for ensuring the universities are more “design-savvy; helping everyone in the institution participate in knowledgeable, design-led change (Goodyear, 2015, p. 37).

This obstacle becomes even more pronounced for first-year curricula, which are designed for prospective students. The intended, initial knowledge level required for first-year curriculum becomes the starting point and the reference for planning progression in terms of discipline knowledge and students’ development. Thus, the strategic positioning of the first-year curriculum makes discipline knowledge requirements a pivot for admission, with important consequences for the first-year experience of both the students and the teaching teams.

We have observed the hidden curriculum and imbalance in our practice, and presume that these phenomena impact on academic teaching teams’ members’ assumptions about their prospective students’ competencies and preparedness for studying at university. That is, we hypothesised that academic teaching teams make assumptions regarding their prospective, first-year students’ competencies levels (expected knowledge), compared to competencies levels required by the university (assumed knowledge), and students’ actual levels of competency. Furthermore, we made two subsequent hypotheses: firstly, that there were some discrepancies between *assumed*, *expected* and *actual* levels of competencies, which impeded both the students’ learning experiences and the academics’ teaching experiences; and secondly, that by suggesting a learning design model of networked partnerships, research-underpinned and evidence-informed solutions could be advanced to address the above-described consequences of imbalance in the curriculum design practices. These hypotheses led to a study that explored whether this imbalance did indeed impede the learning and teaching experiences. This paper reports on findings of the study.

PURPOSE OF THE STUDY

Our research team was involved, to different degrees, in the design, delivery and evaluation of performance of a first year core unit of study offered within the undergraduate science program at a large metropolitan university in Australia. The unit in focus is an introductory research methods unit for science and introduces foundational concepts in mathematics and statistics to develop students’ quantitative skills to analyse, simulate and model scientific data. There are no prerequisites or requirements to enroll in the degree and the unit, however a sound achievement (pass) in Queensland Mathematics B is assumed (assumed knowledge). Mathematics B is a Year 11 and 12 subject covering topics including algebra, and introductory calculus and statistics. This approach to “assume” entry requirements has been the policy of the institution for some time, and is not currently open to change. As such, studies such as the current research, which consider how to work with students’ assumed knowledge, become necessary. Although, as the figure below shows, the vast majority of students in the present unit of study report that they do meet the assumed knowledge requirement.

An analysis of commencing students’ demographic data, including their highest level of qualifications, revealed that the vast majority of enrolled students fulfilled the enrolment requirements of assumed knowledge. Figure 1 summarises the demographic data of students’ qualifications levels.

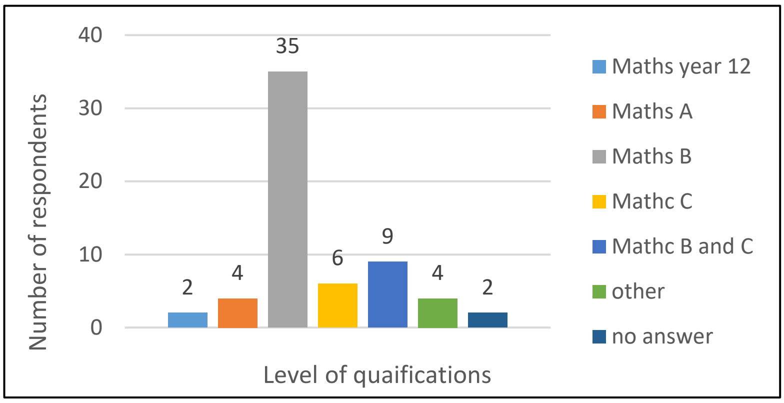

Figure 1: Demographic data of enrolling students' level of qualification (*n* = 60).

Considering the fact that the unit under investigation makes a direct reference to the content knowledge of the high school curriculum, our team was vitally interested in investigating academic teaching teams' opinions about their students' preparedness levels in terms of content knowledge. Thus, we formulated the following research questions:

1. What are academic teaching teams' opinions about:
   a. Commencing students' *actual* levels of competencies in mathematics to study science?
   b. The level to which commencing students satisfy the requirement of assumed knowledge in mathematics to study science?
2. What were academic teaching teams' *expectations* in regards to commencing students' level of competencies in mathematics?

METHOD

This exploratory project (Cohen, Mannion & Morrison, 2007; Yin, 2003) investigated the particular instances of an introductory unit of study in quantitative research methods for science. For this reason, we chose a single-case study (Yin, 2003) as the most relevant design. To ensure deep exploration, we employed the focus group method to collect the data. The following specific semi-structured question (Saunders et al., 2009) was formulated:

> In your opinion, are the commencing students prepared, in terms of levels of mathematical content knowledge, to study a science degree?

Three academic teaching staff out of four participated in the study, all with teaching experience ranging from 1 year (tutoring only) to 5 years of teaching, lecturing and tutoring. On average however, the respondents had 1-2 years' experience, predominantly in tutoring. The group was composed of two tutors completing their Mathematics degree at Honours level and one lecturer with a PhD qualification in statistics. None of the three participants were involved in curriculum design, and only one participant (lecturer) was in direct contact with members of the original design team. This provided an excellent opportunity for testing our hypothesis about the negative effects of the imbalance in the curriculum design practices (i.e. composition of the design teams), impeding learning and teaching practices. Teaching teams were provided with the relevant documentation specifying the content and approaches to learning and teaching; however, no specific training/ developmental activities were offered.

Data collection took place over one week, and closely followed the protocols described in the Ethical Clearance. The focus group was audio-recorded, transcribed and analysed using an in-depth inductive content analysis method (Elo & Kyngäs, 2008). That is, the transcriptions of focus group were coded to identify categories of meaning, overarching opinions encompassing recurring terms and/ or key words.

FINDINGS

In response to the research question, the analysis revealed that the academic teaching teams held three overarching opinions regarding commencing students' actual, assumed and expected levels of mathematical competencies:

1. Commencing students possessed a low level of preparedness in terms of mathematics content knowledge and competencies, and they had unrealistic expectations in terms of the mathematical content of their degree (opinion on commencing students' actual competencies level);
2. The university's approach of stating assumed knowledge was somehow misleading. It appears that the academic teaching teams thought that the commencing students were somewhat misled by the assumed knowledge requirement which implied that students were at appropriate level of mathematical content knowledge and competencies to study science (opinion on effects of assumed competencies level);
3. Academic teaching staff's expectations with regards to commencing students' preparedness levels were incorrect (opinion on expected competencies level).

OPINION 1: LOW LEVELS OF COMMENCING STUDENTS' PREPAREDNESS LEVELS IN TERMS OF MATHEMATICS CONTENT KNOWLEDGE AND COMPETENCIES, AND UNREALISTIC EXPECTATIONS

The analysis of academic teaching staff's responses suggested that many academic educators thought that students selected the science program as an opportunity to have a STEM-related degree, without the need to learn mathematics. For instance, one respondent stated:

> *I think one of their expectations is probably that they are not going to have to study a huge amount of mathematics and statistics because their degree only really, officially contains one maths and stats unit for most of students who will go through it. And any additional mathematics they have to learn they expect it to be as easy as it has been in high school. The extension of high school mathematics.* (Staff 1, lines: 43-47)

This response also suggests that academic teaching staff thought that students were expecting mathematics to be "as easy as it has been in high school". This comment leads to three possible interpretations. First, the academics made strong, yet unverified opinions about their students' motivations to study a science degree (none of the academics actually researched students' motivations to undertake their degree). Second, the academics thought that students expected mathematics to be "easy", and third, that mathematics at high school level was "easy".

Furthermore, in the academic educators' opinion, the problem rested with low levels of students' preparedness and their awareness of mathematics requirements. One respondent summed up this issue in the following way:

> *I think we need to be upfront with students about this. They should have the option to opt out and enroll in "the catch up unit", like that I would not have to struggle with students who do not understand maths.* (Staff 2, lines: 263-265)

This comment also illustrates an opinion held by academics on the teaching teams that the university's requirement that assumed knowledge (rather than specific prerequisites) was misleading for students.

OPINION 2: MISLEADING REQUIREMENT OF ASSUMED KNOWLEDGE

It appears that the requirement to state assumed knowledge was indeed misleading for both students and academics. Students thought that their content knowledge and competencies were at an appropriate level, as they were accepted and allowed to enroll in the degree. By contrast, academic teaching teams commented on the necessity of teaching the unit content "in parallel" with the assumed knowledge content; that is, teaching in a way that explicitly enabled students to catch up on assumed content knowledge while also covering the new content knowledge. When reflecting on this challenge, one respondent remarked:

> *I think it was just an entire semester playing catch up, trying to teach them the content, catching up with two years of school. Like, we were trying to teach them like three months solid content, and that's just exhausting* (Staff 3, lines: 93-95).

Academics also commented directly on the lack of prerequisites. In their opinion, the requirement of assumed knowledge is misleading to many prospective students who do not realise the importance of their actual level of competence in mathematics to what they will learn in science degree. One respondent described this problem in the following way:

> *Students are coming and saying "Oh, I didn't know that I need maths". Maths is an assumed knowledge, therefore it's probably "OK, we are going to do some maths", but I don't think they are coming and expecting to learn new mathematics that they have not seen before* (Staff 2, lines 57-60).

It appeared that the lack of prerequisites was a particular source of frustration to the academics in the study, who pointed towards this factor as the main reason for organising catch up and teaching "in parallel":

> *Honestly, I think if you are not expecting science students to come with the mathematics skills, and you don't have the capacity of selecting them, then you are passing too much time on helping them to catch up* (Staff 1, lines 80-82).

One of the potential sources of the above-identified frustration was the academic teaching staff's familiarity with the high school curriculum and their interpretation of the actual knowledge held by enrolling students. This leads to the third identified opinion, which is related to commencing students' expected levels of mathematics preparedness by academic educators.

OPINION 3: ACADEMIC TEACHING STAFF'S EXPECTATIONS WITH REGARDS TO COMMENCING STUDENTS' PREPAREDNESS LEVELS WERE INCORRECT

Academics expected commencing students' levels of competence to be higher than they were in reality. However, when asked about the level of difficulty of the content knowledge of the unit (i.e. was the unit "too hard"?), all respondents agreed that the content knowledge appropriately catered for the needs of the degree and aligned with other units' content knowledge, assuring students' developmental progression. For instance, one respondent remarked:

> *There is no problem with the content. I don't think the unit is targeting badly, that it is addressed to students with good maths skills and makes leave [sic] students with not so good maths skills. I think that the unit is OK. Some of them may drop off because they find it too difficult, but some might bite through it [sic] and try to get those skills back or catch up* (Staff 1, lines: 64-67).

This comment suggests that academic educators were convinced that the mathematical content knowledge was designed at the appropriate level. Thus, it seems that from their perspective, problems with students' progression were associated with (some) students' low mathematical competencies rather than with the curriculum being too demanding or their expectations being too high.
In summary, academic teaching team members appeared to be confused with regards to assumed and actual student knowledge, and expected a different (i.e. higher) level of competencies than the actual level.

DISCUSSION

The findings appear to confirm our initial hypothesis about the discrepancy between *assumed*, *expected* and *actual* levels of competencies, which impeded both the students' learning experiences and academics' teaching teams' assumptions. However, this exploratory study is only indicative, due to the small number of research participants and their relative inexperience. Although this is an important limitation, it nevertheless identifies areas for further research and points to potential solutions. For instance, the identified discrepancy that may have resulted from the above-identified imbalance in the process of curriculum design, suggests a need for the re-consideration of the learning design process. Thus, we propose two interdependent solutions.

First, we argue in favor of developing a model of informal professional development activities (PDAs) offered to all teaching team members, which would enhance academic teaching teams' understanding of the reasons behind the curriculum design, its principles and key points. The PDAs would also encompass specific training in learning and teaching practices, including task design and teaching strategies. Second, we propose the use of the concept of *microcultures* (Heinrich, 2017; Roxå & Mårtensson, 2015) to enact such a PDA. A *microculture*, or workgroup, can be described in terms of a multidisciplinary team of specialists who function at a meso-level of higher education (Trowler, 2008) (i.e. discipline/ unit of study) (Czaplinski et al., 2017; Fyfield & Czaplinski, 2017; Winter, Czaplinski, Apps & Mallet, 2018). A *microculture* has a flat structure and does not reflect organisational hierarchies (Fyfiled & Czaplinski, 2017; Heinrich, 2017) and the collaboration is founded on three heuristics (Roxå

& Mårtensson, 2015, p. 198): *trust*, *shared responsibility* and *developmental agenda*. Such an open environment provides a non-threatening platform for *significant conversations* (Roxå & Mårtensson, 2015) that occur during structured, yet predominantly informal, catch ups, with formal meetings set up for project management purposes.

Inspired by the Activity-Centred Analysis and Design (ACAD) framework (Goodyear & Carvalho, 2013, 2016), building on the concept of epistemic fluency and diverse knowledges (Markauskaite & Goodyear, 2017a, 2017b) and on our previous work (Fyfield & Czaplinski, 2017; Winter, Czaplinski, Apps & Mallet, 2018), we suggest applying the model of *connected microcultures* to address the identified discrepancies, resulting from the above-described imbalance in the curriculum design. The model fosters academic teaching teams' familiarity with the requirements of the *assumed* knowledge, addresses the problem of academic teaching teams' assumptions in relation to the *expected* knowledge, and prepares them for teaching students with knowledge of their *actual* competence level in mathematics. The proposed model is composed of two *microcultures* and a more formal community of partners, or *community of epistemic fluency*:

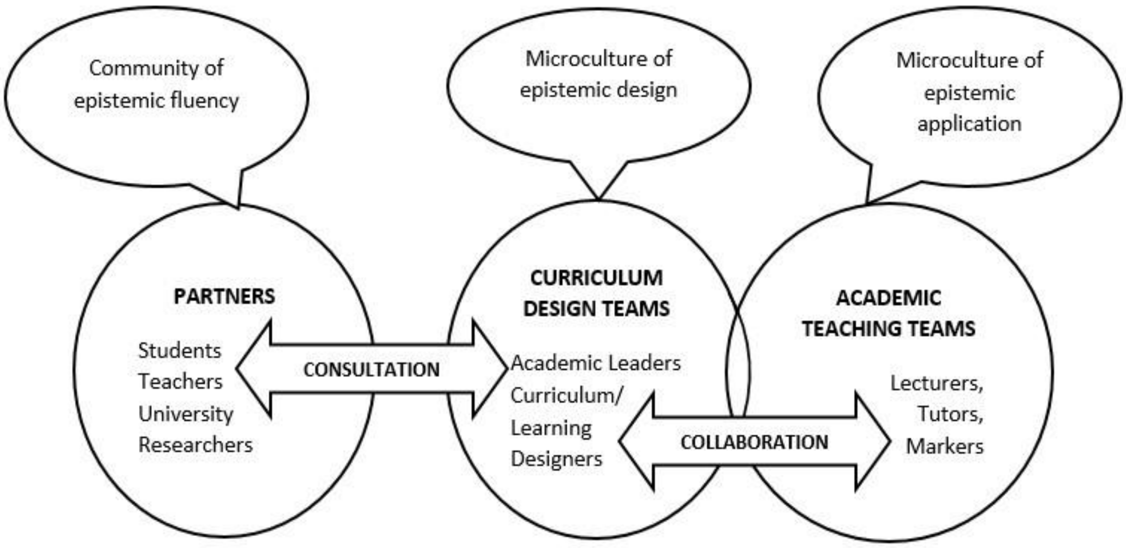

Figure 2: Model of connected microcultures and community

In the centre of the model is the *microculture of epistemic design* that encompasses original curriculum design team members, and specialists in curriculum/learning design (e.g. leading academics, curriculum/learning designers). They closely collaborate with each other and with the members of the second *microculture*, the *microculture of epistemic application* composed of academic teaching team members (e.g. lecturers, tutors, markers). The important factor is that the members of this *microculture* closely collaborate with each other *and* with the members of the first *microculture*. Finally, academic leaders and partners representing diverse knowledges, constitute the *community of epistemic fluency* that is consulted by curriculum design teams on formal and regular basis.

The model we propose offers the opportunity for experts to work in partnership, through *significant conversations*, with curriculum design teams on developing learning experiences for students. The model also provides a platform for the three heuristics to be enacted and the *developmental agenda* to be fostered, as it promotes prosocial values (partnerships), broadens participation (many partners), and enables epistemic fluency (diverse knowledges). In short, the model offers a plausible solution to the above-identified problem of discrepancy between actual, assumed and expected levels of mathematical competencies resulting from the imbalance in the curriculum design.

CONCLUSION

This indicative study, in relation to the identified discrepancy between *assumed*, *actual* and *expected* competencies of students commencing their science degree, indicated that some members of the academic teaching teams had limited and/or biased knowledge of the high school curriculum and the actual level of mathematical competencies of commencing students.

In response, a model of collaboration between curriculum design teams and academic teaching teams has been proposed, which encourages teams of more experienced partners coming from diverse sectors to collaborate, using a *microculture* model, and design learning experiences that respond to the above-quoted call for "greater collaboration between higher education providers, industry and schools [to] help all three sectors understand and adapt to fast-changing needs" (Finkel, 2016, p.1).

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