MAPPING SCIENCE SUBJECTS: A GROUND UP APPROACH

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ABSTRACT

The need to clearly demonstrate the components and outcomes of a curriculum is a major factor in the drive for quality assurance manifest across the tertiary education sector. This project is a detailed gathering of commentary and data about the subjects offered in the Faculty of Science, University of Wollongong (UOW). The project aims to provide a means of tracking concept and skill development through curricula, to identify sharable resources and teaching practice, to clarify support needs and to provide a means for storing and maintaining an ongoing record of commentary and data about each subject. The investigative approach is a type of curriculum mapping based on interviews with key players in the design, delivery and reception of the curriculum. In the process all available materials and data about each subject were gathered.

The methodology has been developed and used first for mapping of subjects within the School of Chemistry, providing a tested and flexible process to facilitate the investigation in the other Schools in the faculty. For Chemistry subjects a dataset of information is now available from which developments in curriculum and teaching management are proceeding. From staff and student interviews and our collective experience we can also report valuable commentary.

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INTRODUCTION

There is a prevailing drive for quality assurance in teaching and learning across the tertiary education sector. This is bringing to the fore development of various methodologies for the documentation and mapping of all components and outcomes of curricula. Within this context the motivation for this project was to find out as much as possible about the subjects[1] offered in the Faculty of Science at the University of Wollongong from multiple points of view, investigating, developing and employing a variety of curriculum mapping and analysis techniques and procedures in the process.

There is a great diversity in rationale and methods for curriculum mapping reported in the literature, depending on the focus of a particular project, the stage of curricula development and the perspectives of those involved. Curriculum mapping is carried out to follow any characteristic of a degree program through that program to ensure coherency (O'Neill, 2009). Where a program consists of various modules, especially some from different disciplines or faculties, it is essential to ensure the sum of the parts makes the desired whole in all aspects of curriculum content, delivery and assessment. Mapping is often focussed on generic or graduate attributes and/or skills (Aabakken & Bach-Gasmo, 2000; Hege, Siebeck & Fischer, 2007; Plaza, 2007; Robely, Whittle & Murdoch-Eaton, 2005; Ross, 1999; Wachtler & Troein, 2003; Willett, 2008). Mapping is also an essential first step in the process of aligning the intended, the delivered and the received curricula (Bath, Smith, Stein & Swannet, 2004; Bruinsma & Jansen, 2007; Harden, 2000; Plaza, 2007; Robely et al., 2005; Wachtler & Troein, 2003). Less widely acknowledged is the importance of explicitly collecting data from students, for example by incorporating survey data into the curriculum mapping dataset (Bath et al. 2004; Bruinsma & Jansen 2007; Plaza 2007; Wachtler & Troein, 2003), which suggests that the received curriculum may not always be taken into account.

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[1] *Terms: (i) 'subject' is used at UOW to designate a unit of study for which credit is gained, 'subject' here does not refer to the topic, field, discipline or area of study; (ii) 'course' is used to designate the complete degree program, composed of 'subjects;' (iii) coordinator is the academic staff member primarily responsible for the discipline content, design, teaching and delivery of a subject; (iv)'subject outline' is the document distributed to students enrolled in a subject, describing the topic, syllabus,timetable, lecturer's contact details, learning outcomes, assessment tasks and marking criteria, modes of delivery, and relevant institutional policies.*

Three of we researchers are academics who represent very different roles within the University of Wollongong. Because of the diversity of our interests and our work in the University, we wished to gather commentary and data for many purposes. Christine Brown, Academic Services Division, has responsibility and interest in ongoing professional development of discipline based colleagues, and via this project seeks to assist academics expand their understanding of the curriculum and its relation to their own research. Emily Purser, Learning Development Unit, has responsibility and interest in the development of student academic literacy. Glennys O'Brien is Director of First Year Studies in the School of Chemistry and came to the project with an initial need to map the curricula in subjects which followed on from First year Chemistry, both within and without of the discipline. The fourth member of our team, Lorna Jarrett, has a background in science (physics) pedagogy and is currently enrolled in a PhD in science education.

The Teaching and Learning institutional structure at this University includes a tier at faculty level called the Faculty Education Committee, responsible for overseeing teaching and learning within each faculty. The Academic Services Division has staff representatives on these faculty committees. The Education Committee of the Faculty of Science (FEC) was the original forum from which this cross-disciplinary investigation arose, made possible by the connection of these three academic researchers and others on that committee. Furthermore, discussions within that committee had uncovered various faculty needs for information regarding teaching management and support across the subjects and degree programs offered by the faculty. Thus the FEC and the particular representatives on it at the time, their roles, their individual experience and especially their engagement and sense of greater purpose, was the catalyst for the project and the reason that it has a broad perspective.

PROJECT AIMS

Generally curriculum mapping projects reported in the literature cover degree programmes as a whole. In contrast, this project has a ground up approach, gathering data and commentary about the individual subjects offered by the Faculty of Science. Thus this project is not so much course curriculum mapping, rather it is a detailed survey of subjects offered by the schools in the faculty for multiple reasons designed to inform many players and accompanied by the evolution of a robust yet flexible methodology.

The primary purpose is to ensure students' adequate development of core and transformative discipline concepts and skills by identifying and tracking where these are introduced and how they are elaborated from first to third year subjects and beyond. This ground up approach is important from the point of view that the subjects are part of a variety of degree programs, both within and outside of the Faculty of Science. The gathered data allows examination of whole degree programmes or any suite of subjects offered by a school or department for consistency of approach in any aspect of the curriculum offered. There were several other purposes for the project:

- To engage staff in rich conversations about their subject and their teaching.
- To provide the schools and the faculty with data to assist development, review and quality assurance at any level of management.
- To identify impediments to learning so as to facilitate and improve collaboration between faculty, academic services and other projects (eg, resources for mathematics support) offering student support.
- To identify, develop and share the mapping methodologies.

The sequence of the investigations was determined by the fact that although there are three schools within the faculty, the researchers began with gathering data and commentary on the subjects offered by the School of Chemistry, because one of us was based in that school. Thus the specific objectives of this first round of the investigations were:

- Develop and test the methodology
- Establish the data set for Chemistry subjects
- Record details of the experience of the investigators to inform the latter parts of the project.

Specific outcomes reported in this paper are focussed on the science discipline perspective, other findings will be reported elsewhere. We report on the methodology, curriculum outcomes and commentary in chemistry and we reflect on valuable findings of the emerging process and our collective experience.

METHODOLOGY

This section describes (i) gathering of information and commentary, (ii) analysis of recorded interviews and discussions, and (iii) storage, analysis and use of subject data. This investigation has ethics approval from the UOW Human Research Ethics Committee.

GATHERING DATA

The gathering of commentary and data about each subject was carried out by a variety of methods, chief of which was a recorded interview with each subject coordinator concurrent with assembling available materials for that subject. The form of the interviews resulting from our cross disciplinary deliberations was a short list of 7 areas of concern and related questions to generate focused discussion with the teaching academics. To conduct the interviews two or three of the researchers visited each academic in their own office; offering an opportunity for discussion and reflection that busy academics do not normally get in their daily practice. The engagement was structured so as to be easy, pleasant, interesting and fruitful for them as well as for each of us.

We have chosen an active interview stance (Holstein & Gubrium, 1997) in order to foster collegiality and to engage staff in deep conversations in both education and discipline terms. Sumison and Goodfellow (2004) caution against the use of superficial approaches, and highlight the need to develop sensitive techniques to allow for nuanced responses from staff. Further, the interview process with guide questions and concurrent gathering of data was established in order to minimise commitment of staff time.

The issues and their guiding questions for the interviews related to:

1. *Subject scope:* core concepts, 'transformative' concepts, skills or competencies developed.
2. *Learning outcomes:* specific objectives or learning outcomes.
3. *Assumed knowledge/ skills:* essential knowledge or skills assumed, pre-requisites.
4. *Maths concepts/ skills:* key mathematical concepts needed.
5. *Available learning and teaching resources:* sharable resources.
6. *Obstacles to student learning:* key areas which are repeatedly difficult, main obstacles.
7. *Relationship to the Graduate Qualities:* particular graduate qualities developed?

Data sources:

- Recorded interview with subject coordinator
- Recorded focus group discussion with students
- Subject outline
- Lab manual / subject handbook
- Other resource materials such as tutorial materials, support materials and assessments.

Participants:

- Interviewers: usually two or three researchers, not just the faculty researcher alone.
- Interviewees: School of Chemistry academic staff as subject coordinators.
- Other lecturers: School of Chemistry academic staff providing content summary.
- School of Chemistry technical staff reporting on use of instrumentation in teaching laboratories.
- School of Chemistry lab technical staff summary of lab administration of subjects.
- Focus group Oct 2009 participants: Students from CHEM101/102, 2008, with P or C grade (P or PASS = 50-64% total mark, C or CREDIT = 65-74% total mark).

Information and data about subjects were also gathered informally. Academic staff members provided summaries of content they delivered in subjects they taught in but did not coordinate. Teaching laboratory staff, who are not often thought of as teachers but have a significant teaching role, helped researchers develop a summary of undergraduate instrumentation experience and laboratory management. It is important to recognise all involved in teaching and ensure a space for their input and perspective.

To date student input on chemistry subjects has comprised of two focus group discussions with students a year after they had completed first year chemistry. Students were asked to volunteer for discussion in focus groups if they had achieved a pass grade (P, 50-64% final mark) or a credit grade (C, 65-74%) in CHEM102 the previous year. Credit or Pass students were sought as these students were considered able to reveal most how they struggled with current and past chemistry or chemistry dependent subjects. These students were sought from the subjects BIOL214 (The Biochemistry of

Energy and Metabolism), CHEM213 (Physical Chemistry) and CHEM214 (Analytical and Environmental Chemistry).The focus groups were held over a lunch hour in week 12 of Spring session 2009, with the students taking on pseudonyms and the discussion recorded.

ANALYSIS OF RECORDED INTERVIEWS AND FOCUS GROUP DISCUSSIONS

The qualitative analysis method for the recorded staff interviews and recorded student discussion groups was informed by Boyatzis (1998), Gubrium and Holstein (2001), Mertens (2005), Pope, Ziebland and Mays(2000), and Rubin and Rubin (2005).

Analysis was done by a researcher who did not participate in the majority of the interviews and who does not teach in the School of Chemistry. The purpose of this choice was to minimise the possibility of the researcher being unduly influenced by pre-existing ideas and assumptions. Interviews were audio recorded but not transcribed. This was because of time and budget constraints but also because the interviews had been designed to cover a number of areas of discussion and collect data that, while not applicable to the research reported here, would be required in other parts of research program; thereby avoiding the need to ask staff to participate in multiple interviews. Each interview was listened to at least three times in its entirety, and sections where discussion focussed on the topics under study were transcribed. On the first occasion, the interview was listened to with minimal pauses in order to gain a general impression of the topics of discussion. During this time brief notes were made of possible themes and significant sections, with times noted in minutes. This approach was informed by the work of Pope et al. (2000). About one week later each interview was listened to again and the order in which interviews were listened to was varied, again to minimise the influence of pre-existing perceptions. Before the second listening, the notes made during the first listening were read. A spreadsheet was used to make notes during the second listening. Analysis focussed on areas of discussion relating to details of subject content, skills taught, assumed knowledge, assessments, resources which could be shared and transformative concepts. However, other segments were included which were considered to be significant to the delivery of curriculum. These included: issues with which students struggled; perceptions of the subject by staff or students; and things that teaching staff found rewarding or frustrating. Each of these interview segments was transcribed and assigned one or more codes. Codes were allowed to emerge from the data: this initially produced a large number of codes which were organised into categories.

After completing this process for all interviews, the spreadsheet notes were read and the interviews listened to again to ensure that segments under study were represented accurately and in sufficient detail. During this time the codes assigned to each segment were refined if necessary.

A second simpler analysis was also conducted by the discipline researcher who listened to all recordings at least once and also focussed on the coding and time mapping from the first analysis to specifically identify issues with possible remedial action at first year.

Limitations of the data analysis method include the possibility that the researchers may have failed to identify some relevant data, leading to bias in the findings.

RECORDING AND ANALYSIS OF SUBJECT DATA

The original intention of the project was to store data within a content management system (CMS) which would be the repository for identified sharable resources and which could potentially allow some data analysis and mapping. This system was not to become available within a practical timeframe, so researchers began with spreadsheets to store the data and perform some simple data searching and analysis. Due to the fact that access to a CMS was anticipated, it was decided to store the data in spreadsheets rather than take the intermediate step of entering it into a database. Use of a database would also have made the data more difficult to access for staff not familiar with using a database.

One spreadsheet was developed for chemistry subjects, within which several different worksheets were developed to cover different areas of details. The data gathered from each subject were entered into this spreadsheet. Worksheets were made for (1) subject outline data, (2) content synopsis, (3) lab manual experiment details (4) instrumentation usage. In each worksheet one row is used for the data of each subject under various headings in the columns. The worksheet for lab details gathered from lab manuals provides multiple column entries for each experiment or lab activity as well as columns for more general data such as support materials available.

In terms of deriving information from the spreadsheet, a Perl based single user web application to search the content of the spreadsheet for qualitative data analysis has been developed (Diment& Trout, 2009). No further specific tools for reporting from the spreadsheets have been developed to date. Although the spreadsheet is large, there are valid reasons for not moving on from this yet:

- Spreadsheets are easily accessed and read by virtually all who would be involved in any way.
- The total number of CHEM / NANO subjects covered is 19, this has not proven unmanageable.
- Document control is maintained by a lead person, those with data entry roles are limited and other users read or use the data.
- Worksheets can be easily copied and rows and columns manipulated into another pattern to answer new queries.
- Some data processing and reporting is possible via development of macros.
- The School of Biological Sciences will use the methodology, but are developing their own suite of worksheets, some of which will be in common with those for Chemistry.

This experience is in common with that of teaching support staff at Curtin University who have developed subject mapping and planning tools using spreadsheets (Oliver, 2010).
As yet sharable materials reside still with coordinators within materials for individual subjects. In the long term these will become available to multiple subjects via the CMS which will support the learning management system. Links will be made from various subject eLearning sites to this repository.

OUTCOMES

The methodology for data gathering, storage and analysis has proven reliable, worthwhile and strong. This suite of procedures is now being used for mapping BIOLXXX subjects, with some simple modifications to suit the requirements of that school.
There is now a data set of information for chemistry subjects gathered into the one spreadsheet, accessible to all staff. Tracking of concepts, skills, various laboratory activities, assessment types from first to third year is now possible. The School has begun various deliberations using this data and associated commentary:

- Development of coherent management of assessment and related policies for laboratory classes across CHEM2XX subjects.
- From both staff and student commentary, there is a very clear indication of problems associated with lack of mathematics skills, in terms of the simplest of algebraic manipulations.
- Due to the value of student commentary from focus group discussions, it is intended to initiate a program of such conversations with a broader group of students carried out once a semester continuing throughout their whole degree.

PROVIDING CLEAR CURRICULA

Clear explicit mapping of concepts and skills in a subject and through a progression of subjects in a discipline helps students to link together concepts learnt in different settings. With this in mind, we formulated our main project aim which was to ensure adequate development of core and transformational skills and concepts. In order to achieve this, we have included gathering data specifically about concepts for each subject. Somewhat surprisingly at times this was not straightforward because, *"as the coordinator of the subject you do not necessarily know everything that is being taught* (in your subject) *because you do not have a copy of the lecture notes ... What we don't have is a one page summary of every single topic area."* Coordinators find they do not know the details of all content taught in subjects they are coordinating. Some coordinators had planned to gather such details, in fact this project is helping to fill the gaps.

In fact analysis of commentary shows that academics do not have the opportunity or the time to look closely at what is happening in the subjects they do teach in or related subjects. Subject coordinators are unable to join the components of a subject together, even less so illustrate connections between subjects, allowing such connections to be made explicit to students. This situation points to an overall lack in the information provided to students about discipline specific subject clusters and whole degree programs, where concepts and skills have not been explicitly woven together.

Outcomes from this lack of connectivity for weaker students were highlighted by focus group commentary and exemplified by one student, Jane: *"Sometimes when it (the concept or procedure or calculation) is taught or explained in a different manner, it does not really connect with the way* (I have learnt it before)*... and I just think what is this guy talking about. It is completely different from what I thought."* (With intoned agreement from another student, John.) While high distinction students will make the necessary connections themselves, struggling students need explicit details, commenting that it can indeed be confusing to have the same concept presented from a different angle. This is of concern, because presenting a concept from different points of view is generally perceived as a powerful learning tool. However, when differing approaches to a particular concept are not apparently compatible, because staff are unaware of the details of concept presentation and application in other subjects, there is a clear negative impact on students struggling coming to terms with this concept.

From the chemistry subjects dataset we can now track development of concepts and skills. Derivatives of this mapping for specific subject clusters and/or degree courses can now be developed by subject or year or degree coordinators and made available to staff and students alike. In addition from staff commentary, we have identified the more general core and transformative concepts which can be regarded as the glue needed to bind subjects together. It is frequently the case that these are not made explicit and yet these could provide an ideal framework within which to cross reference detailed concepts and skills among subjects.

OUTCOMES FOR FIRST YEAR CHEMISTRY

Of particular interest to one researcher is commentary indicating where developments in first year chemistry can be made to better assist student learning. Chemistry staff teaching in second and third year subjects comment that students struggle most due to their inability to recognise and apply first year content. As a result coverage in some second year subjects (notably Physical Chemistry) includes time spent reviewing first year material and consequently less new material is covered. Some staff have made first year chemistry resources available for revising (2nd year Analytical Chemistry) where, ideally, second year students would go over this material before session starts. However it is notable that weaker students tend not to use such resources till they perceive a need.

Focus group discussion analysis revealed related concerns from the student perspective. It is often not clear to students why certain concepts and skills taught in first year chemistry are relevant to their later studies. Some students, especially those in applied degrees, were convinced first year chemistry finished at the end of their first year, and were influenced by comments from older students in the same degree program to the effect that *"as you get more ...into your degree, you won't use the chemistry knowledge."* Science faculty students do have a better perception that material learnt in CHEM101/102 will be used, but some reported reliance on memory rather than referring back to saved materials. As a result both groups of students appear to haphazardly manage their collection and storage of materials to assist future application of concepts and skills learnt at first year. In fact several students discarded what we would have perceived to be valuable materials. These same students, by the end of their second year, were of the mind that *"teachers should enforce the fact that you will need and use this knowledge throughout your degree."*

As a result of this commentary, further development of strategies in CHEM101/102 are planned to enhance content structures and systems already in place, encouraging students to cross reference subject content, concepts, examples, calculations, lab experiments. Provision for content cross referencing is already made via formatting of space within the subject handbooks, however to date little direction has been given about the use of these allotted blank spaces, and informal observation shows the use to be highly varied with some students not using the spaces at all. There is a need to provide structure to these spaces, and examples and advice to students in recording notes and adding cross referencing. Thus content already delivered via lectures in a clear and explicit framework will be more clearly linked to other learning activities and study and, ideally, the whole ordered package retained for reference in later years.

Further, because of the detailed mapping available, explicit concept linking to second year chemistry subjects is now possible. Over the next few months, biochemistry subjects BIOL213/214, will also be mapped, this will allow explicit connections between CHEM101/102 and BIOL213/214 to be made.

CROSS DISCIPLINARY EXPERIENCE

From our experience we can also write that although this research team may be viewed as diverse, in fact each speciality makes a valuable contribution to all aspects of the project and this diversity has been a strength rather than a weakness. Notwithstanding the contribution of each, there was a certain necessary momentum gained by the project when an academic staff member of the faculty and based in one particular school came on board as a major player. We would say it is essential to have such a member as part of the team. This helped open the way for approaches to be made to staff for the detailed interviews. This also provided the team with one researcher who had detailed discipline knowledge, detailed knowledge of the subjects and courses in the School, teaching and coordination experience over years 1 to 3, and sufficient standing in the school to gain the time commitment of research active busy academics. This researcher was also able and willing to commit to this research as their own research per se. We would advise that each school will need a leader as champion for the project and a keeper of the information base (spreadsheet), who collects up any extra new data each year after a subject has been delivered and maintains the information base as a living document.

CONCLUSIONS

There is now a valuable data set of information for chemistry subjects taught at UOW derived from a very detailed analysis of gathered information from and commentary about the subjects. This data set is already proving useful in teaching management. There is also now an established and flexible methodology to develop such a dataset for subjects offered by the other disciplines within the faculty. From our experience mapping curricula at the subject level is proving to be a very worthwhile and interesting exercise as the richness of information available in the commentary and data becomes apparent. The definite sense of collegiality and sharing between the researchers and the interviewed staff, all of whom have intensive research programs, was also very encouraging.

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