A Framework for Integrating Concept Maps into Higher-order Learning Units in IT Education

Rainer Wasinger¹, Andrea Adam², Winyu Chinthammit¹, Judy Kay³, James Montgomery¹
1. School of Engineering and ICT; 2. Tasmanian Institute of Learning and Teaching
The University of Tasmania, TAS, Australia.
3. School of IT, The University of Sydney, NSW, Australia.

ABSTRACT
Concept maps are graphical tools for organizing and representing knowledge. In this paper, we outline how concept maps are being integrated into the summative assessment tasks of a Human-centered Computing unit called ‘Mobile Application Development’. Our work looks at the possible benefits that this integration of a higher-order learning tool can provide to students (e.g. for organizing their thoughts throughout the semester and staying on top of their workload) and to teachers (for teaching and assessment purposes). This is extended upon with a proposed generic framework for integrating concept maps into higher-order learning units throughout Information Technology (IT) education.

Author Keywords
Concept maps; higher-order thinking; methods of teaching and learning

ACM Classification Keywords
H.5.2. Information Interfaces and Presentation: User Interfaces–Evaluation/methodology, Theory and methods.

INTRODUCTION
If universities are to survive, they must look to the quality and relevance of their teaching activities in ways that they never have before [2]. Concept mapping is a higher-order learning tool that has been successfully used in a variety of disciplines - including Engineering [25] and IT [11] - to facilitate students with the formation of deep knowledge and to help students attain meaningful learning [10].

Universities today are under increasing pressure from a number of external influences, including mass demand for higher education, reduced public funding, and students who are paying more for their education [5]. With this realisation, it has become imperative that universities engineer better learning outcomes for their students if they are to survive. A recent report on global trends notes that the challenge of ‘massification’ in the higher-education sector (i.e. bringing education to a mass audience) has in most countries had an overall lowering of academic standards [2]. In Biggs & Tang [5], there is strong emphasis on the need to cater for a growing divergence in student academic levels. This can be achieved by “good teaching” that narrows the gap between academic differences in students, by “getting most students to use the level of cognitive processes needed to achieve the intended outcomes that the more academic students use spontaneously.”

In 1976, empirical research by Marton and Saljo [12] identified two different student approaches to learning: deep learning and surface learning. As Biggs & Tang [5] point out, whereas deep learners set out to understand the ‘big picture’ of what they are learning and how the facts and details make up this big picture, surface learners tend not to focus on the overall meaning and end up less able to comprehend the underlying themes, instead remembering only a list of disjointed facts. Biggs & Tang [5] argue that active teaching methods are particularly useful in today’s university context because they require students to question, to speculate, and to generate solutions, so that students are encouraged to use higher-order cognitive activities. Concept mapping is one such tool for developing higher-order thinking (i.e. deep learning) [25], and is the basis for our proposed change to the assessment tasks in IT and Human-centered Computing units like ‘Mobile Application Development’.

THE ‘MOBILE APPLICATION DEVELOPMENT’ UNIT
Mobile Application Development [23] is a third year unit in the Bachelor of Information and Communication Technologies (ICT) at The University of Tasmania. It is a unit that is taught in person at Launceston and video-linked to Hobart. The class size in 2014 was 45, with 5 students in Launceston and 40 students in Hobart. Facilitation of the classes is supported by academic staff who are present during lectures and tutorials on each of the two main campuses.

A first hands-on experience with concept maps
In 2014, the first 30 minutes of each lecture was devoted to the discussion of class readings, which - due to the rapidly changing nature of the field - substituted the need for a textbook in the unit. Students were provided with one or more research articles that they needed to read each week and then create a concept map for as homework. These articles covered a range of topics including: theory on mobile and ubiquitous computing; its application to the real world; user interface and interaction design; user experimentation; and readings on a specific topic of implementation, which in 2014 was health and exercise. The first reading that students were provided with was on the theory underlying concept maps and how to
use them [17]. The first tutorial was devoted to concept mapping and provided students with brief instruction into their use and practical exercise into their application.

The weekly 30 minute discussion sessions were structured such that students were meant to have read the readings beforehand and come to the lecture prepared with their concept map in hand, containing the core concepts and key ideas presented in each of the papers that they read. During the discussion sessions, students formed small groups of between two and four people and discussed a number of questions that the teacher made available during the class. This was done as group work and both the individual concept maps and group answers were then collected by the academic staff at the two campus locations.

In addition to the two hour seminar each week, students also had a two hour lab. The seminars were structured similar to a traditional teaching approach in which theory is “lectured” to the students, though this form of teaching was accompanied by the 30 minute break-out sessions at the start and a number of in-lecture activities and exercises that were used as the basis for high-impact learning opportunities for the students throughout the semester. Tutorials were used to provide the students with practical hands-on time with the unit’s content. Whereas the lectures were broad in coverage, the research papers (all directly relevant to what the students were learning) focused on specialised topics in the field of human-centered computing and specifically ubiquitous and mobile computing.

First results from the use of concept maps in the unit
In 2014, the use of concept maps as an active learning tool was not tied to summative assessment grading, and after the first few weeks, student completion of the weekly concept maps dropped significantly; so too did the quality of the group discussions, and it was visibly apparent that less and less students were reading the articles despite the continued reaffirmation that the assessment tasks (including the exam) relied on knowing the concepts and content presented in these papers. Due to a combination of instructional factors (heavy teaching workloads; insufficient time explaining the benefits of concept maps; insufficient training into teaching their effective use; the provision of only minimal feedback to students on the concept maps that were submitted), the concept maps were not a particular success. In addition, this was the first time that the new unit was taught and the first time that concept maps had been integrated into the unit. Class survey responses (N=22) showed that students did not find it helpful to create the weekly concept maps (Av=2.32, on a Likert scale ranging from 1=Disagree to 5=Agree).

Proposing a change to our use of concept maps
Despite this somewhat negative first result, some students did find the concept maps useful to them (e.g. students mentioned that it “does help to remember main aspects”). As academic staff, their benefit is also well appreciated in our post-Bologna age of academic teaching [9], in which high emphasis is placed on the quality of teaching, the increased diversity in academic level of students, and teaching that is focused on what students are learning rather than what lecturers are teaching, i.e. constructivism.

Constructive alignment of the assessment tasks and intended learning outcomes in the unit
The use of concept maps in the unit is currently only a learning and teaching activity. To help motivate the use of concept maps in the future, we will make the weekly concept maps form part of the summative assessment for students in the unit. Students will continue creating concept maps on a weekly basis and handing these in and receiving feedback also on a weekly basis. However, combined with better instructional use and clarity on the significance of the readings as the basis for the assessment tasks for this unit, it is hoped that this will permit increased active learning and student engagement with the unit content, and most importantly, in achieving the intended learning outcomes of this unit. The relevance of the readings will also be revised, and the marks awarded for concept maps will be based not on the weekly submissions (for which the students will receive formative feedback) but on the versions of the concept maps that are submitted as part of each of the three internal assessment tasks for the unit. It is believed that these modifications will align with the three core principles of effective assessment outlined in literature such as [8], i.e. that the integration of concept mapping to assist in higher-order learning will: guide students’ development of meaningful learning; inform students on their progress; inform staff on student progress; and also provide data for summative assessment grading.

Practical considerations for student and staff workloads
Change always brings with it a degree of uncertainty. Past work has outlined a number of issues that concept maps bring with them when used for assessment (including the validity and reliability between different mapping techniques) [20]. The use of concept maps must be learnt by students before they can be truly beneficial to them. Teachers also require instruction on how to effectively use concept maps in their units; and facilitation of concept mapping exercises is also an art that needs to be learnt. The time involved in teaching students how to use concept mapping techniques often also competes with the time required to teach the unit material.

Our first results from integrating concept maps into the ‘Mobile Application Development’ unit has highlighted a number of the concerns mentioned above, mainly those to do with making the benefits of concept mapping clear to students; the linking of the concept mapping exercises to the intended learning outcomes; and providing timely feedback to students. In an iterative design approach, the small amount of marks awarded to students for their concept maps will in the next phase be based on attempted completion rather than the overall quality of the concept map. This will make the marking simple, and will still provide an extrinsic motivator for the students to come to lectures prepared with their completed concept maps in hand. This will also allow for the inclusion of formative feedback, which Biggs and Tang [5] state is directly tied to the effectiveness of the teaching method employed. Increased workload on staff will be minimal, with much of the change being around improving facili-
tation by the teaching staff. Increase in student workload will be more substantially, but this is part and parcel in actively engaging and learning in the content of this unit.

**TOWARDS THE INTEGRATION OF CONCEPT MAPS INTO HIGHER-ORDER LEARNING UNITS IN IT EDUCATION**

In [6] it is outlined how concept maps have been used in numerous ways in education, psychology, and organizational settings. We propose that the integration of concept maps can be made generic and thus applied more broadly also to other IT and Human-centered Computing units that have a predominant focus on higher-order learning. This is demonstrated in Figure 1, where a generic assessment task for a higher-order IT unit is broken into three components: the core concept that is being assessed, the theory (that is assessed by the concept mapping component) and the practical application of the core concept to the real-world (e.g. the resulting software application that is developed). As an example, for Software Engineering units, as outlined in the ACM and IEEE Computer Science Curricula 2013 [1], the core assessable concepts might be based on the software engineering lifecycle (e.g. requirements elicitation; analysis and specification; design; construction; verification and validation; deployment; operation and maintenance) and concept mapping would help in assessing the students’ understanding of the underlying theory of these core concepts.

![Figure 1. Generic IT Assessment Task incorporating the use of concept mapping as part of the summative assessment.](image)

**LITERATURE REVIEW**

Based on a 15 year study of nearly one hundred college teachers, Bain [3] outlines a number of characteristics of good teachers. His top three are that they know their subject matter extremely well; they prepare for their teaching sessions as serious intellectual endeavours; and they expect more from students, as outlined in the ACM and IEEE Computer Science Curricula 2013 [1], the core assessable concepts might be based on the software engineering lifecycle (e.g. requirements elicitation; analysis and specification; design; construction; verification and validation; deployment; operation and maintenance) and concept mapping would help in assessing the students’ understanding of the underlying theory of these core concepts.

Biggs & Tang [5] outline how it is not sufficient for students to ‘listen’ and ‘take notes’ in lectures; and that more important is for them - particularly where higher-order learning is specified in the intended learning outcomes - to ‘think’ and ‘apply’ and to ‘do’. Our own research into multimodal interaction [22] found that there are many modality combinations that people use to communicate with humans and with computers; Oviatt [18] takes this further and suggests that learning might also be influenced by the combination of modalities that are used (e.g. writing with pen and paper compared to - for example - the use of a keyboard).

Similar to Mazur [13] and Yamane [24], who found that lecturing entailed large inefficiencies due to its nature of being largely a monologue from lecturer to students, we too agree that seminars should be less about transmitting and more about engaging students in active learning. Our experience is however that students have a natural tendency to assume that learning starts “at” the lecture rather than “before it”, and although we like the notion of the flipped classroom [21], we believe a learning model that sits somewhere in between the traditional and flipped-classroom is a more realistic path to take in engaging students in active learning in today’s university context.

**The benefit of concept maps for higher-order learning**

In [25], it is outlined how the “Tools for Developing High Order Thinking Skills” working group is focussed on Engineering Education, and the authors argue that it is essential to explore tools (like concept mapping) that facilitate the formation of deep knowledge structures. They state that this is because engineering education is facing a changing world in which “how” one thinks is becoming more important than “what” one thinks [25].

Concept maps were originally designed both to present a structure and to find out how students see the structure [15]. They can be used by teachers for teaching and assessment purposes and by students for organizing their ideas. Concept maps have many - as yet - unrealised potentials in addition to these two benefits. Novak and Gowin [16] state that concept mapping is a way to help students and educators to see the meaning of learning material. Strengths of the concept mapping technique are explained in [7] to be that it requires people to grapple with ideas, rethink assumptions, and examine mental models of reality”. These are characteristics of an active learning environment and are the characteristics that we too wish to incorporate into our own student-centred theory on teaching.

When compared with more traditional techniques such as reading, attending lectures, and note taking, concept mapping has been shown to be more effective for learning conceptual knowledge [14, 17]. Freeman & Jessup [6] outline how concept maps also enable shared understanding, help reduce miscommunication between individuals, and increase overall participation of individuals. We believe that the use of concept maps as a learning tool also provides an implicit form of time-management for students, as they learn the material introduced to them throughout a unit. Although some students whose first language is non-English claim that class readings and concept mapping is problematic for them, we believe that even these students can benefit substantially from the use of concept mapping, as its utility is in the mapping of the semantic (i.e. meaning) that rests between languages (i.e. interlinguia).
Administering concept maps in class
A number of articles have been written on the use of concept maps as an assessment tool. In [4] it is outlined that to encourage high student value of concept map exercises, instructors should take note to: design exercises to meet educational goals; provide timely feedback; and clearly align exams/assessments with the concept map exercises. Following these three principles, the authors of that paper state that students will not only value, but will also see the connection between the concept map exercises and the course assessments. In [19] it is described how a concept map assessment task may consist of: a task that elicits connected understanding; a response format; and a scoring system. In [20], a number of concerns with using concept maps for assessment tasks are also outlined; in particular, the authors of that paper argue that before concept map assessments can be used in classrooms, research first needs to provide reliability and validity information on the effect of different mapping techniques, and on training techniques, and on the effect on teaching.

CONCLUSIONS
In this paper, we have outlined how concept maps are currently being integrated into the summative assessment tasks of an IT unit called Mobile Application Development. We have summarised the impact that concept mapping can have on student learning when used for summative assessment, and we have also proposed a generic framework that would allow the integration of concept maps more generally into higher-order learning units in IT and Human-centered Computing.

REFERENCES