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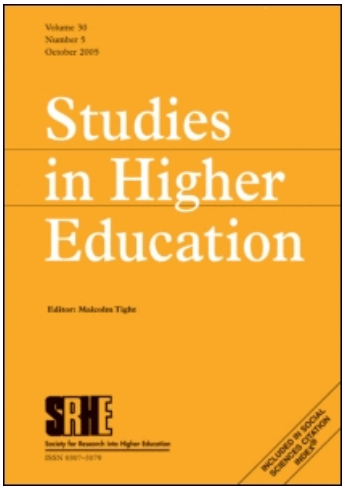

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Making learning visible: the role of concept mapping in higher education

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This article develops the concept-mapping method as a tool for enhancing teaching quality in higher education. In particular, it describes how concept mapping can be used to transform abstract knowledge and understanding into concrete visual representations that are amenable to comparison and measurement. The article describes four important uses of the method: the identification of prior knowledge (and prior-knowledge structure) among students; the presentation of new material in ways that facilitate meaningful learning; the sharing of 'expert' knowledge and understanding among teachers and learners; and the documentation of knowledge change to show integration of student prior knowledge and teaching. The authors discuss the implications of their approach in the broader context of university level teaching. It is not suggested that university teachers should abandon any of their tried and tested methods of teaching, but it is shown how the quality of what they do can be significantly enhanced by the use of concept mapping.

Introduction

In the UK (as in many countries), higher education has changed dramatically in the last 20 years. The numbers of students taking part in university education has risen from 500,000 in the 1960s to 2 million today (see the Higher Education Research Opportunities website; HERO 2007). As participation has increased, so too has the variety of entry-level qualifications and experiences, cultures, expectations and motivations of our university students. Some aspects of the qualification process have also changed. Modular course provision has become common, and assignment tasks tend to be richer and more varied than they previously were. Nevertheless, the basic methods of university teaching remain largely unchanged. This is despite significant increase in average class size and a considerable decline in staff to student teaching ratios. In large-class situations, in particular, many lecturers are troubled by an apparent lack of opportunities for student questions, the difficulty of achieving genuine student-centred teaching and a real need for tools with which to measure student learning quality. These issues are the concern of this article. To address them we focus on just one method – concept mapping – and show how it can be used to enhance the quality of university teaching without recourse to large-scale change in teaching methodology.

The article is presented in three parts. First, we explore what it means to learn at university level. We develop a simple definition of learning with utility among all of the cognate disciplines of higher education. We use this as a framework for better understanding university teaching practice, and identifying some of the issues that must be addressed if university teaching is to be improved. Second, we explain the concept mapping method and show how it can be deployed in the course of teaching. We focus on the ways that lecturers can identify and respond to the needs of their students (even among large classes), and we show how students can be helped to learn

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meaningfully for themselves. We end the article with a brief discussion of the wider role of the university academic. Many university staff appointments require commitment to both teaching and research. We show how research into student learning within specific subjects and disciplines can help to integrate teaching and research activities. We argue that concept mapping can facilitate teacher–student interactions in the creation and extension of knowledge, as well as its transmission. We suggest that the emergence of new and individually acquired meaning is a genuinely authentic definition of higher education.

Towards a common definition of university learning

It is an aim of this article that we explore and develop a common definition of university-level learning. There are several important texts on university teaching (e.g. Prosser and Trigwell 1999; Nicholls 2002; Ramsden 2002), and all of them offer significant insights into what it means to teach at university level. They also all agree that university teaching should be underpinned by a theory of learning, but none attempts to define a general model of university learning. Instead they draw heavily on the research into student learning approaches (e.g. Säljö 1975; Marton and Säljö 1976, 1984; Entwistle, Meyer and Tait 1991). As a consequence, many of these texts emphasise issues of 'difference' among learners as a basis for teaching. This is not easily reconciled with the demands that are faced by the teachers of higher education (Nicholls 2002). The 'learning style' literature is also circumspect, because it lacks any underpinning theory (see Coffield et al. 2004a, b), and often fails to distinguish between the different processes of learning and of teaching (Jarvis 2006).

Learning as change

In order to provide an alternative to the 'learning style' approach we start with one of the most widely used general models of adult learning: Kolb's learning cycle (Kolb and Fry 1975). This is shown in Figure 1.

Although Kolb's learning cycle has its origins in the literature of continuing education, there can be little doubt that it can contribute to an understanding of learning at university level. This is because it takes 'experience' as the starting point for learning, and suggests that learning occurs by similar and sequential processes. Thus, individuals must experience, reflect, theorise and test new knowledge in order to learn. Kolb and Fry (1975) suggest that this is true of learners in all situations, including the classroom experience of formal teaching. The approach subsumes the notions of difference, since it suggests that, while different people may have different affinities for one part or other of the cycle, ultimately learning occurs only when the cycle as a whole is complete.

A similar approach has been developed by Jarvis (e.g. Jarvis 1992, 1993). Jarvis interviewed 200 students (Jarvis 1993) and used their descriptions of learning to build general and abstract descriptions of learning (Jarvis 1992). These were then combined to construct a single model (Figure 2).

The model has some broad similarities with Kolb's learning cycle but it is also different. Perhaps most significantly, Jarvis starts with 'the person' as the central agent in the process of learning (Jarvis 2006). With hindsight it might be obvious that learning exists only as a personal and subjective experience, but prior to Jarvis's work this was not so succinctly stated. Second (and related to this), Jarvis argues that learning is actually defined as personal change: if someone is changed by an experience then they have learnt from it and the absence of change is indicative of non-learning. Thus Jarvis (1992) provides a powerful synthesis with the following definitions and implications for pedagogy:

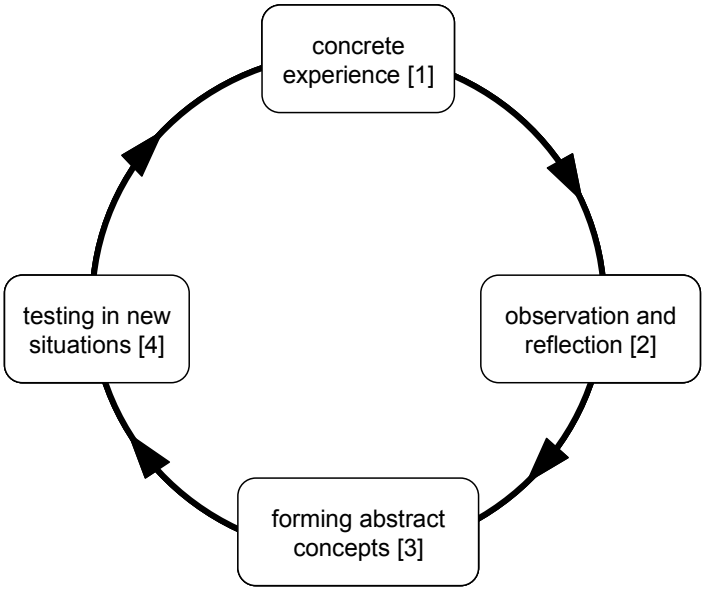


Figure 1. Kolb's learning cycle (after Kolb and Fry 1975).
Kolb and Fry (1975) describe learning as a cycle. First the person has an experience [1], then they observe and reflect upon it [2]. This is done in order to form new ways of thinking about the subject [3], so that finally what has been newly understood can be tested [4] before the phases of the cycle are repeated.

- Learning is personal change.
- The absence of change is non-learning.
- Change must be measured to differentiate between learning and non-learning outcomes.

Furthermore, Jarvis's model has some important things to say about the causes of non-learning and the quality of change where learning occurs. First, presumption ('I know that already'), non-consideration ('I don't need to know that') or rejection ('I have thought about it but it is not something I need to know') all lead to non-learning. Second, learning (where it does occur) can be reflective (using practice, evaluation, reasoning and memory to achieve change) or it can be non-reflective (relying on memory alone). Thus, Jarvis's model states that the learner chooses (deliberately or otherwise) to adopt strategies that will affect the quality of their learning. This issue of 'learning quality' is the focus for much of the following discussion.

The quality of change in learning

Some very similar conclusions to those of Jarvis were reached, independently, by Novak (e.g. Novak 1998). Novak describes cognitive change within a single continuum that extends between rote and meaningful learning. He defines meaningful learning in the following ways:

(1) Relevant prior knowledge. That is, the learner must know some information that relates to the new information to be learned in some nontrivial way.
(2) Meaningful material. That is, the knowledge to be learned must be relevant to other knowledge and must contain significant concepts and propositions.

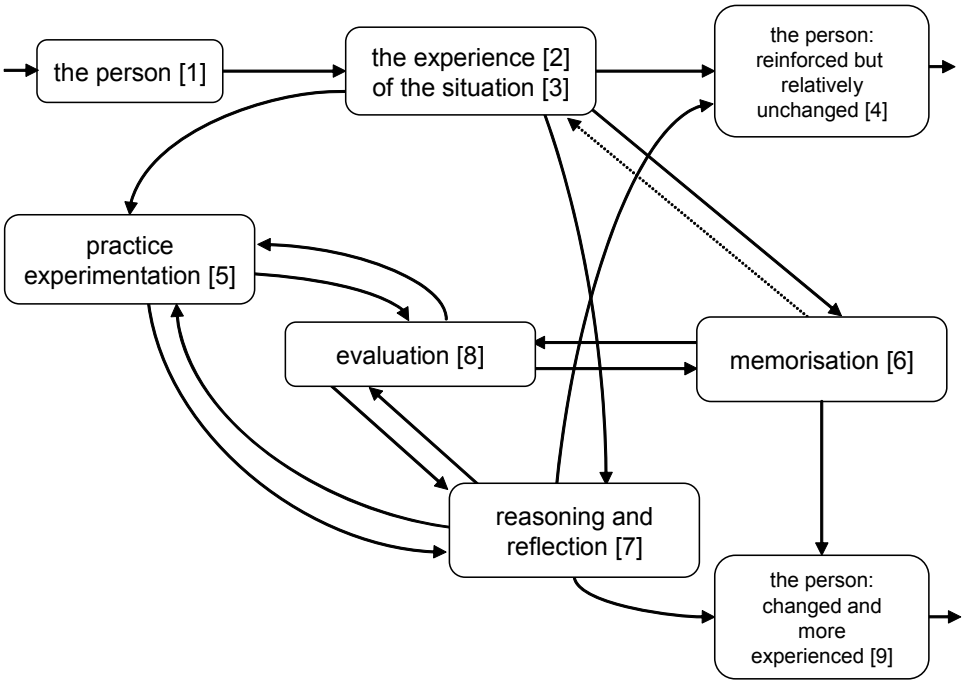


Figure 2. Jarvis's model of learning (after Jarvis 1992).
Jarvis (1992) states that the person [1] is the most important element in any description of learning. This is because he defines learning as personal change (compare the difference from [1] to [9] and from [1] to [4]). According to Jarvis, there are nine possible outcomes of learning (or non-learning) and these can be defined by the various routes through the processes of reflection, evaluation, experimentation and memorisation.

> (3) The learner must choose to learn meaningfully. That is, the learner must consciously and deliberately choose to relate new knowledge to knowledge the learner already knows *in some nontrivial way.* (Novak 1998, 19)

As a ground for pedagogy, this is even more specific than the work of Jarvis. It suggests that rote learning can be distinguished from meaningful learning by measures of integration among newly acquired and prior knowledge (Hay 2007). Novak's definition of meaningful learning is summarised in Figure 3.

Like Jarvis, this approach suggests that knowledge and understanding should be measured before and after teaching, but, more than this, Novak provides an empirical framework for assessing the quality of any change that may have occurred. Novak also developed the concept-mapping method for just this purpose. This has been extended by Hay (2007) and Hay, Wells, and Kinchin (forthcoming), and is explained in Figure 4.

Briefly, Figure 4 is a graphic summary of data reported by Hay (2007) and Hay, Wells, and Kinchin (forthcoming), where concept mapping was used to track knowledge change among university students. Where there was no change in knowledge (before and after learning), this

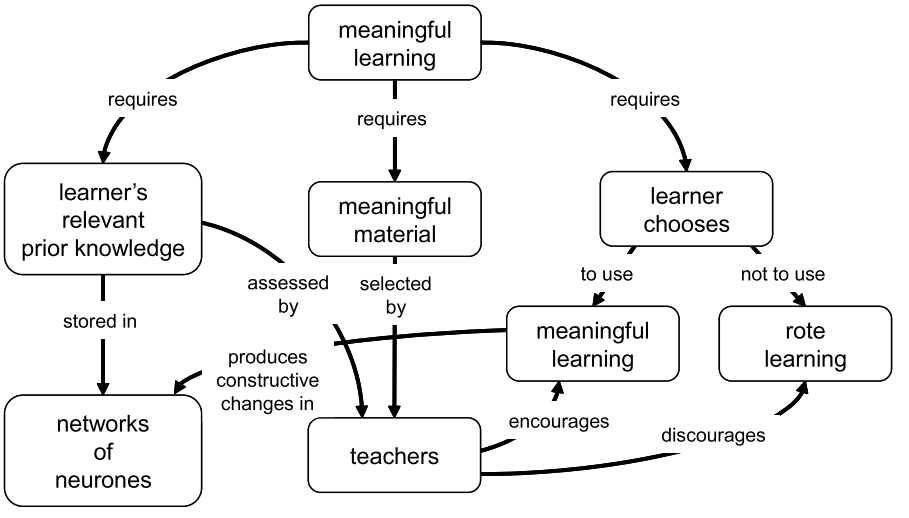


Figure 3. Novak's concept map of meaningful learning (after Novak 1998).
This concept map explains Novak's definition of meaningful learning and provides a framework for understanding how Novak understands teachers' roles in the support of learning.

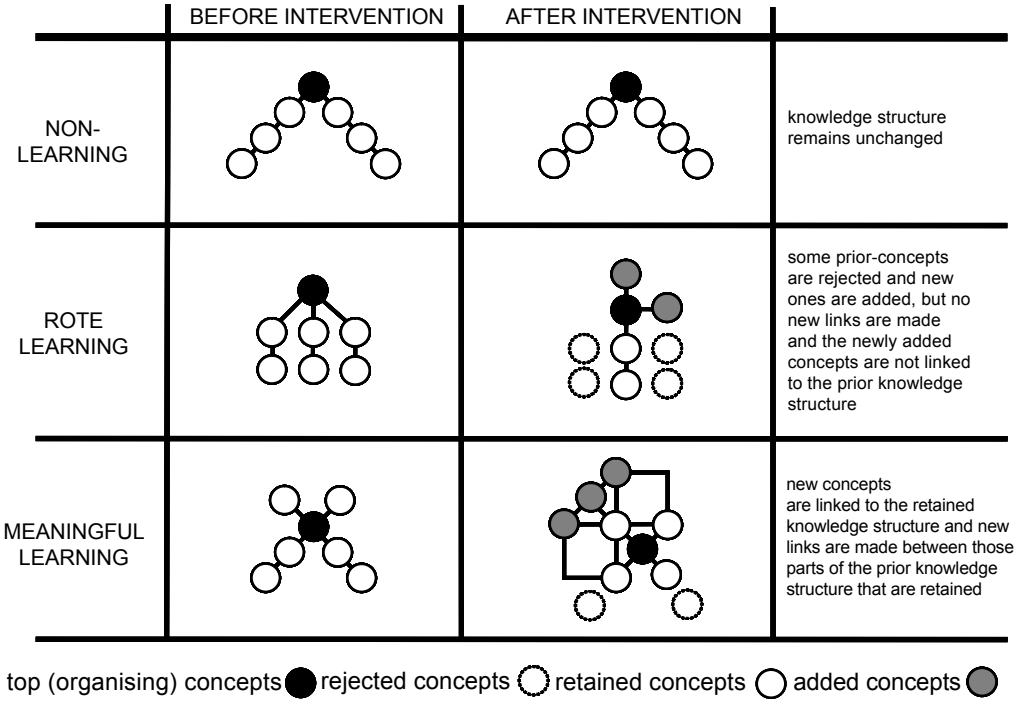


Figure 4. Measures of learning quality.
Hay (2007) used the concept mapping method to compare students' knowledge structures *before* and *after* teaching. In this summary of the data, concepts are shown as circles and the links between them are drawn as lines.

was deemed non-learning (after Jarvis), and where change occurred, the degree of integration between new material and extant parts of the prior-knowledge structure was used to classify the learning quality. Rote (or surface) learning was observed where the new material was added superficially without integration, and meaningful (or deep) learning occurred where new and old material were recombined to make new meanings.

The importance of prior knowledge

Together, the approaches of Jarvis and Novak define learning as change. Where knowledge change is a consequence of the integration of new material and the prior-knowledge structure, this satisfies the criteria of meaningful learning. Rote learning entails superficial changes in knowledge without integration. This definition can be applied in any discipline, and is just as applicable to skills learning or to changing behaviours, but for simplicity we will focus here on cognitive change alone. This is because change in knowledge and understanding is a feature of all university-level learning, whereas the learning of skills and behaviours is less widely distributed among the disciplines of higher education.

That learning is change and that change is measurable is a simple definition with wide utility. But it also necessitates that prior knowledge *must* be measured as the first step in documenting learning. Prior knowledge is the baseline from which learning can be calculated and its quality assessed. The definition also suggests that the quality of students' learning will be determined in large part by their starting positions. Students who have a good grasp of a topic beforehand will be better equipped to make sense of the teaching they receive. This is common sense, and it is therefore surprising that it is not more widely acknowledged in teaching and curriculum design at university level. It is not enough to argue that selection for university entrance ensures common standards of knowledge and understanding. Our own data show that there can be considerable difference in the understandings of students who have achieved similar examination results (Hay 2007; Hay et al. forthcoming; Hay, Wells, and Kinchin forthcoming). Most universities use attainment at schools level to determine access to higher education, but most teachers continue to report a wide range of pre-existing understandings among their students.

Two articles provide empirical evidence for the role of prior knowledge in student learning (Hay et al. forthcoming; Hay, Wells, and Kinchin forthcoming). Their data suggest that, without the active participation of teachers in the measurement of student prior knowledge, teaching is 'locked up' in structures and in terminology that is inaccessible to students. As a consequence, 'experts' can give 'lessons' that other 'experts' will deem to be excellent, while failing to engender understanding among their student audience. In such cases, students learn by rote (if they learn at all) or resort to other resources from among their wider human social interactions.

Hay et al. (forthcoming; Hay, Wells, and Kinchin forthcoming) also show that there are three different dimensions to prior knowledge, all of which can affect student learning. These are conceptual richness, knowledge structure and misconceptions. The three dimensions are explained as follows:

(1) Students are obviously advantaged by a rich prior knowledge, and helped too if there is a good overlap between what they know already and at least some of the teaching that they experience. It is out of prior knowledge that students interpret what they are taught, and the richer their knowledge to begin with, the greater the likelihood of subsequent understanding.
(2) The structure of prior knowledge (the ways in which it is organised) can have an important impact on a student's capacity for learning. Kinchin, Hay, and Adams (2000) show

that different people go about structuring their understanding in different ways: Hay and Kinchin (2006) suggest that some of these cognitive structures are more amenable to change (learning) than others. Figure 5 is a summary of this strand of research.

(3) Prior knowledge inevitably forms a scaffold for new learning, but where it comprises significant misconceptions then new knowledge acquisition is impeded. Understanding student misconception to begin with is an important part of the work of a teacher, and has long been understood in schools-level education (see Driver et al. 1994), and more generally, in adult education too (see Jarvis [2006], for example).

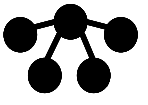
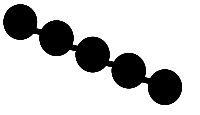
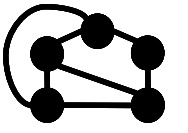
	SPOKE	CHAIN	NETWORK
Structure			
Hierarchy	single level	as many levels as concepts (but often these are unjustified)	several justified levels
Additions	additions to the central concept does not interfere with others	cannot cope with additions near the beginning of the sequence	additions and deletions have varying effects as 'other routes' are often available through the map
Deletions	generally have no effect on the overall structure unless the central (organising) concept is deleted (which leads to complete collapse)	disrupt the sequence below the deletion	
Links	often simple	often compound (making sense only when the map is read as a whole)	often rich and complex showing deep understanding
General	these structures indicate 'learning readiness' they are flexible and amenable to change in the course of learning	these structures are 'active' they are common to enterprise or to clinical practice where specific sets of actions must be carried out in sequence	these structures are 'scholarly' they often include alternative 'viewpoints' and even contradictory ideas

Figure 5. Prior-knowledge structure and learning.
Hay and Kinchin (2006) show that some ways of organising and storing knowledge are more amenable to learning than others. Different knowledge structures in particular (chains, spokes and networks: Kinchin, Hay, and Adams 2000) have different utilities but they also have different propensities for change.

All these issues make it important that students are helped to understand their own starting positions. As Ausubel suggests, understanding students' prior knowledge is a key step in teaching (Ausubel 1963, 1968; Ausubel, Novak, and Hanessan 1978): 'The most important single factor influencing learning is what the learner already knows; ascertain this and teach him/her accordingly' (Ausubel 1968, 36).

In small-group teaching and one-to-one tutorials, measures of, and responses to, student prior knowledge are an integral part of teaching. It is in large classes and in the delivery of lectures, in particular, that most university teachers fail to use student prior knowledge as a basis of teaching. This is not a purposeful neglect of the issue, but arises from a lack of awareness of the tools with which prior knowledge can be measured in large groups. It is important, then, that Novak's concept-mapping method can be used to measure prior knowledge in a class of 400 students just as quickly and as easily as with a single person. This is explained below.

The concept-mapping method

Concept mapping is one of a broad family of graphic organising tools, that includes mind mapping (Buzan and Buzan 2000) and spider diagramming (Trowbridge and Wandersee 1998). Yet Novak's method (Novak 1998) has some very specific rules that set it apart from other techniques. These are a consequence of the careful definition of learning (already described), and facilitate the use of the method for the measurement of learning quality.

A concept map comprises the 'bare bones of language'. Concept maps consist of concept labels that identify specific ideas (concepts) and the links between them, which explain how concepts are related to make meaning. A pair of concepts and their respective link makes a single proposition, and a concept map is made from any number of propositions to give a personal definition of any particular idea or phenomenon (Novak 1998). Each proposition is a statement of understanding and the validity of each assertion is open to scrutiny. Thus, the method is much more stringent than mind mapping, for example, and actively differentiates between knowledge (of appropriate concept labels) and understanding (that is the product of concept linkage). It is a powerful teaching tool since it facilitates the declaration of understanding among teachers and students.

The method can be taught in 10–20 minutes, and most students will find another 20–30 minutes sufficient to construct a reasonable map. This means that concept maps can be made within the time allocated for most university teaching sessions. Analysis of large numbers of maps can be time consuming (although quicker by far than the analysis of, say, individuals' interview transcripts), but Kinchin, Hay, and Adams (2000) show that a considerable amount of information can be gleaned very quickly indeed using structure alone as an indicator of prior knowledge. More stringent methods of analysis are described by Hay (2007) and Hay, Wells, and Kinchin (forthcoming), and can be combined with a simple sampling strategy. Alternatively, students themselves can be made responsible for the analysis of their prior knowledge, either in groups or individually. This can be a particularly powerful approach when it is combined with repeated measurement in the course of learning, so that students can see their knowledge and understanding change.

Concept mapping is already used in many different ways in school and university education. These are summarised in Table 1 and include lesson planning, measurement of change, organisation of group work and the sharing of knowledge and understanding. The use of concept mapping in the measurement of prior knowledge has already been discussed, and two more applications of the method are described below. Above all else, however, concept mapping can be used to make abstract knowledge and understanding visible to underpin its utility.

Table 1. Uses of the concept mapping method.

Use	Explanation	References
Assessing change In the course of learning	Concept maps are made by students to describe the same topic over and over again in the course of learning. The concepts and links are compared to assess the changes that have occurred.	Novak and Musonda 1991; Novak and Symington 1982; Eskilsson and Helldén 2003; Iuli and Helldén 2004; Hay 2007; Hay, Wells and Kinchin Forthcoming.
Identifying student misconceptions	Persistent misconceptions can be shown by analysis of the propositions used to describe individuals' understandings	Kinchin 2000; 2002; Hay *et al* 2008.
Teaching practice	The quality of the dialogue between teachers and students can be enhanced through the use of concept mapping since the method facilitates an exchange of individual knowledge and understanding.	Kinchin 2003; Kinchin 2004; Kinchin, deLeij and Hay 2005; Kinchin and Hay, 2007.
Lesson planning	Teachers can use concept maps to plan their lessons: where they map their own understanding first and use their maps to organise the knowledge and information that they will present, second.	Martin 1994; Kinchin and Alias 2005; Kinchin 2006a,b; Kinchin and Hay 2007
Assessment	Concept maps can be used to test knowledge and understanding for the purposes of both formative and summative assessment.	Edmondson 2000.
Cognitive typology	Concept maps have been used to show the cognitive structures that different people use to structure and organise their thinking.	Kinchin, Hay and Adams 2000; Hay and Kinchin 2006.
Identification of expertise	Concept maps can be used to show measurable differences between experts and novices.	Novak and Gowin 1984; Kinchin 2001.
Team working	Different knowledge, understanding and team roes can be managed and integrated through the use of concept mapping.	Hughes and Hay 2001; Kinchin and Hay 2005.

Measuring change and learning quality

We have already seen how concept mapping can be used to reveal prior knowledge. This is a necessary baseline if the method is to be used to track change. When a student maps the same topic in the course of their study, then a comparison of two or more such 'snapshots' enables measurement of learning quality (Hay 2007). Those parts of the knowledge structure that are new can be readily differentiated from those that are old, and the degree of integration (between new and previously existing ideas) can be measured. Figure 6 shows some of the results that can be obtained using this approach in the course of teaching. Figure 6a is a model of rote learning and Figure 6b is an example of meaningful change. Both are based on real data, and illustrate one of the key issues that we have argued already; that student prior knowledge is a good predictor of the meaning that can be constructed out of subsequent teaching.

Figure 6c shows some of the complex changes that may occur in the course of learning; changes that may cause teachers and learners considerable problems if they are not made visible. The student in this case study began a course of learning with a simple prior-knowledge structure and learnt, at first, by rote addition. Later, however, they found that what was new was irreconcilable with what they had understood to begin with. The result was a period of 'disjuncture', during which the student was less able to explain the topic than they had been before. Eventually they achieved a new grasp of meaning, but this came after a difficult period in which they might easily have given up. By making the learning process visible, the concept-mapping method can show who is in most need of support and when this support should be given.

Among others, Laurillard (2002) states that there is remarkably little published work documenting cognitive change among learners at university. This is perhaps attributable to learning having been deemed too complex and too intractable an issue to be amenable to empirical measurement. The approach that we have described here suggests that this is not so. Indeed publications by Hay (2007) and Hay et al. (forthcoming) show that concept mapping can be done to achieve longitudinal measures of student learning quality in higher education. We suggest that this should become a central strategy in the practice of higher education teaching. It is relatively simple to achieve and can provide a research-led foundation for university teaching. The tracking of student knowledge change should also be linked to measures of convergence on 'expert' understanding.

Sharing knowledge in the course of learning and teaching

Figure 7 shows how students go about the integration of new material within existing prior knowledge. If what is new is not integrated it must be acquired by rote and is likely to be quickly forgotten. But there is a broad consensus among university lecturers that rote learning is common in higher education (see Ramsden [2002] and Kinchin, Lygo-Baker, and Hay [2008] for a more detailed discussion of these issues). This probably explains why most university teachers claim to teach even some of the most basic issues again and again at higher levels of study. Ultimately, learning can only be the responsibility of the learner. As both Jarvis and Novak point out, the learner must choose to learn meaningfully. But such a stance does not negate the responsibilities of the teacher. Teachers can (and should) teach in ways that encourage student meaning making. As we have already seen, this should begin with measurement of student prior knowledge, almost by necessity. Concept mapping can be used to do this, but afterwards the method can also be repeated to make the students' new and emerging understanding visible to the teacher. Doing so provides a framework for understanding what is being understood and what is not. Our own data show that the neglect of meaningful learning among students is often a consequence of the ways in which new material is presented (Hay, Wells, and Kinchin forthcoming). Rote

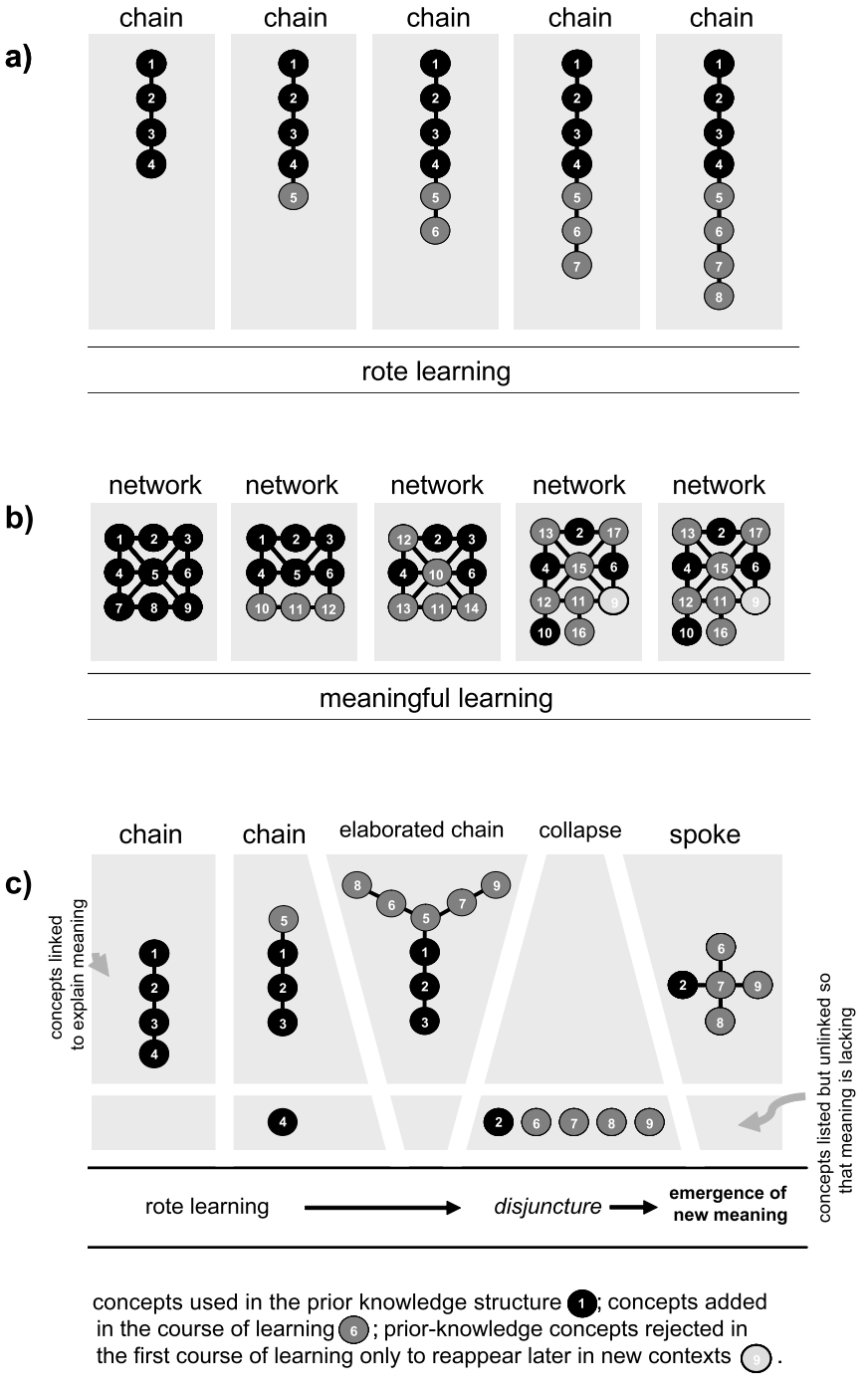


Figure 6. Measuring the quality of learning.
Concept mapping can be used to reduce abstract knowledge to concrete diagrammatic representation. When the same topic is mapped through time then the maps can be compared to measure change. This affords the documentation of learning quality and reduces specific 'learning events' to observable phenomena.

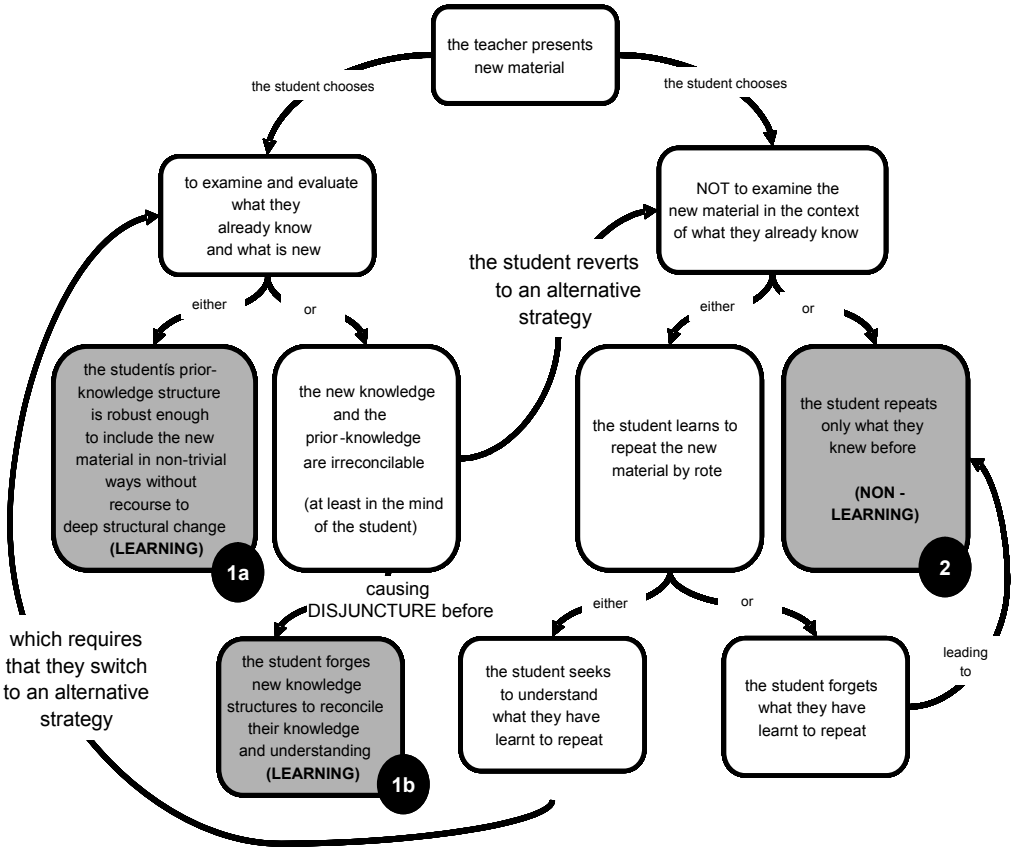


Figure 7. A general model of learning quality.
Students must choose to learn meaningfully by the purposeful integration of new knowledge with existing understanding. Some students can grasp the meaning of new teaching quickly because their prior knowledge supports new understanding (1a); others will find new learning more difficult as a consequence of their prior knowledge (1b). Some students will remain unchanged despite the teaching they receive and this comprises non-learning (2). Students who first learn by rote will learn meaningfully later if they can integrate their new learning with their prior knowledge. Otherwise they will tend to forget what they have been taught and revert to non-learning.

learning is often attributable to the teaching that students receive, and to the ways in which students come to perceive the assessment of their learning at university (Kinchin, Lygo-Baker, and Hay 2008).

Kinchin and Hay (2007) show how conventional teaching, and large-class lectures in particular, can act to promote rote learning (Figure 8). This is because lecturing requires that teachers convert complex scholarly networks of knowledge to simple and linear narrative chains. These chains are disclosed in lecturing, but the underlying understanding from which they were first constructed is rarely made clear to students. This is compounded by so much lecture-style delivery being accompanied by a linear sequence of bullet points in PowerPoint (Kinchin 2006a, b). The overall effect is not conducive to meaningful learning. It emphasises linearity (rather than the connectivity out of which genuine understanding arises) and suggests to students that there is a single right answer to be memorised (Kinchin and Hay 2007). That which is learned by memory alone is easily forgotten, and non-learning in higher education is a common consequence (Kinchin, Lygo-Baker, and Hay 2008).

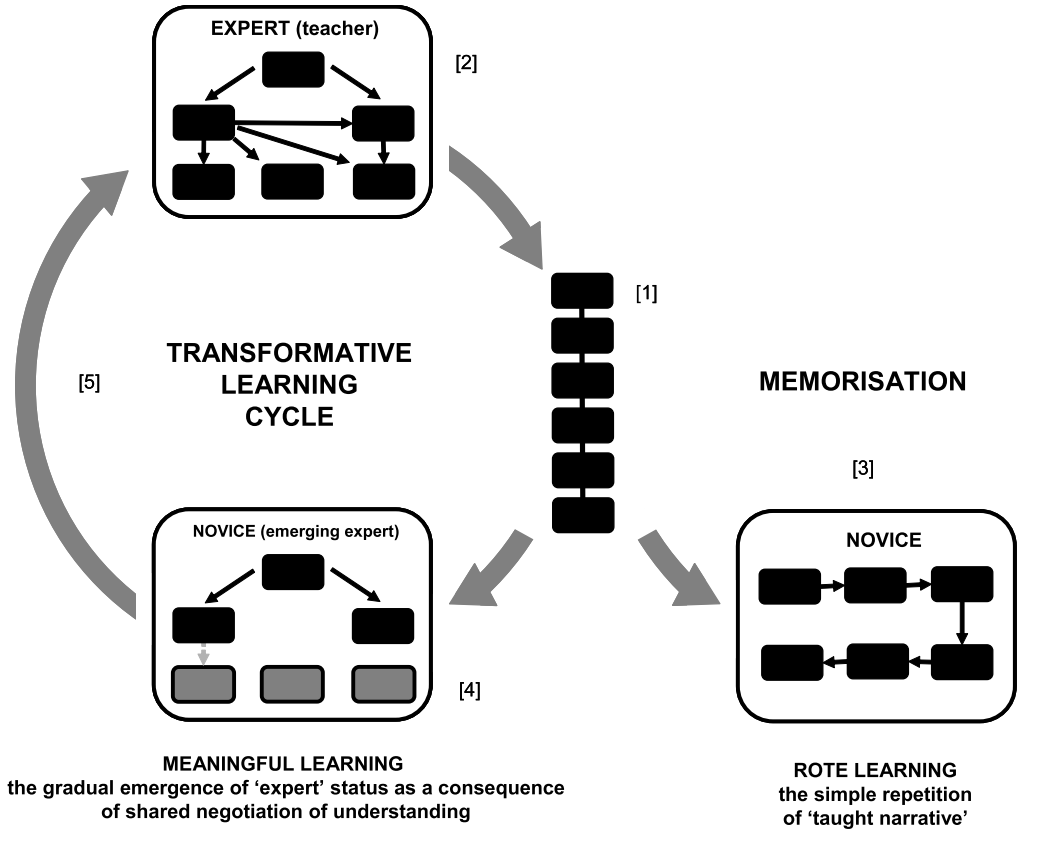


Figure 8. A model of teaching and learning.
University teachers tend to use lectures to present simple narrative sequences [1] to their students. These are actually constructed out of complex underlying knowledge networks [2], but rarely is this richness of understanding disclosed to their students. As a consequence students often choose to memorise the taught material [3], rather than engaging in a process of new-knowledge construction [4]. Nevertheless, teachers and students can use concept mapping to promote meaningful student learning [5].

Concept mapping offers a means by which these concerns can be addressed. Where teachers map their understandings of a topic, this can be used to give students access to the complexity and richness of the knowledge that belies their simple narrative explanations. Where students map the same topic as their teachers, comparing their maps can help to show the ways in which students can (or cannot) construct meaning from the new material they encounter. If this is done through time, it can reveal the learning process itself, by helping teachers and students to understand which new concepts need further explanation to facilitate meaningful learning. The approach will also indicate the order in which new material must be introduced if it is to be understood. We suggest that a simple exercise involving students directly in the construction of new understanding should probably be a part of all university-level teaching. Students can be asked to map their prior knowledge, and all of the concepts that they use can be written on Post-it Notes (or other movable labels). Then some of the new concept labels that their teachers hope to introduce can be disbursed, and new mapping can be done by the students to show whether or not the new material can be linked to prior knowledge. Such an approach actively promotes the process of meaningful learning among students, but it is also important because it involves teachers in the research of their students learning. It is a practical exercise in new-knowledge creation

(at least for the students concerned), and it incurs negligible costs (of equipment or staff time). It is tenable with very large student groups, and affords immediate benefits to both students and teachers. Students are helped to understand the topic and also to learn what is expected of them in higher education (i.e. the grasp of understanding and the construction of meaning). Teachers are able to find out whether or not their teaching facilitates meaningful learning, and, if not, what needs to be changed so that it does.

Concept mapping activities like this allow teachers to identify the new concepts that students find troublesome or difficult to acquire. There is now a rich literature on 'troublesome knowledge' (e.g. Perkins 1999) and threshold concept acquisition (e.g. Meyer and Land 2003; 2005). Nevertheless, higher education still lacks the empirical data that show where, when and how new knowledge and understanding is acquired. The learning trajectories of all students are likely to be different as a consequence of their different prior knowledge and experience. But understanding the ways in which people go about the construction of meaning is also likely to afford the extraction of general principles for the enhancement of teaching and learning. As we have said already, student learning in higher education is under-researched, but using concept mapping in the course of teaching can embed the research of student learning in university teaching. These issues are further explored below.

Concept mapping and the role of the university teacher

Figure 9 shows a general model of university teaching that is developed out of the arguments presented in this article. It implies that responsible university teaching will include four distinct practices, all of which can be achieved through concept mapping. These are:

(1) measures of student prior knowledge;
(2) the deliberate presentation of new material in the context of a known student knowledge base;
(3) active engagement in the development of new student meaning making through the purposeful disclosure of underlying knowledge and understanding;
(4) measurement of change among the student population so that learning (where it occurs) is identified and the causes of non-learning are addressed.

It is difficult to envisage any cogent arguments against these aims excepting, of course, that they are difficult to achieve, particularly among large classes unless specific methods are developed to achieve them in the normal course of university teaching. We hope, therefore, that we have shown how the concept-mapping method can do just this. Our own research (in collaboration with other teachers in higher education) attests to the utility of the method even where classes are very large indeed (e.g. Hay and Kinchin forthcoming) where the method is described for use among student groups of 250 and more).

Conclusions

This article has shown how the use of the concept-mapping method can add significantly to the quality of university teaching. Concept mapping is a teaching tool and a method of measurement of learning quality. There might be other means of achieving both of these functions (of teaching practice and the measurement of learning). Interviewing is an obvious example, but it is time consuming and impractical with all but the smallest student groups. Thus, concept mapping is likely to have an important role in the future development of higher education and its research. We do not suggest that concept mapping should replace the conventional methods of teaching in

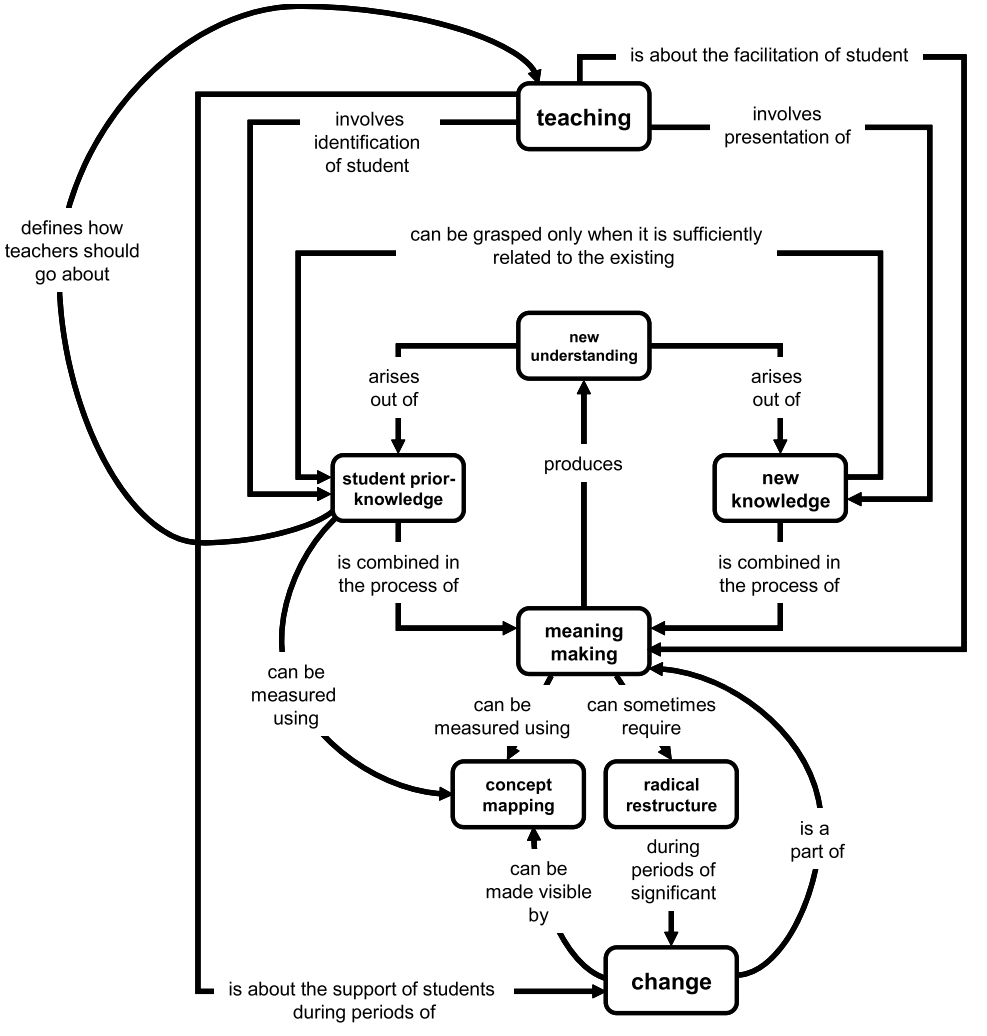


Figure 9. A model of university teaching practice.
Authentic teaching at university level comprises measures of student prior knowledge; meaningful presentation of new material; active engagement in the development of new student meaning-making; and measurement of change among the student population. All of these can be facilitated by the use of concept mapping. In using concept mapping to these ends, teachers engender meaningful learning among their students, but also accumulate important research data about the quality of learning and teaching. This is a rich source of empirical data that might eventually lead to a research-led teaching practice in each of the disciplines of higher education.

higher education (lectures, tutorials, seminars, practicals, clinical experience, etc.). Nevertheless, the quality of conventional university teaching can be considerably improved by its use. In particular, concept mapping enables the engagement of teachers and learners in the processes of discovery. Higher education is about more than the transmission of knowledge; it entails the extension and creation of knowledge as well.

Concept mapping makes learning visible. It is a lens through which the quality of learning can be determined. Teachers can use it to promote meaningful learning among their students,

but, wherever and whenever they do, they will be collecting valuable data about the teaching that is appropriate to their subjects and disciplines. This can provide a documented research base from which teaching can be developed. It is an empirical methodology out of which a science of teaching may eventually arise.

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