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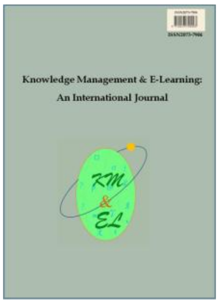

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Designing problem-based curricula: The role of concept mapping in scaffolding learning for the health sciences

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Abstract: While the utility of concept mapping has been widely reported in primary and secondary educational contexts, its application in the health sciences in higher education has been less frequently noted. Two case studies of the application of concept mapping in undergraduate and postgraduate health sciences are detailed in this paper. The case in undergraduate dental education examines the role of concept mapping in supporting problem-based learning and explores how explicit induction into the principles and practices of CM has add-on benefits to learning in an inquiry-based curriculum. The case in postgraduate medical education describes the utility of concept mapping in an online inquiry-based module design. Specific attention is given to applications of CMapTools™ software to support the implementation of Novakian concept mapping in both inquiry-based curricular contexts.

Keywords: Concept map; Inquiry-based leaning; Problem-based learning; Medical education; Dentistry; Health sciences; First year; Medical education professional development; Learning technologies; Blended learning

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1. Introduction

The focus of this special issue of Knowledge Management and E-Learning, is twofold. First, there is an interest in moving the field of Novakian concept mapping (CM) beyond primary and secondary education towards examining advances in its application to academic research. Second, the special issue seeks to describe advances in the application of concept mapping in higher education, specifically university and professional education contexts. The two case studies presented in this paper aim to address these foci by sharing and evaluating innovative practices in designing meaningful learning experiences using Novakian CM within larger curriculum designs. Both cases employ an outcomes and inquiry-based approach in the field of health sciences education. The first describes the use of CM to support the first year experience in an integrated, student-centred, interactive, collaborative and problem-based curriculum in undergraduate dental education, while the second describes how CM has been incorporated into an inquiry-based online continuing professional education course on problem-based learning (PBL) for medical educators. Both learning contexts are related to the health sciences but the two cases differ not only in terms of content but, most importantly when considering curriculum design, also of level of learners (undergraduates versus academics) and learning modality (face-to-face versus online). The common thread to both contexts is the application of problem-based learning as curriculum design (Lu, Bridges, & Hmelo-Silver, 2014; Bridges, McGrath, & Whitehill, 2012).

CM arose from the seminal work of Joseph Novak (1998) who developed it from the theories of David Ausubel, an educational psychologist who took a cognitive view to educational psychology and stressed the role of knowledge organisation and the importance of prior knowledge in learning new concepts. While the applications of CM were initially in science education, current applications have expanded across disciplines. As a technique for representing knowledge visually, concept maps can be considered as knowledge graphs displaying networks of concepts. These networks consist of labelled *nodes* which are point or vertices in the network signifying a *concept* and *links* which are drawn as arcs edges or arrows to denote the *relations* between concepts (Novak & Canas, 2008). Links can be non-directional indicating simple associations or unidirectional indicating causality or bi-directional indicting an exchange or interaction/interdependence. The process of linking can, therefore, be simply associative or specified and divided into categories such as causal or temporal relations. Additional to the basic structure of concepts and links is the application of propositions defined as:

> *statements about some object or event in the universe, either naturally occurring or constructed. Propositions contain two or more concepts connected using linking words or phrases to form a meaningful statement*. (Novak & Canas, 2008, p.1)

Another distinctive feature of CM, in comparison with, for example, the more singular focus of mind mapping, is an emphasis on hierarchy moving from general concepts at the top level to greater specificity along the chain of linking nodes. Cross-links are also important to concept map design in that they enable illustration of critical connections as well as hypothesising between trees within a hierarchy. Concept mapping, therefore, supports memory in both revising past work and in acquiring new content. A meta-analysis of studies of CM across educational sectors (Nesbit & Adesope, 2006) found that "in comparison with activities such as reading text passages, attending lectures, and participating in class discussions, concept mapping activities are more effective for attaining knowledge retention and transfer" (p. 434). This was specifically noted with regard to supporting "theories claiming that that concept maps lower extrinsic cognitive load by arranging nodes in two-dimensional space to represent relatedness, consolidating all references to a concept in a single symbol, and explicitly labeling links to identify relationships" showing their potential to "have more to offer than the mere reduction of information" (Nesbit & Adesope, 2006).

In building on from work in primary and secondary science education, Hay, Kinchin, and Lygo-Baker (2008) have indicated the general utility of CM for higher education arguing for the transformative power of concept mapping in converting abstractions into concrete visual representations. In summary, they saw four applications of concept mapping for meaningful student learning in higher education:

- "identification of prior knowledge (and prior-knowledge structure) among students;
- presentation of new material in ways that facilitate meaningful learning;
- sharing of 'expert' knowledge and understanding among teachers and learners;
- documentation of knowledge change to show integration of student prior knowledge and teaching." (Hay, Kinchin, & Lygo-Baker, 2008, p. 295)

However, CM in higher education is not only for individual and group brainstorming to access and organise prior knowledge, to communicate complex ideas, and to synthesise and integrate prior learning with new knowledge, it is also increasingly being used as an assessment tool.

In what follows, we explore the utility of integrating CM into two problem-based curriculum designs within the health sciences. Of particular interest is the relationship of CM to supporting phases of the PBL process; to supporting constructive alignment in curriculum design (Biggs & Tang, 2011); to enhancing the first year undergraduate experience; and in using CM software in blended approaches to PBL.

2. Background

2.1. Problem-based learning (PBL) in the health sciences

Problem-based learning (PBL) began in medical education in North America and has mushroomed globally first in medical education, then to other areas in health sciences education such as dentistry (Winning & Townsend, 2007), nursing, physiotherapy and speech and hearing sciences (Fletcher, Weekes, & Whitehill, 2014; Whitehill, Bridges, & Chan, 2014). As a global phenomenon, PBL has moved from North America to Europe and Asia with heightened interest in Chinese health sciences curricula since the mid-2000s. As described elsewhere (Lu, Bridges, & Hmelo-Silver, 2014), PBL can be considered in terms of philosophy, curriculum design, and learning method. Philosophically, PBL takes a constructivist view with students actively collaborating to co-construct knowledge. Such a view situates knowledge as a fluid process of exploration rather than as a fixed product for content delivery.

In terms of curriculum design, if used as an organising framework for a spiral curriculum design, PBL can support matrix-based approaches to integrating knowledge. Integration occurs both vertically across domains and horizontally across disciplines with knowledge supporting and being supported by practical training and with key concepts being re-visited at strategic points throughout the curriculum. Finally, the largest body of literature examines PBL as an approach to learning whether this is viewed as a cycle (Hmelo-Silver & Eberbach, 2012; Bridges, Botelho, Green, & Chau, 2012) or as a step-based model such as the 7-step Maastricht model (Moust, Berkel, & Schmidt, 2005; Schmidt, Van der Molen, Te Winkel, & Wijnen, 2009).

2.2. Concept mapping (CM) in the health sciences

Concept mapping (CM) is most widely applied in health sciences as a tool to integrate learning across disciplines, mainly in structuring knowledge. A key benefit has been seen as a method to gain "unique insights into how an individual organizes his or her knowledge or comes to think about a problem" (West, Pomeroy, Park, Gerstenberger, & Sandoval, 2000). A recent quasi-experimental longitudinal study of CM in a two-year registered nurse baccalaureate program (Lee et al., 2013) found the application of concept mapping to be significant to the development of critical thinking. Another study in nursing observed a learning pathway with CM in a growth from linear to networked knowledge representations as students adapted to the tools (Hsu & Hsieh, 2005).

Clinical applications of CM have been reported as also productive in terms of engagement, visualisation of issues connected to a patient case, focussing organisation of elements of care and having strong utility in time management (Adema-Hannes & Parzen, 2005). One study in nurse education sought to evaluate students' integration of non-linear relationships over a three semester period. Students' CM mean scores improved over time and the maps produced indicated increased sophistication with regard to non-linear thinking and building more complex interrelationships between concepts. The study concluded that CM was a powerful tool for clinical education in nursing. Work in dental education (Kinchin & Cabot, 2009) has examined concept mapping in a course on removable partial denture design and found it to be effective in terms of encouraging active learning, eliciting expert knowledge structures, scaffolding learning, and making student thinking processes transparent so that teachers could provide timely and effective feedback.

Applications of CM in assessment within the health sciences have produced some interesting research. West et al's (2000) study of CM assessment for 21 physicians in training (9 first year residents and 12 second and third year residents) sought to assess not only reliability but also if the maps assessed conceptual change in the physician's thinking using a pre-post-test design. Post-test results indicated significant improvement of concept maps following instruction. An interesting outcome was to challenge the domains being examined in standardised testing conducted by regulatory examining boards. A more recent study in medical education in Saudi Arabia (Kassab & Hussein, 2010) found that, in terms of assessor judgement practices, the inter-rater reliability of concept map scores was very strong. Given that the aesthetic elements of CM could be seen as open to subjective judgement, this study indicates promise for the reliability of concept mapping as a summative assessment instrument.

2.3. Concept mapping (CM) in PBL curricula

It is argued that problem-based learning (PBL) is more effective when linkages are made between focal concepts rather than understanding concepts in isolation (Gijbels, Dochy, Van den Bossche, & Segers, 2005), and so PBL educators and curriculum designers have incorporated CM as both a learning tool for formative feedback purposes and as a valid method for assessing the goals of PBL summatively (Mok, Whitehill, & Dodd, 2014). Zwaal and Otting (2012) conducted two studies with PBL groups in vocational hospitality education with mixed findings. Their application of CM did not lead to improved identification of the PBL learning issues nor did it affect time spent on the PBL process; however, a positive finding was that students working with CM were more satisfied with two key aspects of the problem process when supported by CM, namely, the decision-making process, and group communications.

Particularly relevant to the two cases described below, have been other experiences with CM in problem-based learning in the health sciences. Mok, Whitehill, and Dodd's (2014) 3-year longitudinal study of CM in a fully-integrated, problem-based Speech-Language Pathology (SLP) curriculum adopted a standardized assessment instrument, the Concept Map Assessment Profile (CMAP) for statistical analysis across three measures of learning outcomes: GPA, a standardized PBL examination and tutorial scores. Building on Novak and Gowin's (1984) scoring criteria for evaluating propositions, hierarchy, linking and exemplifying, the new tool included a fifth attribute of 'overall appearance' in developing a SLP profile using a sliding scale as in a rubric. The five attributes corresponded to different aspects of critical thinking namely comprehensiveness (nodes – identifying and labeling relevant concepts), content (linking words as explanations rather than classifications, evaluation of propositions and integrating through cross-links), and clarity (overall appearance in terms of understandability in peer review).

3. Case 1: Concept mapping in 1st year Dentistry

3.1. Constructive alignment

Concept mapping (CM) was introduced into the problem-based undergraduate dental curriculum at The University of Hong Kong on its advent in 1998 to assist students in the organization of declarative and procedural knowledge. In terms of design, concept map drawing is encouraged in the first phase of the problem cycle (Bridges, Botelho, Green,

& Chau, 2012) in order to activate prior knowledge and generate ideas and hypotheses. In this initial phase, after exposure to the problem-at-hand and establishment of the facts of the scenario, students engage in brainstorming for generation of ideas. A facilitator, or the students themselves, may, after a period of brainstorming, suggest drawing a concept map to manage and integrate the pooled knowledge from the group discussion. This is often co-constructed on a whiteboard with input from all group members with regards to suggesting nodes and propositions, creating links and refining the overall structure of the map. Concept maps may again be used as a part of the group learning process in the second tutorial when, after a period of independent research and study and learning, students return to their groups to share new knowledge. To consolidate learning after the second tutorial, concept maps are often included as a group assignment (locally known as a 'product'), which is intended to bring the problem-cycle to a conclusion and to reinforce the communication of knowledge to answer a particular question which has arisen from the problem at hand. Formative feedback is provided to all group concept maps and these are shared across the groups. Embedding concept maps across the problem cycle can be seen as supportive philosophically of the PBL learning process and practically in terms of facilitating and representing student cognition.

Understanding of the role of concept maps at the level of alignment within the problem cycle is critical for facilitators and students Fig. 1 illustrates the critical junctures within a problem cycle where concept mapping, may be best utilised to "explore learners' knowledge structures, foster meaningful and collaborative learning" (Torre, Durning, & Daley, 2013). That is, during the first tutorial where prior knowledge has been identified and hypothesising begins; during the second tutorial when collective sharing has occurred and new knowledge is applied to the problem at hand; and finally as a consolidation phase at the end of the problem cycle.

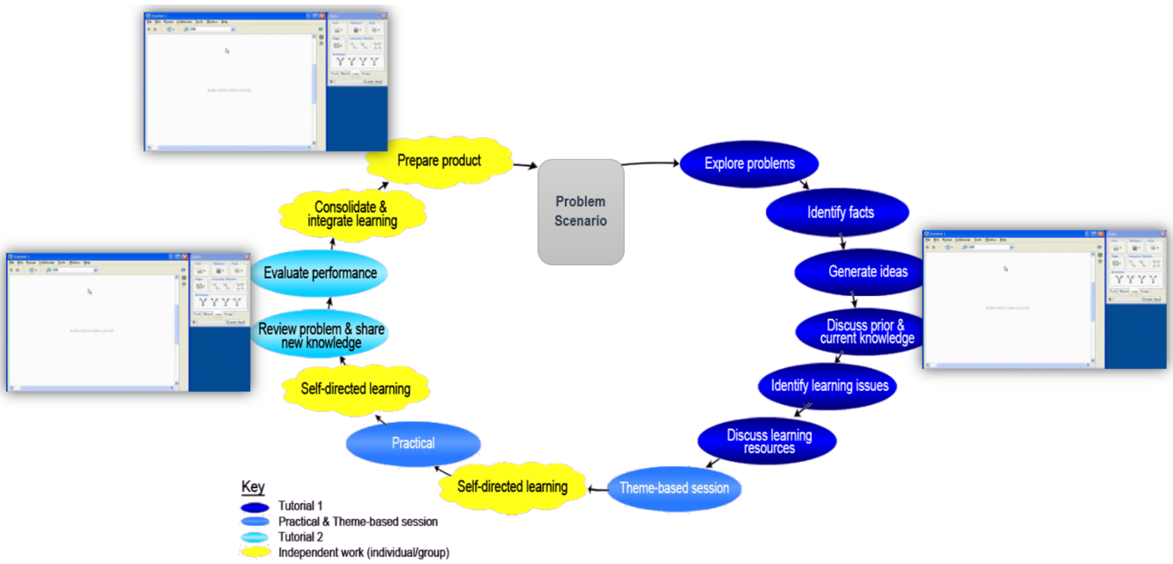

Fig. 1. CM opportunities within the PBL problem cycle

Further to the notion of alignment and curriculum design is the application of concept mapping as a summative assessment tool. A modified 'Triple Jump" assessment applies concept mapping in the first 'jump' to establish students' prior knowledge. The second 'jump' is the PBL group discussion and the third 'jump' is an individual viva based upon one of the learning topics identified in the examination problem. Moderated assessment using a locally-devised assessment rubric strengthens the application of the core principles of outcomes-based learning. Criteria for the concept map 'jump' address not only factual knowledge but also concept map design.

3.2. The first year experience and PBL

Across higher education, the first year experience has been found to be significant to student retention and attrition and increasing attention has been given to student induction and orientation with growing interest in Hong Kong (Webster & Yang, 2012). Additional attention has also been drawn to the relationship between inquiry-based learning and the first year experience with some scholars advocating research in the first year of undergraduate curricula (Levy & Petrulis, 2012). While problem-based curricula have been acknowledged as attaining high learner motivation within courses and enhanced learner outcomes on graduation, the challenges for students on entry to PBL programmes remains a dilemma for curriculum designers (Prosser & Sze, 2014; Winning et al., 2012). The 1998 PBL undergraduate dental curriculum from inception incorporated a week-long orientation beginning with a short presentation regarding problem-based learning, programme structure, execution and resources, as well as Faculty expectations. Students then engaged with the most experienced tutors in a 'practice PBL' with reflection and feedback focusing on the PBL process and group engagement. Following the implementation of institutional first and final year surveys (Prosser, 2013), student satisfaction feedback highlighted the issues of adjustment to PBL in the first year whilst reinforcing the improved outcomes of PBL by the end of the programme. An extended induction programme was then implemented in 2007 building on the initial week-long orientation with additional reflective exercises and conducting 2-3 hr workshops across the entire first year. Induction into concept mapping aimed to: a) orient students to the difference between various graphic organisers that can support learning in PBL; b) introduce Novakian CM; and c) apply CMapTools™ as learning software for group PBL assignment preparation, production and uploading to the Learning Management System under a blended learning philosophy (Bridges, 2015).

The first, whole class (~55 students) activity was to allocate groups with a topic and ask them to:

- brainstorm the topic individually using post-it-notes (one for each concept);
- collate all concepts onto a list on the lecture room wall;
- organise into nodes, propositions and cross-link on large sheets of paper to design affixed to the wall.

The whole class then viewed each other's maps in an art gallery-style tour of the tiered lecture theatre. The de-briefing and contrastive analysis of maps aimed to remind students of the first step in designing a concept map by reinforcing the critical need for a Novakian concept map to address a specific question.

The following concept mapping workshop introduced both the stand-alone and distributed versions of CMapTools™. The first implementation began with Version 4.12 (http://cmap.ihmc.us/conceptmap.html; Florida Institute for Human & Machine Cognition, Florida, USA) with updates ensuing accordingly. A sample Year 1 group concept map consolidating learning from a PBL problem and using the CMapTools™ software is provided in Fig. 2. The map indicates a complex network of concepts relevant to clinical learning or what Kinchin, Cabot, and Hay (2008) refer to as "chains of practice" that are "indicative of procedural sequences that characterize observable clinical practice" (p.94).

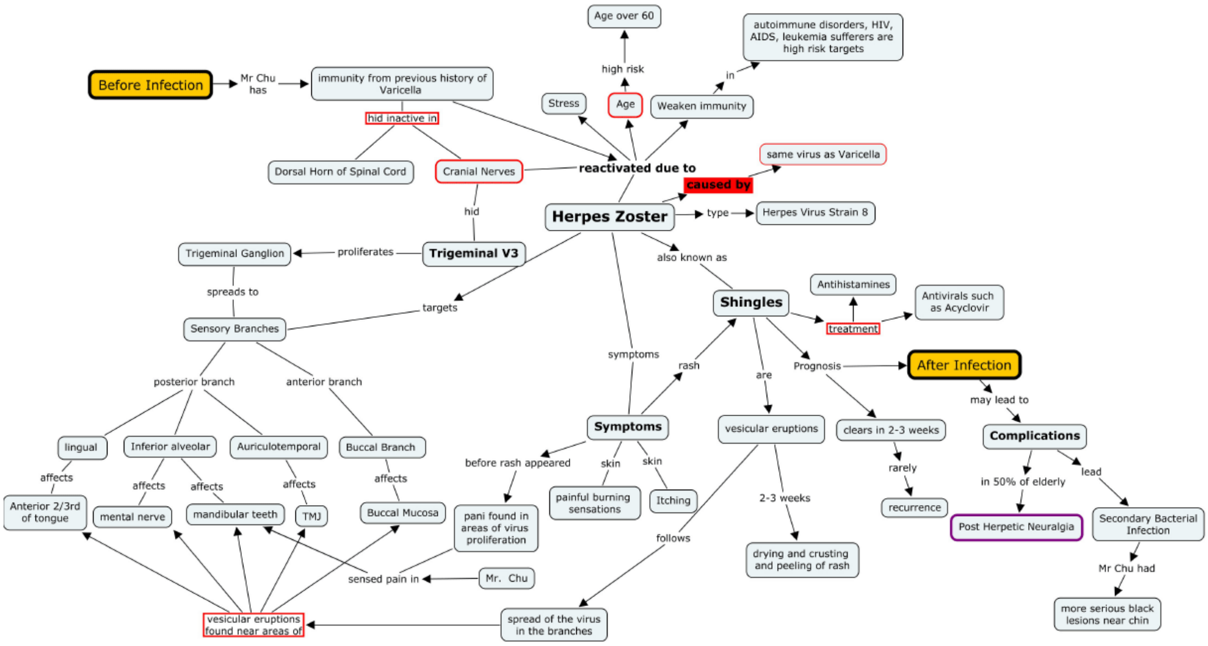

Fig. 2. Sample year 1 group concept map

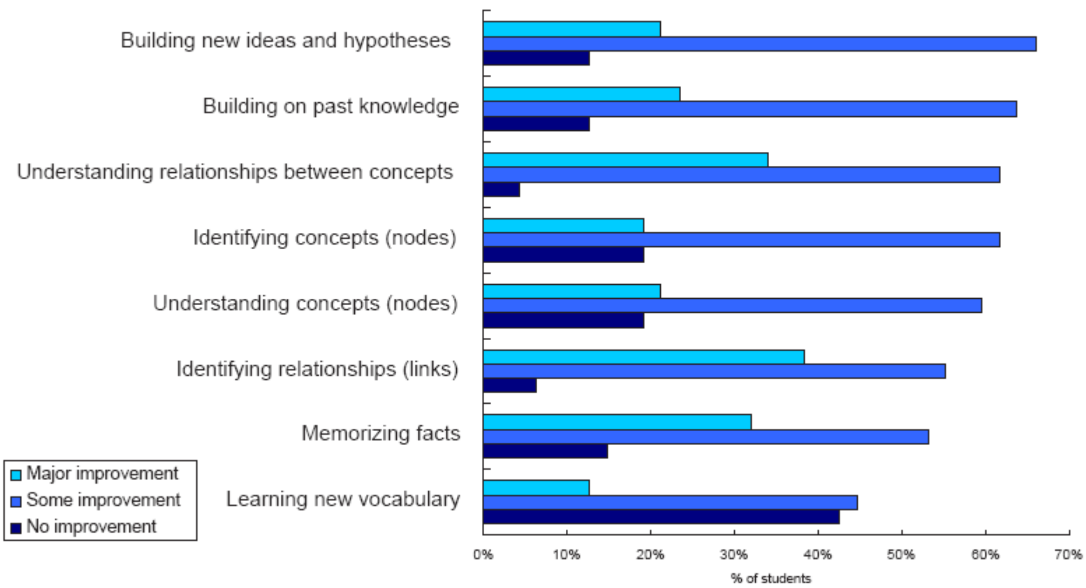

Fig. 3. 2008-09 BDS student survey on learning with CMapTools™

Evaluation of the first cohort to the new induction programme (n=52) was conducted by online survey in the 22nd week of the academic year with a 90.4% response rate. Questionnaire items explored students' perceptions in terms of:

- the efficacy of concept mapping as a learning tool;
- their group's modes of working towards task completion; and
- their evaluation of the effectiveness of single (stand-alone) and multi-user (network connected) CmapTools™.

The results as shown in Fig. 3 indicated improved perceived learning outcomes across the desired aspects of 'building new ideas and hypotheses', 'building on past knowledge' and 'identifying' and 'understanding' concepts and their relationships. The least perceived impact was in terms of vocabulary acquisition which was taken to be positive given the goal of conceptual development rather than surface learning of terminology.

Interestingly in terms of the first year experience, the evaluation also indicated that, when asked to identify their preferred mode of working – synchronously or asynchronously - students had a greater preference for synchronous, face-to-face meetings working at the same computer using the single-user CMapTools™ than working asynchronously with the multi-user, distributed format where the map was constructed remotely on a server (Bridges, Dyson, & Corbet, 2009). Supportive of the notion of induction across the entire first year was the item regarding the extension of use of concept mapping to 'other aspects of your BDS (Bachelor of Dental Surgery) studies'. 21 students indicated positively and, when asked to elaborate, indicated that they transferred their PBL concept map experience to three other aspects of their learning: summarizing readings (n=17); examination preparation (n=9); and content revision (n=8).

Adjustment to a new curriculum structure and programme which re-situates knowledge is a challenge. The incorporation of scaffolded activities to support the application of Novakian concept mapping for problem-based learning within an extended first year PBL orientation and induction programme was positively received by the responding students.

Table 1
CIMHSE – PBL module description and learning outcomes (http://www.imhse.hku.hk/cimhse/module_pbl.php)

Description

In the spirit of PBL, this module adopts an inquiry-based approach. Participating health sciences educators will be led though a series of interesting tasks and activities aimed to promote deeper understanding of critical issues in PBL programmes. These issues will range from philosophical considerations to PBL curriculum design and management to student learning and facilitator approaches within the tutorial process itself. In weaving between these macro and micro implementation issues, we aim to provide a stimulating and engaging module that considers PBL from multiple perspectives. We hope you enjoy the learner-centred approach we have designed and look forward to meeting you online!

Learning Outcomes

1. Engage in an inquiry-based learning process
2. Identify and critically evaluation a range of curriculum philosophies and educational principles underpinning curriculum models
3. Describe the design features for curriculum-level implementation of PBL
4. Outline the stages within the PBL process

Analyse the dynamics of tutor facilitated, small group learning.

4. Case 2: Concept mapping in medical and health sciences professional education

The Certificate in Medical and Health Sciences Education (CIMHSE) is a distance-education only certificate course for educators across the health sciences conducted through The Institute of Medical and Health Sciences Education, Li Ka Shing Faculty of Medicine, The University of Hong Kong. Although well-experienced in implementing problem-based learning in the undergraduate curriculum, the long-running certificate course had not offered a module on PBL until the launch in 2013 of the module described here. When faced with the challenge of 'teaching' PBL via a distance education mode, the team (Bridges and Chan) opted to design an inquiry-based online approach rather than attempt synchronous online PBL as had been undertaken in a separate project (Ng, Bridges, Law, & Whitehill, 2014). Rather than simulate the PBL face-to-face tutorial online, the designers undertook to engage participants in active, asynchronous online inquiry. The module description and aims (Table 1) explicate this intention.

Table 2
PBL module design (phases 2 & 3 – concept mapping)

Problem Statement (sequential disclosure)	**Learner Task**	**Online resources**
Part 1 Your current Health Sciences curriculum is now 12 years old and you are joining the curriculum management team. You have never really thought about how the whole thing fits together before so it's time look beyond your own teaching experience.	1) Create a concept map using CMapTools™. Focus question: *How do the elements (e.g. space, staff….) of a health sciences curriculum interact with each other?* Tip: Reading 1 may assist your thinking here. Think of a jigsaw puzzle and how the elements fit into the whole picture. > *upload to Discussion Forum* 2) Comment on each other's concept maps in the online forum – be ready to ask some questions & seek clarifications.	- Readings on curriculum design - Webinar explaining the principles of constructing concept maps - CMapTools™ software download link - CMapTools™ demonstration
Part 2 Your new Dean has instituted a self-initiated faculty review in the middle of your professional accreditation cycle indicating she wants to see a 'paradigm shift' to move to an inquiry-based curriculum.	1) Create a concept map identifying the underlying concepts of an inquiry-based, integrated curriculum > *upload to Discussion Forum* 2) Comment on each other's concept maps in the online forum – be ready to ask some questions & seek clarifications.	- Two readings on the theories underlying problem-based learning

The inquiry-based approach, therefore, draws on an unfolding sequential scenario as an overarching stimulus and framework. Tasks linked to each to stage of the scenario are uploaded to the group forum on the Learning Management System (Moodle™) for collaborative commentary and discussion. Summative assignment tasks were uploaded to the assignment section on Moodle. Concept mapping (CM) is introduced into the second of eight stages in the sequential problem. An original webinar was produced and uploaded as a resource to guide the medical educator participants as to the purposes of concept mapping and then introduce them to the CMapTools™ software. The two tasks for concept mapping were designed as per Table 2.

Qualitative feedback was provided by participants in a closing video reflection. Of particular note was how positive students were to the inquiry-based design supported by innovative tasks such as concept mapping. Remarks regarding CMapTools™ as a tool for online learning were overall supportive. Of note to the module design was the embedding of two CM tasks. This enabled learner progression in that formative feedback on their map designs in Phase 1 informed the concept maps generated in Phase 2. The latter final CMs were universally more sophisticated products indicating not only refined tool usage but also improved conceptualisations.

5. Discussion

Daley and Torre's (2010) review of concept mapping in medical education indicated four core functions in the adoption of CM in these curriculum contexts: promoting meaningful learning; providing an additional resource for learning; enabling instructors to provide feedback; and conducting assessment of learning and performance. In both cases above, CM was explicitly incorporated as a resource to scaffold student learning. Scaffolding in education encompasses a variety of instructional techniques used to move students progressively toward deeper understanding and, ultimately, greater student-centeredness and independence in the overall learning process (Sawyer, 2005). The notion of scaffolding in education has tended to focus at the level of task. In both of the cases described above, the induction of learners who were unfamiliar with Novakian concept mapping was conducted at task level to support both metacognitive analysis of CM as a tool and the cognitive processing of key concepts and their relationships. Providing a theoretical rationale for Novakian concept mapping and explicit instruction on how to use the CMapTools™ software scaffolded learner acquisition of this new skill.

For the first year undergraduate dental students, practical exercises illustrating the importance of the role of the guiding focus/question in shaping the final product supported a deeper understanding of the conceptual bases of concept mapping. Explicit instruction as to the steps of map construction was followed with breakout groups creating posters with concept maps drawn using 'post-it' notes as nodes and propositions which were displayed on the lecture hall walls. A roving commentary by the instructor following students' art gallery style viewing provided feedback to individuals and highlighted common strengths and weaknesses. The ensuing exercise introduced CMapTools™ with a breakout task using the CM drawing software, uploading maps to the Learning Management System then sharing with the whole class. Peer and facilitator feedback focussed on map design features as well as application of affordances of the software such as the use of colour to support hierarchies.

In the postgraduate PBL module, tutors' online feedback on both maps was structured at both the conceptual level and in terms of capitalising on the affordances of the CMapTools™. Placing this feedback on a common online forum prompted learners to view each other's concept maps, reflect on the feedback provided and contribute their own comments or questions. The utility of shared understandings and guided practice was key to the scaffolded introduction of the tool in preparation for independent application.

In both cases, critical to the transition to independent practice was the application of whole group feedback on early attempts at creating concept maps. Torre, Durning, and Daley (2013) consider both the collaborative practice of joint construction of concept maps in conjunction with instructor feedback as core to successful implementation. Indeed, in terms of preparing future clinicians, collaborative concept mapping with facilitator feedback has the dual advantage of making one's judgements transparent for critical review and for ongoing development as a health professional. Torre, Durning, and Daley (2013) also noted that, particularly for medical education,

> *It is important for trainees and teachers to understand that concept mapping is a learning activity that can assist trainees in learning how to learn. Understanding your own learning processes is a critical skill that can lead to lifelong learning and progressive development of competent and eventually expert physicians. One of the strengths of concept mapping is that it allows for the students to reflect on their own misunderstandings and take ownership of their learning.* (pp. 202-203).

Adjustment to a new problem-based curriculum structure and programme which re-situates knowledge as a dynamic process rather than a static product (Lu, Bridges, & Hmelo-Silver, 2014) is a challenge for undergraduate students. The incorporation of scaffolded activities to support the application of Novakian CM for problem-based learning within an extended first year PBL orientation and induction programme was well received by students. However, as well as highlighting the role of scaffolding at task level, the brief case studies have illustrated how the structured introduction to CM provides a different form of scaffolding within an overarching curriculum design. As such, concept mapping was utilised to support constructive alignment of learning outcomes, learning experiences and content, and assessment (both formative and summative) (Biggs & Tang, 2011) in both problem-based contexts.

While the two cases above indicate possible pathways for introducing learners to concept mapping and CMapTools™ software as first time users, they also illustrated the complementarity between Novakian concept mapping and inquiry-based learning. Indeed, for Dentistry, CM supports, to some extent, almost every element of the undergraduate curriculum introduced in the Faculty of Dentistry at The University of Hong Kong in 1998. The curriculum is an integrated one and no systems, subjects, disciplines or other subdivisions of learning are catered for separately. All pre-clinical, para-clinical and clinical learning seeks to be integrated. CM is integrative in nature, not only in integrating prior knowledge with new knowledge but also in fostering integration across disciplinary areas as they relate to concepts which arise from professionally related problems. As Mintzes, Wandersee, and Novak (1998) proposed, meaningful learning is evident when learners create "well integrated, highly cohesive knowledge structures that enable them to engage in the type of inferential and analogical reasoning required for success in the natural sciences'' (p. 41). Analysis of feedback indicated that the first year students clearly reported some or major improvements in identifying interrelations through CM activities. For an integrated student-centred curriculum, the recognition by student themselves of the interrelationships and inter-connectedness of so much requisite professional knowledge, skills and attributes is essential. It is clear that the students' perceived that CM contributed to improving their abilities in this regard.

Students who are admitted to professional courses in university in which the results of school leaving public examinations play a part in determining acceptance usually have a proven track-record of being successful in memorizing facts. Interestingly, CM was reported by the 85% of first year dentistry students to have brought about some or major improvements in their ability to memorize facts. While Novakian CM educational philosophical bases focus on higher levels such as meanings and concepts, the first year dentistry students also allowed CM to improve what they may value in learning, i.e. 'memorizing facts'. While the CIMHSE health sciences professionals were not surveyed, their general feedback on the utility of concept mapping was in organising concepts as components and illustrating interrelationships through cross-linking. The critical step of labelling links is supported by the software and prompted students to consider patterns of relationships.

Concept map (CM) generation is a student-centred activity, and while both cases reflected heightened engagement, when it came to use of CM software, the first year Dentistry study showed the students had a clear preference for face-to-face collaborative effort in assembling a concept map, which fosters the kind of student-centred collaborative learning fundamental to the curriculum. The first year students reported that CM improved to some or a major extent the building of new ideas and more importantly building on past knowledge. Often first year students in a professional undergraduate degree programme feel that they have everything in front of them in terms of their professional development. CM allows them to appreciate how much knowledge they already have, and how they can build upon that prior knowledge. The first of the four applications of CM elaborated by Hay, Kinchin, and Lygo-Baker (2008) were shown to have been realised.

The same outcomes were also noted for the more challenging asynchronous, online environment developed under a distance education model of in-service education for medical teachers from a wide array of fields – basic biomedical sciences, clinical medicine, dentistry and nursing. The inquiry-based structure supported CM introduction with short, multimedia demonstrations combined with the practice of continuous CM feedback from both faculty and peers. This resulted in high perceived satisfaction and improved concept mapping techniques by these adult learners.

6. Conclusions

The two cases of implementation of Novakian concept mapping (CM) in health sciences curricula illustrate how CM can be employed at both undergraduate and continuing professional education levels to support student learning outcomes in inquiry-based curricula. Critical to both cases was the need to carefully induct learners into both the underlying principles (as a rational for) and the applications (as a guide how to) of concept mapping and the CMapTools software. CM was shown to facilitate the philosophical basis of PBL with respect to constructivist, collaborative approaches to knowledge building using the prior knowledge and already acquired learning skills as the bedrock. The two cases in health sciences education illustrate the role of CM for learning design both at task and curriculum level.

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