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A comprehensive text analysis of lecture slides to generate concept maps

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A R T I C L E I N F O

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A B S T R A C T

Current instructional methods widely support verbal learning through linear and sequential teaching materials, focusing on isolated pieces of information. However, an important aspect of learning design is to facilitate students in identifying relationships between information. The transformation of linearity in teaching resources into integrated network models such as concept maps facilitates effective knowledge organisation by constructing relationships between new and existing knowledge. However, the manual construction of concept maps from teaching materials places an additional workload on the academics involved. Consequently, this research investigates the effectiveness of automated approaches in extracting concept maps from *lecture slides* and the suitability of auto-generated concept maps as a pedagogical tool. We develop a set of Natural Language Processing (NLP) algorithms to support concept-relation-concept triple extraction to form concept maps. Structural and graph-based features are utilised to rank the triples according to their importance. The natural layout of the lecture slides is incorporated to organise the triples in a hierarchy, facilitating highly integrated structure. Our evaluation studies identify promising results, with several case studies demonstrating a statistically significant correlation ($r_s > 0.455$) between auto-generated concept maps and human experts' judgment. Auto-generated concept maps were rated from 'good' to 'very good' by the academics on evaluation factors such as *coverage, accuracy,* and *suitability* as a pedagogical tool. Thus, auto-generated concept maps from this research can be utilised as a positive alternative to the manual construction of expert concept maps and further, it is possible to utilise these maps for a wider range of applications including knowledge organisation and reflective visualisation of course contents. Our research contributes to bridging the gap between linearity in teaching materials and the necessity of creating integrated network models from teaching resources.

1. Introduction

An important aspect of designing teaching material is to facilitate students in understanding the important concepts of the domain and the relationships between new and existing information. With the popularity of open online learning platforms and the lack of teachers' presence, it is crucial to embed knowledge organisation opportunities to assist learners. Current instructional methods, particularly sequentially-structured lecture slides which are developed on top of presentation

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frameworks are not very supportive in aiding learners in identifying complex relationships between information, which can result in poor knowledge organisation (Kinchin, Chadha, & Kokotailo, 2008). Despite the richness of the knowledge structures of the teachers, the ultimate form of the lecture slides is a series of bullet points. There has been a long-standing criticism of the cognitive style of PowerPoint presentations where it is believed to weaken verbal and spatial reasoning when utilised as a lecture delivery mechanism (Tufte, 2003). Irrespective of its pedagogical value or cognitive ability, point-based lecture slides are embedded in the culture of teaching and hence, widely popular across the world (Bartsch & Cobern, 2003; Apperson, Laws, & Scepansky, 2008).

There have been numerous educational benefits in utilising knowledge organisation techniques over text representations. Among them, the use of knowledge maps as a knowledge organisation technique demonstrated significantly higher performance for recall, subjective concentration, and motivation over traditional text (Hall & O'Donnell, 1996). Low ability students taught using knowledge maps recalled more central ideas than students who were taught using traditional text (Patterson, Dansereau, & Wiegmann, 1993). Students with low prior knowledge learned most when the lecture is accompanied by knowledge maps (Lambiotte & Dansereau, 1992). Students performed significantly better on complex programming problem solving using knowledge maps over traditional hierarchical representations (Gao, Wang, & Gao, 2015). Concept maps are amongst one of the well-established educational visualisation tools, assisting learners in organising, sharing, reflecting, and representing knowledge (Novak & Gowin, 1984). Concept mapping is grounded in the *Assimilation theory* which states "*learning takes place by the integration of new concepts and propositions into existing concept and propositional framework held by the learner*" (Ausubel, 1968; Novak & Gowin, 1984). The hierarchical nature of concept maps supports this theory by identifying the general concepts held by the learner prior to introducing more specific concepts. The integration of relevant prior knowledge in learning new information (i.e. *meaningful learning*) enables the construction of effective knowledge structures. Additionally, the use of concept maps to identify relations between concepts and more progressively, identification of cross-links between concepts, involves a high level of cognitive performance (Novak & Canas, 2006).

Since 1997, more than 500 empirical studies have utilised concept maps for effective learning and teaching activities (Nesbit & Adesope, 2006), particularly assessing the conceptual understanding, conceptual change (i.e. evolution of conceptual understanding over time), and misconception (Novak & Gowin, 1984). In addition to the benefits for learners, concept maps can be used to create 'conceptually transparent' curriculum planning where domain concepts are organised in advance (i.e. *advance organisers*) without introducing redundancies or lessening its organisation (Novak & Canas, 2006). Concept maps demonstrate the ability in externalising experts' tacit knowledge which is often difficult to articulate well to others through text representation (Novak & Canas, 2006). Therefore, the ability to generate concept maps from teaching materials provides one way of assessing whether the learning design has been transferred successfully to teaching materials.

Therefore, this research focuses on supporting the knowledge organisation of teaching materials (i.e. *lecture slides*) through concept maps. Our motivation is supported by numerous previous studies (Bradley, Paul, & Seeman, 2006; Kinchin et al., 2008). As stated in previous studies, it is challenging for teachers to express complex knowledge structures explicitly using point-based lecture slides. Therefore, it is unpredictable for teachers to perceive how students will interpret and reconstruct the knowledge. It is possible for learners to construct false hierarchies that are not the intention of the teachers. According to Kinchin et al. (2008), the integrated knowledge structure of an expert ('expert structure') is transformed into teaching space using the sequence of slides ('teaching sequence'). Therefore, students often interpret the information presented early in the sequence as the most important. Therefore, a combination of lecture slides and concept maps are encouraged to an epistemologically balanced teaching approach (Kinchin et al., 2008).

The widespread adoption of concept maps is hindered by the substantial assistance and feedback required by learners constructing concept maps. Most learners struggle to identify correct concepts, relations, and their hierarchical organisation. More specifically, learners struggle to identify relation labels and cross-links between concepts both of which involve higher mental load (Novak & Canas, 2006). This occurs mainly when traditional teaching resources such as lecture slides and textbooks focus more on isolated pieces of information than their inter-relationships. All, Huycke, and Fisher (2003) stated that "*helping students to formalise concept links is one of the most challenging tasks in teaching*". In a study by Chang, Sung, and Chen (2001), 94% students expressed that concept map construction is an effort-demanding task and requires scaffolding during concept map construction.

In order to overcome the issues associated with manual concept map construction, the idea of *expert maps* (also known as *expert skeleton maps* (Novak & Canas, 2006), *teacher-prepared maps* (Nesbit & Adesope, 2006), *expert-generated maps* (Olney, Cade, & Williams, 2011)), or concept map critique (Schwendimann, 2016) is introduced. Expert maps are prepared by domain experts (i.e. teachers) with the intention to utilise for learning, comparison, evaluation, problem-solving, and scaffolding purposes for students (Ruiz-Primo & Shavelson, 1996; Chang et al., 2001). The construction of expert maps places an additional workload on the academics involved, requiring the multifaceted expertise of the domain, and the creation of complex concept maps. In this work, we use the term 'expert maps' to denote the concept maps constructed by the domain experts.

Therefore, our main focus of this work is to develop techniques to extract concept maps from *lecture slides*. We aim to utilise auto-generated concept maps to design numerous pedagogical activities and assessments for students including providing concept maps as a scaffolding resource for educational question answering. Auto-generated concept maps facilitate as a reflective visualisation of course contents for teachers as well as students. Additionally, Intelligent Tutoring Systems (ITS) such as *Guru* (Person, Olney, D'Mello, & Lehman, 2012) and *Betty's Brain* (Leelawong & Biswas, 2008) utilised auto-generated concept maps to model domain knowledge and to create concept map learning activities. Olney et al. (2011) utilise the auto-generated concept maps from Biological textbooks to generate questions for students. Auto-generated concept maps from