Concept mapping in Introductory Physics

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ABSTRACT. Concept mapping is a meta-learning strategy based on the Ausubel-Novak-Gowin theory of meaningful learning. In a concept map, concepts are related with linking words to form propositions. By expanding this concept-proposition link, one eventually forms a web of concepts whose meanings are embedded in the presented map. The paper describes the author's experience with students' use of concept maps and how concept maps are scored. The strategy was utilized as an advance organizer and as an assessment tool (for diagnostic and summative purposes). Sample concept maps constructed by students taking up Introductory Physics are presented.

KEYWORDS: *Assessment tool, Concept mapping, Meta-learning strategy, Physics course, Scoring interpretation*

Concept mapping is a meta-learning strategy based on the Ausubel-Novak-Gowin theory of meaningful learning (Ausubel, Novak, Hanesian, 1978; Novak, Gowin, 1984). It had its origins in research done at Cornell University to study changes in students' understanding of science concepts over a 12-year span of schooling (Novak, 1990). The Cornell University group, led by Joseph Novak, worked with the idea that new concept meanings were acquired through assimilation into existing concept/prepositional frameworks. This idea of hierarchical representation of concept/prepositional frameworks was eventually described as "cognitive maps" or "concept maps".

Basic to making a concept map for a piece of scientific knowledge is the ability of the student to identify and relate its salient points to a general (or super-ordinate) concept. Concepts can be connected with linking words to form propositions (for example, potential energy may be classified as either gravitational potential energy or elastic potential energy). Wandersee (1990) describes a concept map as a schematic device for representing a set of concept meanings embedded in a framework of propositions.

Novak, Mintzes, and Wandersee (2000) posit that learning may proceed in two different ways. Rote learning occurs when the learner makes no effort to relate new concepts and propositions to prior relevant knowledge s/he possesses. Meaningful learning occurs when the learner seeks to relate new concepts and propositions to relevant existing concepts and propositions in her/his cognitive structure.

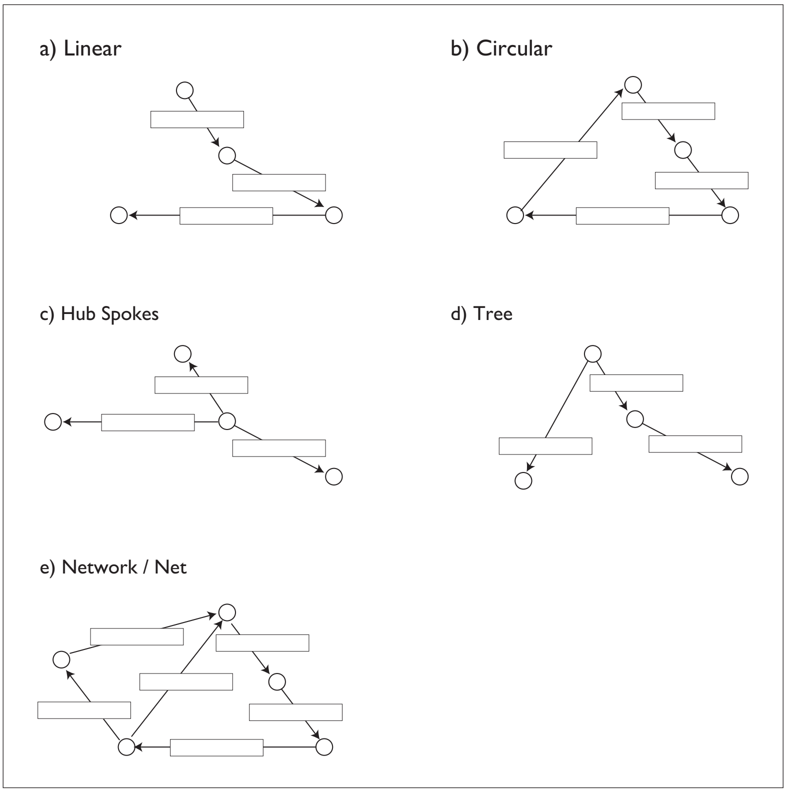
When students are presented with innumerable bits of information to be recalled, it is difficult for them to consider how each bit of information relates to what they already know, thus they resort to rote learning.

The perspective presented by Edmondson (2000) - "the fundamental goal of education is to facilitate learning through shared meaning between teacher and student" - views students as active participants in the process of knowledge construction and not simply as passive recipients of knowledge that is "given" by the teacher. As noted by Novak, Mintzes, and Wandersee (2000), students who learn meaningfully integrate information from different sources. Students form connections between new information and material that has been previously studied.

During the early years of research in concept maps, Symington and Novak (1982) found that primarygrade students are capable of developing very thoughtful concept maps, which they can explain intelligently to others. This observation led the researchers to explore even more the value of concept maps in organizing the instructional material and helping students learn this material.

Yin et. al. (2005) describe a concept map as follows, "[concept map] includes *nodes* (terms or concepts), *linking lines* (usually with a unidirectional arrow from one concept to another), and *linking phrases* which describe the relationship between nodes. Linking lines with linking phrases are called *labeled lines*. Two nodes connected with a labeled line are called a *proposition*. Moreover, concept arrangement and linking line orientation determine the *structure* of the map (e.g. hierarchical or non hierarchical)".

Building on the spoke, chain, and net structures proposed by Kinchin (2000), researchers from Stanford University (Yin et. al., 2005) propose five possible structure types that could be used to describe concept maps.



Concept maps: pedagogical implications

The main idea behind concept mapping is that expertise or understanding can be assessed by asking a student to construct a map by relating concepts in a hierarchical structure using prepositional statements as the links or connectors. This resulting map reflects the student's mental structure related to the concept(s) presented. Concept maps provide the educator a glimpse into the learning of the student, in particular with the qualitative aspects of students' learning. They reveal students' cognitive structures due to prior knowledge and experiences. They also reveal errors, misconceptions, and alternative frameworks (Edmondson, 2000). Kinchin (2000) emphasized "pupil-produced maps" as the ones that are most beneficial in the learning process, arguing that concept maps are able to reveal students' misconceptions in learning that

are not captured by traditional assessment tools.
Although much research has still yet to be done on student's facility in using concept maps, Good (2000) notes that the process of concept mapping is recognized by most science educators as a valid way to assess understanding and as a useful instructional tool. Mistades (2003) described the use of concept maps both as an advance organizer for a chapter and as an assessment instrument (both for diagnostic and summative purposes) for an Introductory Physics class for Liberal Arts students.
Concept maps have allowed the researcher to determine what particular concepts the students have clearly grasped and which concepts would need a little bit more polishing. Edmondson (1995) discussed the positive effect of concept maps in the development of a problem based veterinary curriculum. In a study that implemented concepts maps as a methodology to teach and evaluate the critical thinking of senior clinical nursing students, Daley, et. al. (1999) showed that there is a statistically significant increase in concept map scores possibly indicative of the increase in student's conceptual understanding and critical thinking. First-year college chemistry students who were taught the use of concept maps to help them understand the concepts involved in the experiments they performed responded very positively toward the use of concept maps. They felt strongly that constructing the maps helped them understand the conceptual chemistry of the experiments (Markow, Lonning, 1998).

Concept maps: scoring schemes

Several schemes for scoring concept maps have been suggested. McClure, Sonak, and Suen (1999) compared six different scoring methods of concept maps and found them all to be correlated with each other. Shavelson and Ruiz-Primo (2000) presents a scoring scheme adapted from the outline developed by the Cornell University (Novak, 1990) group:

a) score the components found in the student's map, focusing on three components:
  - propositions (concepts and content)
  - hierarchy levels (relationships, links, and cross-links)
  - examples

b) compare a student's map with an expert's map
c) a combination of map components and comparison with an expert's map

The scoring scheme devised by Markham, Mintzes, and Jones (1994) utilized six observed aspects of a student's map:

1) number of concepts presented
2) concept relationships
3) branchings
4) hierarchies
5) cross-links, and
6) examples

Concept maps prepared by Introductory Physics students

The following figures represent concept maps in Physics prepared by students of De La Salle University - Manila in their Introductory Physics course. Notice the varying level of sophistication in each sample, by looking at the number of concepts placed in the map, links and cross-links involved, prepositions used to link the various concepts, and examples that were given.

Figure 1 shows the various components looked into when scoring a student's concept map. An analysis conducted by Johnson et. al. (1991) of the growing body of research on collaborative learning showed that when students work in small groups and cooperate in striving to learn subject matter, the end result is a positive cognitive and affective outcome. Figures 2 and 3 are sample concept maps created by a group of students in class. Figure 4 depicts a concept map with a lot of branchings, examples, and cross-links involved in the diagram.

The following concept maps were designed by the students of the course.
They highlight the importance of concept mapping in didactics, not only for content representation but also to assess students achievements. (editorial note)

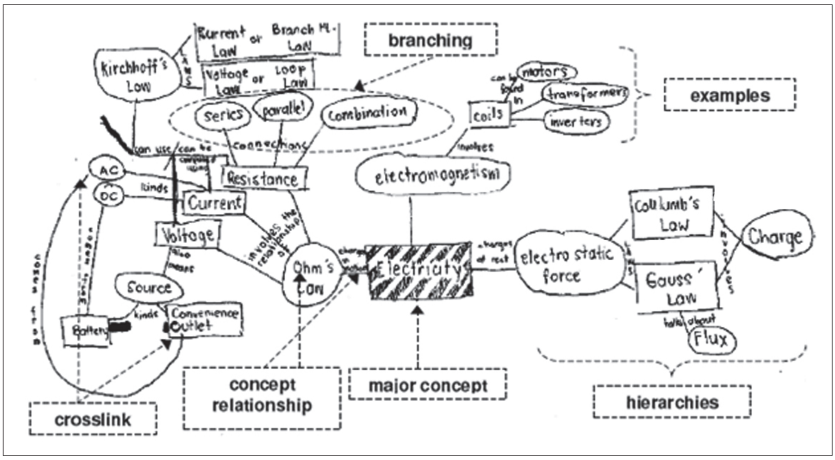


Figure 1. Student's concept map in Electricity

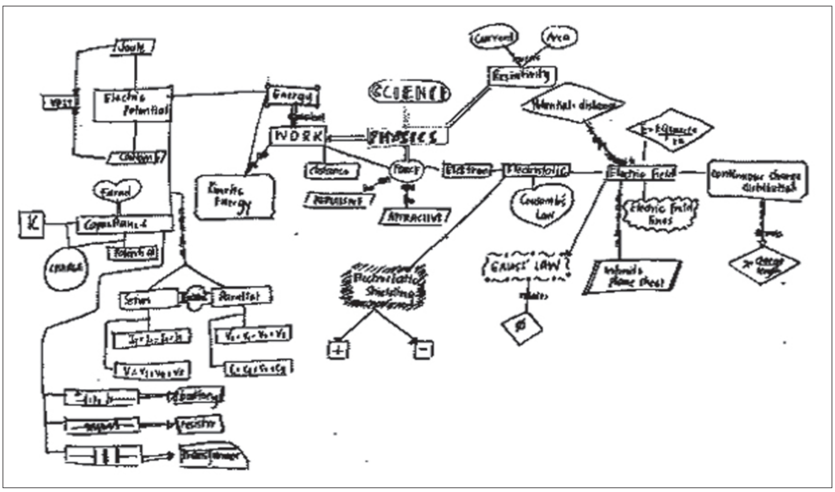


Figure 2. Group concept map in Electricity

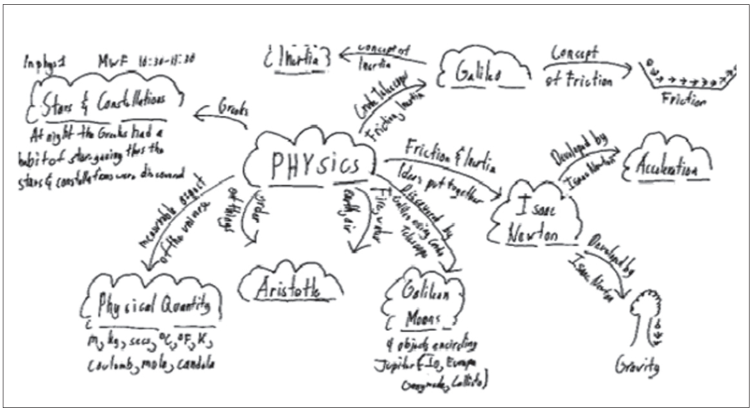


Figure 3. Group concept map in Physics

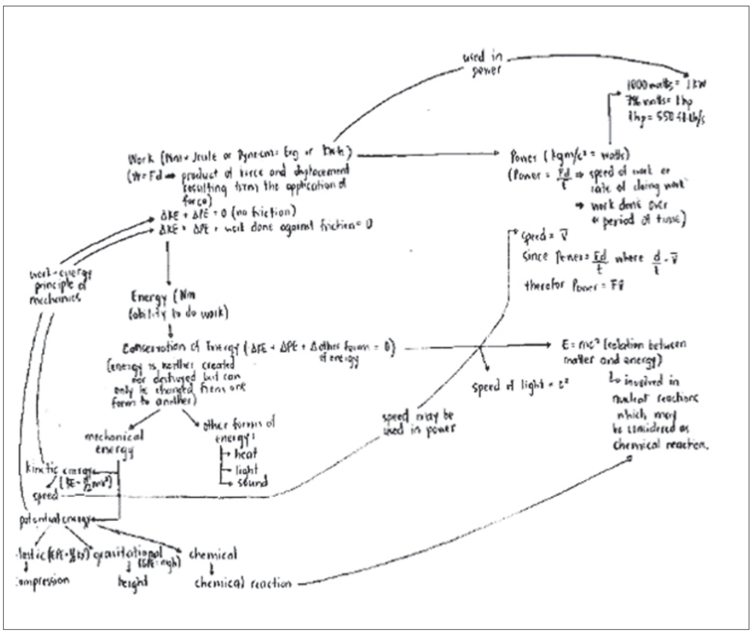


Figure 4. Student's concept map relating work, energy and power

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Sintesi

Le mappe concettuali, mutuate dagli studi e dalle teorie di Ausubel, Novak e Gowin, costituiscono una delle principali strategie di apprendimento attivo, orizzontale e collaborativo, uno strumento di valutazione e di organizzazione concettuale avanzata. Un gruppo di studenti dell'Universitàdi Manila è stato coinvolto in un lavoro di riflessione metodologica sull'applicazione delle mappe concettuali per l'indagine dei presupposti teorici della Fisica. Vengono presentati nell'articolo le mappe preparate da un gruppo di studenti dell'Università di Manila, un lavoro di introduzione al corso di Fisica. La complessità delle mappe presentate varia a secondo del livello di sofisticazione e della quantità dei concetti presenti. Le quattro mappe (mappa concettuale degli studenti sull'Elettricità, mappa concettuale di gruppo sull'Elettricità, mappa concettuale di gruppo sull'Introduzione alla Fisica, mappa concettuale degli studenti sull'Introduzione alla Fisica).

I sistemi di valutazione delle mappe riguardano proposizioni, livelli di gerarchie ed esempi (sistema di valutazione di Sahavelson e Riuz- Primo), nonché i sei aspetti di Markham, Mintezes e Jones: numero di concetti presentati, relazioni tra concetti, la ramificazione, gerarchie, grado di reticolazione e esempi. Nel quadro di queste teorie di valutazione, vengono evidenziate in concreto le componenti valutate dai docenti in una mappa concettuale, i risultati prodotti dal gruppo, fino ad arrivare al lavoro concettuale più complesso realizzato nella figura numero 4.

Le mappe concettuali, gerarchiche o non gerarchiche, includono nodi (termini o concetti chiave), linee di collegamento (con frecce unidirezionali, di solito), frasi di collegamento che descrivono il tipo di relazione che intercorre tra i due concetti. Esistono almeno cinque modelli differenti di mappe, cinque diversi tipi di struttura: lineari, circolari, mozzo a raggi, ad albero, reticolari. Sono strumenti che, talvolta, rendono possibile all'insegnante capire le modalità di apprendimento degli studenti, le strutture cognitive acquisite delle precedenti esperienze formative, rendono inoltre evidenti gli errori che non emergerebbero nell'apprendimento tradizionale.

Edmondson nei suoi studi ha dimostrato l'utilità delle mappe concettuali applicate ad aspetti formativi critici del curriculum veterinario. Markow e Lonning hanno invece applicato le mappe concettuali con studenti al primo anno di chimica del college.