Using Concept Mapping as a Quality Learning Strategy for Engineering and ICT Undergraduates: An Exploratory Study

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Abstract: The evolution of holistic education arouses some pertinent questions of the validity and quality of learning, especially in the delivery of education in technical fields such as engineering and information and communications technology (ICT) which involves spatial and interconnecting ideas. A confronting fact is, institutions of higher learning (IHLs) today are facing an uphill task in multiple attempts to wholesomely educate the generation-Y. Born between the years of 1980 to 2000, their lives have been largely shaped by visual cues of globalization, multiculturalism, terrorism, and heroism rather than textual-based teaching-learning styles of yesteryears. This paper aims to review some of the previous research findings pertinent to these areas of interest. It also intends to present an exploratory research work that is being conducted based on phenomenology approach of the German philosopher Edmund Husserl (1859 – 1938) to study the use of concept mapping as a strategic instructional and assessment tool for learners in the fields of engineering and ICT.

Literature Review

Introduction – Understand how Learners Really Understand

Many researches of technical faculties reported a serious mismatch of applied teaching-learning styles (Felder & Silverman, 1988). A serious conjecture at present is how often colleges do; corresponding faculties, administrators and teaching staffs understand these differences? How often, as a collective, do educators give proper attention to the multiple intelligences of diverse learners in technical fields of study when designing lesson plans and conducting lectures? Furthermore, it is an irrefutable fact that there exist an incomplete understanding of cognitive and meta-cognitive sciences that tertiary teaching professionals have unintentionally ignore due to the lack of training in structured pedagogical and educational psychology, which otherwise may help them to devise more appropriate instructional and assessment strategies in order to improve learners' learning. From the psychological testing perspective, the purpose of having assessment is to evaluate the individual's psychological constructs that represent the degree of students' competency (skill and knowledge) through tests and measurements of sampled behaviours.

The quality of (meaningful) learning can be loosely reflected by the word 'understanding'. Understanding is a product of conceptual restructuring that is driven by a need to make meaning out of objects and events in the real world (Mintzes et al., 2000) (Eds.) Concepts are important because they constitute the basic units of meaning and thereby the fundamental building blocks of knowledge. When linked together in precise ways, two or more concepts form a proposition.

Contemporary Teaching-Learning Mismatch Issues

Numerous research findings based on a study of preferred learning style dichotomy continuum, with respect to the way how participants input information from the surrounding settings, revealed that most engineering undergraduates are classified as *'visual'* rather than *'verbal'* learners (Felder and Brendt, 2005 & Wong, 2006). The 'Visual' distribution percentages obtained in these researches were found 82% and 89% respectively. Anderson (1991) and Felder & Silverman (1988) reported that the teaching style and student learning style happen in opposite sides. They concurred that the teaching style employed by many engineering lecturers was found to mainly follow the 'Verbal' instead of 'Visual' style. Therefore, a serious teaching-learning mismatch occur in engineering education in general.

At the time of writing, there are no replicated findings for learners in the ICT field on their learning styles. However, it is irrefutable that ICT studies necessitate the acquirement of innovative mindset and a largely coherent cognitive framework to enable novel algorithms, solutions and meaningful learning of learners in computer science and other relevant sub-fields to be developed. In this respect, ICT studies share similar and often identical needs in teaching-learning paradigms as that of the engineering field. Both of which are science-related fields. As propounded by Pearshell (1997, pp. 194-195);

> Research in the cognitive aspects of science learning has provided strong evidence that successful science learners as well as professional scientists develop elaborate, strongly hierarchical, well-differentiated, and highly integrated frameworks of related concepts as they construct meanings…

The contemporary challenges for engineering educators are to devise a more effective teaching approach to maximize the overall learning effectiveness towards meaningful learning in engineering. Sad to say, most curriculum efforts across all educational levels emphasize on what essentially is an overstuffed "*laundry list*" of topics to be taught instead of "*doing less for more*". The net result may be inadvertently encouraging classroom activities that supports rote rather than meaningful, tranformative, or 'deep' learning. In addition, poor assessment or testing practices reward the wrong kind of learning. As Pendley, Bretz, and Novak (1994, p15) noted:

> *… regardless of how conceptually complete the material presented to the student is, the instruction alone does not convey understanding … answering numerical poblems correctly does not necessarily indicate or reflect a students conceptually understanding of the material.*

Similary, Mintzes et al. (2000, Eds., p18) asserted:

… the focus of student evaluation is proposition knowledge, it is aimed at determining the level of content and factual knowledge they have mastered, not the degree to which they have developed a well-intergrated understanding.

The fact that generation Y learners are more apt to gain information from interactive visualization channels such as 3-D software interface and the borderless Internet means more students tend to encounter learning difficulties to comprehend basic principles being taught in their courses. Could it be safely assumed that transferred knowledge from educators through classical lectures and text-based teaching-learning methodologies be treated as discrete units of knowledge by the students where in turn is extended as new information is introduced? What instructional approach then would help technical instructor and learners to negotiate for a more accurate, aligned and structured hierarchical abstract concepts, which ultimately is a bona fide allowance to achieve common agreement in the knowledge construction.

Apart from the opposing verbal-visual styles among professors and learners that accounts for the teaching-learning mismatch issue, a few other important notions of knowledge and learning described below in this paragraph bring further insights on how teaching-learning mismatch can be exacerbated.

First, there are two types of knowledge – explicit and tacit. Explicit knowledge is easier to recognize. It can be articulated in formal language including grammatical statements, mathematical expressions, specifications, manuals and so forth. Tacit knowledge, on the other hand, is hard to articulate with formal language. Instead, it is personal knowledge embedded in individual experience and it involves intangible factors such as personal belief, perspective, and the value system (Tobin, 1998). **Second**, learning is personal and idiosyncratic. Therefore it is a matter of individual responsibility. It cannot be shared. Meanings (body of knowledge), on the other hand can be shared, discussed, negotiated, and agreed upon (Novak & Gowin, 1984). Learning and internalising knowledge demands an active engagement of learners whereby they build their own knowledge (Savander-Ranne & Kolari, 2003). In the social contructivism perspective, understanding rests on shared meaning, a trait that philosophers sometimes called intersubjectivity. Hence, the fundamental function of education in the epistemology stance is to create, to share and to change the meaning of experience; and the prime instructional goal is to successfully facilitate learning through shared meaning between teacher and student. In this regard, Gowin (1981, p63) states:

> *A back-and-forthness between teacher and student can be brief or it can last a long time, but the aim is to achieve shared meaning. In this interaction both teacher and student have definite responsibilities. The teacher is responsible for seeing to it that the meanings of the materials the student grasps are the meanings the teacher intended for the student to take away. The student is responsible for seeing to it that the grasped meanings are the ones the teacher intended.*

Third, from the constructivist learning perspective also, knowledge is a construction of reality. The combination of prior learning experiences and existing situational context contribute to the learning process of learners who interactive with other members by assimilating and accommodating information to construct that particular knowledge domain. Prior knowledge also has an impact on the comprehension of visualisations (Shah & Freedman, 2003).

Fourth, as learning spaces change, knowledge spaces or cognitive structures also change. Hence, the term 'evolutionary epistemology' dubbed to describe the dynamic characteristic of knowledge as well. In other words, knowledge or cognitive (meaning-making) structure of individuals is constantly being modified, fine-tuned and continuously re-presented, re-constructed, shared and perceived among learners within a particular contextual and legitimate peripheral participation of a community of practice.

Knowledge is a human construction that is a natural outgrowth of the capacity of human beings for high level of meaningful learning (Novak, 1977; 1993; 1998). From these notions/characteristics of knowledge and learning, we realized that the meaningful learning of the body of knowledge not merely involve the individual's inherent understandings derived form implicit personal cognitive structure (which cannot assessable directly by instructors) but it also encompasses the shared meanings owned by groups of people, that can be explicitly demonstrated via visual-spatial presentation of information. Therefore, for meaningful learning to occur, teaching-learning process cycles should operate in an **adaptive closed-loop** manner for formation of shared meaning. In other words, effective teaching-learning practice requires a feedback mechanism that allows instructors to assess learners' mental representation, and able to dialectically negotiate with learners about the misconceptions or alternative knowledge frameworks.

Implicit in the goal of shared meanings (or knowledge) is the assumption that teaching and learning is a shared enterprise, that teachers and students must work together to construct knowledge and negotiate meaning. Using concept maps as a visualization tool can allow both instructors and learners to reflect and negotiate the intended concepts, relying on a common platform of visual/graphical information. Concept maps provide teachers an avenue for developing insights into student understanding, as evidenced by well-organized and richly elaborated knowledge structures, valid propositional relationships, and interrelationships (Mintzes et al., 2000) (Eds.).

Concept mapping was invented at Cornell University in USA by Novak and the members of his research group (Stewart, Van Kirk & Rowell, 1979). Concept map appears in the form of diagrammatic network consists of nodes and links. Nodes represent concepts and links represent the relations between concepts (Novak & Gowin, 1984; Eric, 1997; Turns & Atman, 2000). As stated by Novak & Gowin (1984), the concept maps fundamentally intended to represent meaningful relationships between concepts in the form of propositions. Propositions are two or more concept labels linked by words in a semantic unit. Figure 1 illustrates an example of the basic structure of concept map. The content of this map can be read as follows: *Telecommunication systems are complex systems that transmit information formats include signalling, text, audio, graphic and video.*

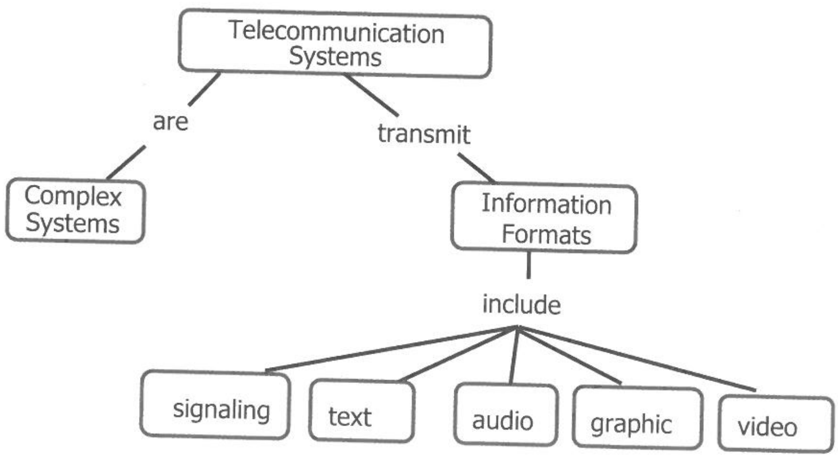

Figure 1 The Basic Network Structure showing Nodes and Links

The Uses of Concept Maps for Solving Teaching-Learning Mismatches Problems in Technical Courses

The fact that the present generation Y learners are more apt to visual cues is highly encouraging some form of forward adaptation in the teaching-learning methodologies. Carroll, Thomas, and Malhotra (1980) found that subjects who were given spatial representations were faster and more successful in their problem solving. Typically, visualisations benefit those learners who have high spatial abilities more than those who have low visuospatial abilities (For example, see Gyselinck, et al., 2002).

Firstly, visualization can make complex information easier to comprehend (Larkin & Simon, 1987; Oestermeier & Hesse, 2000; Zhang & Norman, 1994). As put forth by Arnheim (1972) and later McKim (1980), the physical, spatial, or visual representations are easier to retain and manipulated as compared to textual or numeric representations.

Second, they provide an external representation of information that has analogue properties (Hegarty & Steinhoff, 1997; Zhang, 1997).

Third, they may produce deeper processing because they allow users to select, compare, and integrate materials with other materials as well as their own prior knowledge (Mayer, 2002).

Fourth, they can be attractive and very motivating.

According to Shneiderman (1998), suitable representations of problems are critical to solution finding and to learning. Concept maps provide a diagrammatic means to establish spatial and visual clarity in interpreting the contents in the learner's cognitive mind. The maps are well-organized and richly elaborated knowledge structures. This visualization tool also helps to identify errors, omissions, or misconceptions, and they depict the important organizational functions and certain conceptual play in shaping understanding as well as the resistance of some conceptions to change – an absolutely crucial matter to address in the often abstract concepts presented in technical courses. In dealing with conceptual changes, Helm & Novak (1983) and West & Pines (1985) quoted that numerous studies have shown that students bring relevant knowledge framework of varying degrees of quantity and quality to new learning tasks. The challenge has not only helped students elaborate the conceptual understanding they already possessed, but especially to modify these knowledge structures that contain misconceptions or alternative conceptions or frameworks. Concept maps have been useful in helping students to recognize and modify faulty knowledge structures (Feldsine, 1983; Novak & Gowin, 1984). In fact, concept maps was developed and constructed based on the additional ideas from Ausubel's theory that cognitive structure is organized hierarchically, involves superordinate-subordinate relationship of concepts, and that most learning occurs through derivative or correlative subsumption of new concepts meanings under existing concept/prepositional ideas (Novak, 1977, pp. 83-93) as illustrated in Figure 2.

In short, concept maps have been particularly helpful in representing quantitative as well as qualitative aspects of student learning. It can be a learner's study tool as well as a teacher's evaluation tool. Concept maps allow both instructors and learners to reflect their implicit minds mutually and thus, improve dialogical negotiation to align conceptual understanding of the topics under studied. Figure 3 shows an example of a test question based on concept mapping approach.

Research Methodology

Case Study Sample

This research case study was carried out by two instructors acting as action researchers who played the role as participant observers via two groups of learners: Diploma in Electrical and Electronic Engineering (14 participants) and Diploma in Information Technology (12 participants).

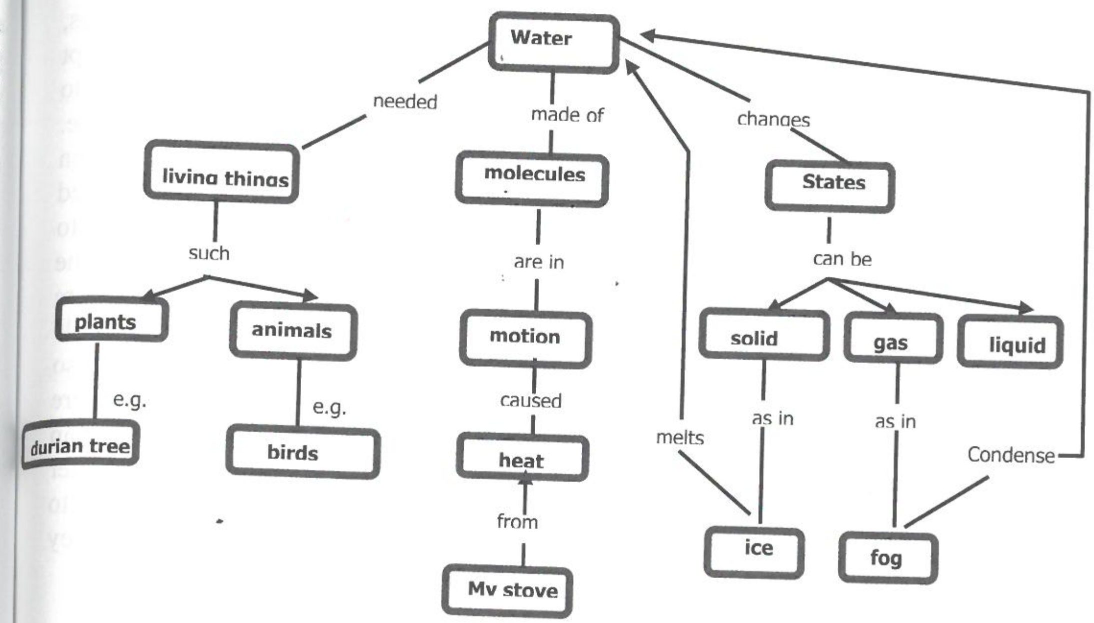

Figure2 The Hierarchical Structure of a Concept Map on Water and its Associated Concepts

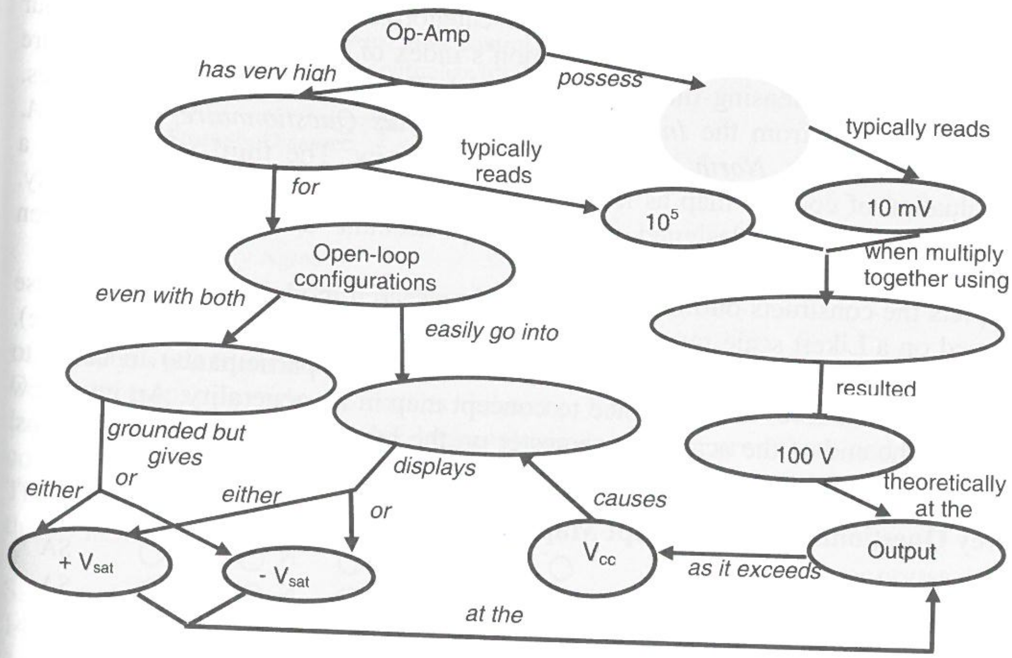

Figure 3 Using Concept Map in a Progress Test

Intervening Classical Test-based Learning

The research has started since May 2007, proceeded until end of August 2007. During the early stage of the semester, the two researchers explained to respective learners on the applications and ideas about concept mapping. In order to train the learners' skills on drawing concept maps, initially the researchers performed 'on-the-spot' demonstration on how to construct a concept map during the initial lectures. Turns and Atman (2000) stated that concept maps are easy to explain to students, the training and the construction of the maps can occur at the same time. Soon after a mini-lecture covered on a selected topic, 'on-the-lesson' exercises were then immediately assigned to learners and requesting them to produce the map within a stipulated timeframe. Pair-exercises were encouraged. In this research, it took about two-three lessons to overcome the learning curve. Feedbacks for improving the map construction provided within the shortest possible time, mainly through face-to-face coaching. Subsequently, learners were challenged to produce more concrete concept maps via formal multidimensional gradable assessment activities, which included quizzes, tests, assignments, note taking, lab reports and so forth. Again, immediate feedbacks about the strength and weakness in their maps were communicated. The feedback was aimed to discuss the skill gap development of the map construction technique with another chance given to students to allow them to reproduce a better concept map and resubmit for re-assessment. A new, better mark allocation was made to encourage them to re-submit a more complete, integrated and precise concept map. Hence, they could be motivated towards empowered learning.

The Survey Instrument

The survey instrument was administered in the English language and consisted of four parts. The first presented questions pertaining to the general learning styles and soliciting general demographic information from the respondents. The second probed further in detail on the preferred learning styles in an exploratory attempt to categorize the respondents into four preferred learning styles according to the Felder-Solomon's Index of Learning Styles. These are namely, the Active-Reflective, Sensing-Intuitive, Sequential-Global and Visual-Verbal styles. These questions were adapted from the *Index of Learning Styles Questionnaire, Barbara A. Solomon and Richard M. Felder, North Carolina State University*. The third was to have a comprehensive evaluation of concept map as learning tool in the respondent's course of study. Lastly, the fourth quadrant was designed to explicitly account a comparison between conventional text-based learning and concept mapping.
Table 1 below depicts the constructs outlined in the paper's research model. Responses to these questions were based on a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). These survey questionnaires were distributed to respondents (all 26 participants) in order to gather statistical data on their level of acceptance to concept map in its generality. An interview was also conducted at the end of the academic semester on the learners' feelings and opinions, appreciation level, and difficulties they faced using concept maps.

Table 1 Survey Questionnaire on Concept Map

1.	Concept map is easy to use.	○ SD	○ D	○ N	○ A	○ SA
2.	I am in control of the contents of the concept map.	○ SD	○ D	○ N	○ A	○ SA
3.	I will be able to learn how to use all that is offered in a concept map.	○ SD	○ D	○ N	○ A	○ SA
4.	Reading through the concept map is easy to do.	○ SD	○ D	○ N	○ A	○ SA
5.	Using concept map is engaging.	○ SD	○ D	○ N	○ A	○ SA
6.	The concept map matches my needs in learning other modules as well.	○ SD	○ D	○ N	○ A	○ SA
7.	Getting started with a concept map is easy.	○ SD	○ D	○ N	○ A	○ SA

8.	My concept map is flexible and changeable.	○ SD	○ D	○ N	○ A	○ SA
9.	Finding a concept that I want in the concept map I made is easy.	○ SD	○ D	○ N	○ A	○ SA
10.	It is easy to make use of this concept map to communicate my misunderstanding(s) to my lecturer.	○ SD	○ D	○ N	○ A	○ SA
11.	Discovering new concepts is possible with a concept map.	○ SD	○ D	○ N	○ A	○ SA
12.	I learn faster using a concept map than text-based reading.	○ SD	○ D	○ N	○ A	○ SA
13.	The concept map is satisfying to use as it tells me what I know and do not know.	○ SD	○ D	○ N	○ A	○ SA
14.	I find my concept map allows lecturers to discover my understanding of this module, thus helping me to have deeper understanding.	○ SD	○ D	○ N	○ A	○ SA
15.	Doing revision with concept map is easier and less stressful.	○ SD	○ D	○ N	○ A	○ SA
16.	Concept map facilitates objective discussion within my study group.	○ SD	○ D	○ N	○ A	○ SA
17.	My mistakes and misunderstanding can be resolved by referring to my peer's concept map.	○ SD	○ D	○ N	○ A	○ SA
18.	Concept map can be used as a gauge (benchmark) to determine my level of understanding in this module.	○ SD	○ D	○ N	○ A	○ SA
19.	Using concept map gives me more control over my learning as it enables me to visualize (draw out) my knowledge.	○ SD	○ D	○ N	○ A	○ SA

SD	= Strongly Disagree
D	= Disagree
N	= Neutral
A	= Agree
SA	= Strongly Agree

Data Analysis and Discussion

Concept maps provide numerous inherent benefits for classroom teaching and learning. Information harnessed from the data analysis depicted a prominent and promising usefulness of concept maps in classroom teaching and learning in both engineering and ICT field of study. The descriptive statistic (mean scores, standard deviations and the percentage distribution) for all the 19 items were displayed in Table 2.

Six out of fourteen response items possessed mean score above 3.90. They were: items 4, 11, 12, 14, 15 and 19. From this list, both items 14 and 19 posses the top two highest mean scores, above 4.0. Over 77 % of the participants chosen "Agree (A)" or "Strongly Agree (SA)" for these two item scores. These results revealed an important fact. That is, majority of the participants believed that the concept map learning (CML) approach is able to help them to gain deeper understanding and it provides better control over their learning as their inherent idiosyncratic knowledge stored as mental representation can be made explicit, shared, discussed, and improved using the visualization technique. Turns and Atman (2000) in their research on using concept maps for engineering education also made a similar conclusion. They found that concept maps represent an innovative way to assess, and gain insight, into student learning about the relationships among concept. Therefore concept map should be seen as a valuable component of an assessment toolbox.

Item 11 (Discovering new concepts is possible with a concept map.) returned a 73 % "Agree (A)" and "Strongly (SA)". In addition, item 15 (Doing revision with concept map is easier and less stressful.) returned an 80.8 % "Agree (A)" and "Strongly (SA)".
96.15% of the sample was found 'Active' learners. A simple bivariate correlation study among these items and the 'Active' learning style dimension was carried out. Significant correlation coefficients are as summarized in Table 3.

Several comments from the interviewees supported the statistical data in this research. For example:-

"Concept map is able to display the whole ideas in one sheet of a paper and make it easier to understand…" (Kenny, male student)

" Learning the concept map make the process more entertaining and less stressful, interaction between the lecturer and students also improve and useful." (Kevin, male student)

"… the use of concept map, it can remind me about the next things about the topic… I always use it to test if I understand the topic or not. If I can draw it easily, that means I already know a lot about that particular topics." (LCW, male)

"I can understand the overall subject after drawing in one glance. Using concept map therefore saves my time when I am doing my revision. " (Carol, female).

Table 2 The Descriptive Statistics on the Use of Concept Map

Item	Mean	Std Dev	SD	D	N	A	SA
Concept map is easy to use.	3.81	.801	0	3.8	30.8	46.2	19.2
I am in control of the contents of the concept map.	3.50	.812	0	7.7	46.2	34.6	11.5
I will be able to learn how to use all that is offered in a concept map.	3.73	.724	0	3.8	30.8	53.8	11.5
Reading through the concept map is easy to do.	3.92	.055	3.8	7.7	1.5	46.2	30.8
Using concept map is engaging.	3.54	.647	0	3.8	42.3	50.0	3.80
The concept map matches my needs in learning other modules as well.	3.65	.936	0	15.4	19.2	50.0	15.4
Getting started with a concept map is easy.	3.08	.891	3.8	19.2	46.2	26.9	3.80
My concept map is flexible and changeable.	3.15	.834	3.8	15.4	42.3	38.5	0.00
Finding a concept that I want in the concept map I made is easy.	3.73	.604	0	0	34.6	57.7	7.70
It is easy to make use of this concept map to communicate my misunderstanding(s) to my lecturer.	3.65	.977	0	11.5	34.6	30.8	23.1

Discovering new concepts is possible with a concept map.	3.92	.688	0	0	26.9	53.8	19.2
I learn faster using a concept map than text-based reading.	3.92	.935	0	7.7	23.1	38.5	30.8
The concept map is satisfying to use as it tells me what I know and do not know.	3.77	.710	0	0	38.5	46.2	15.4
I find my concept map allows lecturers to discover my understanding of this module, thus helping me to have deeper understanding.	4.08	.744	0	0	23.1	46.2	30.8
Doing revision with concept map is easier and less stressful.	3.96	.824	0	7.7	11.5	57.7	23.1
Concept map facilitates objective discussion within my study group.	3.46	.647	0	0	61.5	30.8	7.70
My mistakes and misunderstanding can be resolved by referring to my peer's concept map.	3.38	.941	0	23.1	23.1	46.2	7.70
Concept map can be used as a gauge (benchmark) to determine my level of understanding in this module.	3.81	.895	0	11.5	15.4	53.8	19.2
Using concept map gives me more control over my learning as it enables me to visualize (draw out) my knowledge.	4.04	.662	0	0	19.2	57.7	23.1

Table 3 Summary for Significant Item Correlation

No	Significant Correlation Coefficients	Comments
1	$R_{12,4} = 0.561$ at $p = 0.001$	Find reading through concept maps is easy, faster than text-based learning and less stressful.
2	$R_{12,15} = 0.687$ at $p = 0.001$	
3	$R_{4,15} = 0.687$ at $p = 0.000$	
4	$R_{14,11} = 0.637$ at $p = 0.000$	Using concept map allows me to discover new concepts, draw out my knowledge, and thus help for deeper understanding.
5	$R_{14,19} = 0.562$ at $p = 0.005$.	
6	$R_{11,19} = 0.446$ at $p = 0.05$.	
7	$R_{(VIS,12)} = 0.469$ at $p = 0.05$	Visual learners perceive that they learn faster using concept map compared to text-based learning. Strong statistical correlation between Visual Style score to Preference of using Concept Map-based learning.
8	$R_{(VIS, CML)} = 0.454$ at $p = 0.05$	

Assessment of the concept maps from students who had worked on a common topic reveals that the individual's map outlooks are different from each other. This demonstrated that although conceptual meaning is shared but learning takes place idiosyncratically. This implies the existence of individual different personal creativity power. This phenomenon also indicates that accountability and responsibility for learning lies within the individuals. The teacher's role should focus to facilitate with effective delivery methods. Working in pairs allow the members to talk, to reflect, and to verify the other member's meaning by asking questions, discussing, and making decisions to agree to the propositions. Consequently, through this intercative negotiation process, their mental representations or cognitive structures are aligned towards closer shared meanings. Novak and Gowin (1984) also said 'Learning the meaning of a piece of knowldege requires dialogue, exchange, sharing, and sometimes compromise'. It is also a negotation process.

Conclusion

There are a few interesting phenomena discovered in this exploratory research study. We have found that almost 100% of the respondents are visual learners. The significant correlations between the Visual-CML, and Visual-Item12 suggested that majority of Visual learners preferred CML approach, and they perceive that CML allows them to learn faster as compared to the traditional text-based learning (TBL) approach. Since majority of the engineering students are 'visual' oriented, instructional techniques that incorporate visuospatial cognition could enrich the learning effectiveness and maintain high interest in the subject being taught.

Also, interviewees revealed that many of them find concept maps useful because they save their time for revision before taking their examination. However, many of them felt that the most difficult part of drawing concept maps is deciding the liking proposition words to be used, and it is difficult to start due to lack of training. In addition compelling is the difficulty in making decision as which inter-related concepts should be included into the concept maps. Turns and Atman (2000) suggested that a key to distinguishing among the students who learned a lot and those who were less successful may be the ability to see complex connections among the various topics covered in the class, which also has been observed in this research. Pearsall, Skipper, and Mintzes (1997, p213) also commented:

> *It appear that student who report employing 'active', 'deep' information processing strategies tends to construct more elaborate, well-differentiated frameworks of knowldege.*

Inevitably, the utmost desire for instructors in any education practice is, they wish that conceptual understanding for learners should be aligned and be congruent with the intended pedagogical attempts made by respective instructors through reflection, discussions and revisions of the learning products generated by students. We need more assessment and evaluation formats that make "*the thinking of the learner overt*"; and also, provide opportunities for them to be examined, questioned, and athey are able to accommodate progressive conceptual changes towards a potential larger and complex learning space. Concept map as explored by many other researchers also concur that it can serve as a powerful instructional tool to assess students' understanding toward this goal. For example, Beyerbach and Smith (1990) quoted that it is possible to organize our teacher education curriculum around concepts, which are central and common to students' maps and to develop and to expand that framework, we might achieve a better mesh between our theories and theirs. Concept map indeed can be a tool, which promotes reflection, and modify students' misconceptions and alters their mental representation, as it is a form of closed-loop learning model.

In summary, based on these research findings, the quest to have an effective educational experience or quality of learning using concept maps, the following criteria are necessary:

- clear responsibility and accountability ought to be established for both teachers and the students,
- 'real' learning required teachers to realise the cognitive structure, and devise appropriate instructional and assessment strategies to facilitate learning activities, and be able to measure learning outcomes.
- 'real' learning required a positive learning environment that encourage learners to feel enthusiatic and want to actively participate in the learning activities continuously.

The researchers have high confidence that future research on utilization of concept map as strategic instructional tool can be rewarding as it is able to change the landscape of practitioners in the education fields, especially for disciplines that involve abstract concepts and visual spatial information.

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