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CLOSENESS INDEX (CI) AN ASSESSMENT TOOL FOR STUDENTS' PERFORMANCE OF CELL THEORY

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ABSTRACT
The research investigated the impact of concept mapping on students' performance in cell theory. Fifty-four first year elective science students of Osei Kyeretwie Senior High School in Kumasi, Ghana were used for this investigation. The study was a quasi-experimental research designed with quantitative and qualitative data using concept-mapping as an interventional teaching strategy. The students' concept maps were subjected to analysis using closeness index techniques developed by Goldsmith, Johnson and Acton, 1994. The results revealed that the performance and concept mapping construction ability of the students, as well as, their content knowledge in cell theory improved tremendously. It also revealed that there exist a significant difference in the achievement levels of the students in the cell theory for both the experimental and control groups after the introduction of the intervention activity using the concept mapping. This proves concept mapping as an instructional technique capable of improving students' performance in cell theory.

KEYWORDS: Closeness index, Concept mapping, Senior High School, Achieving Levels

INTRODUCTION

Concept mapping is an instructional tool that is currently gaining popularity in the field of science education (Abimbola, 1997). The concept and theory of Concept Mapping had its roots in education, and education and learning probably still constitute the bulk of its use (Cañas, Hill & Lott., 2003). Hence, the purpose of this section is to review a number of studies of the effectiveness of Concept Mapping as a learning tool. The issue is not whether or not Concept Mapping enhances learning. Like any other tool, the effectiveness of Concept Mapping depends on how it is used and the conditions in which it is applied. There is no doubt that Concept Mapping can enhance learning. An earlier review of the educational effectiveness of Concept Mapping (Horton, McConney, Gallo, Woods, Senn & Hamelin., 1993) concluded that Concept Mapping can have educational benefits that range from what can only be described as huge, all the way to having negative effects (i.e., when some alternative instructional intervention produced learning effects greater than Concept Mapping) .Although the great majority of the studies reviewed showed differing degrees of positive effect for Concept Mapping.

The development of learning strategy and knowledge tools such as concept mapping, semantic networks and others, are all efforts made to improve science education. Similarly, the large number of studies conducted on various aspects of science education is an indication of science educators' search for solutions to the problems facing meaningful learning of scientific concepts and theories. This study is therefore an attempt at contributing to the solution of the problems facing meaningful learning of scientific concepts and theories. The goal of a study expressed by Nicoll, Francisco and Nakhleh (2001) was to investigate the value of using Concept Mapping in general chemistry and, more particularly, to see if Concept Mapping would produce a more interconnected knowledge base in students, compared to ordinary instruction. The results showed that the Concept Mapping group knew more concepts, more linking relationships, more "useful" linking relationships, and had no more erroneous linking relationships than the non-Concept Mapping students. Despite some design flaws (e.g., non-random assignment, and more high school chemistry experience among the treatment group) these findings were very impressive for Concept Mapping, as it relates to the development of an interconnected knowledge base and meaningful learning. In 1993, Trowbridge and Wandersee conducted a study to describe how concept mapping could be used as an integral instructional strategy for teaching a college evolution course. The study sought to evaluate the usefulness of incorporating concept mapping in a college course in evolution, and its effects on students' understanding of evolution. It also sought to determine if students' concept maps revealed critical junctures in learning. The students were taught how to construct concept maps and were made to submit concept maps after each course lecture. Results of the study indicated that critical junctures in learning evolution could be identified by checking the degree of concordance of super ordinate evolutionary concepts appearing on the students' concept maps. The use of seed concepts, micro mapping, a standard format and standard concept map checklist was noted to make the use of concept-mapping strategy feasible for the instructor to implement and for the students to adopt. In a related research, Pankratius (1990) sought to test if Concept Mapping, and especially the amount of Concept Mapping, would affect achievement in physics problem solving. The main variable was the amount of Concept Mapping practice/experience the students were engaged in. One treatment group created Concept maps at the beginning of a unit and continued to improve upon them throughout, a second treatment group made Concept Maps once at the end of a unit. A control group did not make Concept Maps. The results showed statistically significant differences, with both treatments performing better than the control, and the periodic Concept Mapping being more effective than Concept Mapping just at the end of the unit.

Schmid and Telaro (1990) tested the effectiveness of Concept Mapping on High School Biology Achievement and again assessed their students' academic ability levels. The study was conducted in Montreal, Canada and involved students at levels "4 and 5" of the Canadian system. The subject matter was on the nervous system. The experimental design combined treatment and control crossed with three levels of Academic Ability (high, medium, and low). The results indicated that the helpfulness of Concept Mapping increased as groups went from high to medium and then to low ability. The authors speculate that Concept Mapping helps low ability students to a greater degree because it requires them to take an organized and deliberative approach to learning, which higher ability students are likely to do anyway.

A study by Czerniak and Haney (1998) was designed to test if the addition of a structured Concept mapping to instruction in a physical science course would improve achievement, reduce anxiety toward physical science, and reduce anxiety about teaching physical science at the elementary school level. The results showed that Concept Mapping increased achievement, decreased anxiety for learning physical science, and decreased general (trait) anxiety. Results did not indicate an increase in self-efficacy for teaching physical science.

The goal of a study by Bascones and Novak (1985) was to test the effect of Concept Mapping on students' problem solving in physics. The teaching process used in this study was based on Ausubel's (1968) theory of meaningful learning. The course was a required physics course taught throughout Venezuela. The design involved two groups. The treatment group had general-to-specific orderings of content and routine Concept Mapping exercises, while the control group had traditional instructional methods. The results showed large effects in favour of the treatment group on every test administration and at all ability levels. The results of this study clearly present a strong statement for the benefit of the instruction that was based on Ausubel's (1968) learning theory and some sort of utilization of Concept Maps.

Concept mapping is a process of constructing web diagrams, involves mapping out logical relationships among concepts in a hierarchical order, using links and nodes such that the most general concepts are at the top of the map, with the most specific concepts at the bottom of the map. A concept map, according to Novak and Gowin (1984), is a schematic device for representing a set of concept meanings embedded in a framework of propositions. It is a two-dimensional hierarchical diagram that illustrates the interconnections between and among individual concepts. Concept maps provide a visual road map showing the pathways that we may take to construct meanings of concept and propositions. According to Novak and Gowin (1984), concept maps is both a meta-learning and meta-knowledge tool diagrams that represent organized knowledge in a web and crosslink relationship as a vehicle for knowledge elicitation (KE), and for generating models of domain knowledge (Cañas, *et. al.,* 2003) as represented in (Fig.1). Although originally developed as an evaluation tool, concept mapping is now widely used in many other aspects as an instructional strategy in education. For instance, it has been used as a tool for curriculum development by Edmondson (1995) and Wallace and Mintzes (1990). According to Abayomi (1988), Esiobu and Soyibo (1995) and others, it could be used as an instructional strategy to promote meaningful learning among students at all levels in the educational system. Abrams and Wandersee (1996) used concept mapping to identify students' misconceptions while Bayerbach and Smith (1990) employed concept mapping to help teachers to become effective in their teaching. It could also be used as an evaluation tool as describe by Lay-Dopyer and Bayerbach (1988), and Moreira (1978). The cell theory has been used for this study due to the unifying role it plays in the proper understanding of modern biology. It was also chosen because it is a relatively major component of the West African Examinations Council biology syllabus for Senior High Schools.

The purpose of this study is to find out the impact of concept mapping as an instructional strategy on students' performance in the teaching and learning of the cell theory using the Closeness Index (CT) technique developed by Goldsmith, Johnson and Acton (1991).

METHODOLOGY

The study used concept-mapping as an interventional teaching and learning strategy. The study used fifty-four first year elective science students at Osei Kyeretwie Senior High School in Kumasi, Ghana. The students' concept maps were also subjected to analysis using Closeness Index (CI) technique developed by Goldsmith, *et. al. (*1994) as explained below:

Closeness index scoring Technique

To illustrate the closeness index scoring comparison method proposed by Goldsmith *et al* (1994). Fig. 1a is taken as an expert concept map, $G_e= (V_e, E_e,)$, where V_e and E_e are the sets of concept nodes and relation links in the map, respectively. Figure 1b is a student concept map, $G_s= (V_s, E_s,)$. To compare the maps, we first search in each of them for concept nodes that are connected to each node *n* from $V= V_e \cup V_s$. The sets of such nodes are represented as $N_n{}^{(E)}$ and $N_n{}^{(S)}$. For instance, in Fig. 1a node A has links to nodes B and C in G_E, but in G_S, A is connected to nodes C, D, and E. Therefore, $N_A{}^{(E)} = \{B, C\}$ and $N_A{}^{(S)} = \{C, D, E\}$. After the sets of adjacent nodes for a given node are determined, the intersection of the two sets ($I_n = N_n{}^{(E)} \cap N_n{}^{(S)}$) and their union ($U_n = N_n{}^{(E)} \cup N_n{}^{(S)}$) are determined. Going back to the example above, the intersection of $N_A{}^{(E)}$ and $N_A{}^{(S)}$ is $I_A = \{C\}$, and their union is $U_A= \{B, C, D, E\}$. Now that we have I_n and U_n, we define the closeness index for node n as $C_n = |I_n| \div |U_n|$, where | | means the number of nodes in the set. By this definition, the closeness index for node A in Fig. 1 can be calculated as:

$C_A = |I_A| \div |U_A| = 1/4 = 0.25$. After the closeness indexes for all nodes in the two concept maps are calculated, we can define the closeness index of the two concept maps as:

$C (G_e, G_s) = 1 \div |V| \sum C_i$, Where $V=V_e \cup V_s$

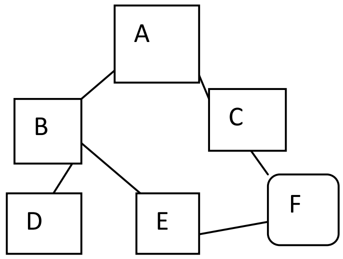

Fig.1a: Expert(teacher) concept **map**

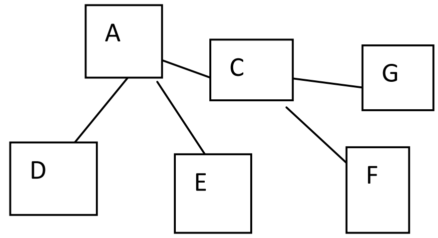

Fig. 1b: Student concept map

C (G_e, G_s) = 1÷| V| ∑ C_i, WhereV=V_e ∪V_s Therefore, the **Total closeness index, c=0.321**

The Fig. 1b is a poorly constructed concept map because it has a low closeness index value of 0.321, which is less than 0.5, thus, approaching (0.0) when compared with that of the expert concept map.

RESULTS

The Closeness index marking scheme developed by Goldsmith, *et. al.* (1994) was used for scoring the nine-group concept maps constructed by the three different ability levels (Low, Middle and High) on the cell structure, components and their functions.

Scoring key

TABLE 1: Nodes of teacher (expert) and student's concept map been compared

A = Cell	I = Spindle fibre	P = Nucleus	W = Lysosome
B = Organelle	J = Centriole	Q = D .N. A.	X = Energy flow
C=Plasma membrane	K = Cell division	R= Endomembrane system	Y = Chloroplast
D= Cytoskeleton	L = Mobility	S=Endoplasmic recticulum	Z =Mitochondrion
E = Mov't into cell	M = Information flow	T = Vacuole	Mt = Photosynthesis
F = Microtubule	N = Ribosome	U = Golgi bodies	Nt=Cellular respiration
G = Flagella	O=Protein synthesis	V = Protein package	Pt = A.T.P.
H = Celia			

TABLE 2: Comparing the nodes of 1st group of high achievers' to a teacher (expert) concept map as a sample for the 2nd and 3rd groups.

U	$N_n^{(E)}$	$N_n^{(S)}$	I_n	U_n	C_n
	{B,C,D}	{ B,C,D}	{B,C,D }	{B,C,D }	1
B	{*A*,M,X,R}	{A,M,X,R }	{ A,M,X,R}	{AM,X,R }	1
C	{A,E}	{A,E }	{A,E }	{A,E }	1
D	{A,E,F}	{A,E,F }	{A,E,F }	{A,E,F }	1
E	{*C,D*}	{C,D }	{C,D }	{C,D }	1
F	{*D,J,G,I,H*}	{ D,J,G,I,H }	{ D,J,G,I,H }	{ D,J,G,I,H }	1
G	{F,L}	{F,L }	{F,L }	{F,L }	1
H	{F,L}	{F,L }	{F,L }	{ F,L}	1
I	{F,K}	{F,K }	{F,K }	{F,K }	1
J	{F,K}	{F,K }	{F,K }	{F,K }	1
K	{I,J}	{I,J }	{I,J }	{ I,J}	1
L	{H,G }	{ H,G }	{ H,G }	{ H,G }	1
M	{ N,P,B}	{N,P,B }	{N,P,B }	{N,P,B }	1
N	{M,O }	{M,O }	{M,O }	{M,O }	1
O	{ N}	{N }	{N }	{N }	1
P	{Q,M }	{Q,M }	{Q,M }	{ Q,M}	1
Q	{P }	{P }	{P }	{P }	1
R	{ B,S,T,U,W}	{ B,T,U,W}	{ B,T,U,W }	{ B,T,U,W,S }	0.8
S	{R }	{Φ }	{ Φ}	{Φ}	0
T	{R }	{ R}	{R }	{R }	1
U	{R,V }	{R,V }	{ R,V}	{ R,V}	1
V	{U }	{U }	{U }	{U }	1
W	{ R}	{ R}	{ R}	{ R}	1
X	{ B,Y,Z}	{B,Y,Z }	{B,Y,Z }	{B,Y,Z }	1
Y	{X,Mt}	{X,Mt }	{X,Mt }	{MT,X }	1

Z	{ X,Pt,Nt,}	{ X,Pt,Nt }	{ X,Pt,Nt }	{ X,Pt,Nt }	1
Mt	{Y,Pt }	{ Y,Pt }	{ Y,Pt }	{ Y,Pt }	1
Nt	{Z }	{Z }	{ Z}	{Z }	1
Pt	Z,Mt	{ Z,Mt }	{ Z,Mt }	{ Z,Mt}	1

C (G_e, G_s) = 1÷| V| ∑ C_i, WhereV=V_e ∪V_s Therefore, the **Total closeness index, c=0.953**

TABLE 3: The closeness index mean score of the High Achievers

High Achievers	1st Gp	2nd Gp	3rd Gp	Mean scores
Total closeness index scores	0.96	0.94	0.96	0.953

TABLE 4: Comparing nodes of 1st group of middle achievers' to the teacher (expert) concept map as a sample for the 2nd and 3rd groups

U	Nn(E)	Nn (S)	In	Un	C n
	{B,C,D}	{ B,C,D}	{B,C,D }	{B,C,D }	1
B	{A,M,X,R}	{A,M,X,R }	{ A,M,X,R}	{AM,X,R }	1
C	{A,E}	{A,E }	{A,E }	{A,E }	1
D	{A,E,F}	{A,E,F }	{A,E,F }	{A,E,F }	1
E	{C,D}	{C,D }	{C,D }	{C,D }	1
F	{D,J,G,I,H}	{ D,J,G,I,H }	{ D,J,G,I,H }	{ D,J,G,I,H }	1
G	{F,L}	{F,L }	{F,L }	{F,L }	1
H	{F,L}	{F,L }	{F,L }	{ F,L}	1
I	{F,K}	{F,K }	{F,K }	{F,K }	1
J	{F,K}	{F,K }	{F,K }	{F,K }	1
K	{I,J}	{I,J }	{I,J }	{ I,J}	1
L	{H,G }	{ H,G }	{ H,G }	{ H,G }	1
M	{ N,P,B}	{N,P,B }	{N,P,B }	{N,P,B }	1
N	{M,O }	{M,O }	{M,O }	{M,O }	1
O	{ N}	{N }	{N }	{N }	1
P	{Q,M }	{Q,M }	{Q,M }	{ Q,M}	1
Q	{P }	{P }	{P }	{P }	1
R	{ B,S,T,U,W}	{ B,S,T,U,W}	{ B,S,T,U,W }	{ B,T,U,W,S }	1
S	{R }	{R}	{ R}	{R}	1
T	{R }	{ R}	{R }	{R }	1
U	{R,V }	{R}	{ R}	{ R,V}	0.5
V	{U }	{Φ}	{Φ}	{Φ }	0
W	{ R}	{ R}	{ R}	{ R}	1
X	{ B,Y,Z}	{B,Y,Z }	{B,Y,Z }	{B,Y,Z }	1
Y	{X,Mt}	{X,Mt }	{X,Mt }	{MT,X }	1
Z	{ X,Pt,Nt,}	{ X,Pt,Nt }	{ X,Pt,Nt }	{ X,Pt,Nt }	1
Mt	{Y,Pt }	{ Y,Pt }	{ Y,Pt }	{ Y,Pt }	1
Nt	{Z }	{Z }	{ Z}	{Z }	1
Pt	Z,Mt	{ Z,Mt }	{ Z,Mt }	{ Z,Mt}	1

C (G_e, G_s) = 1÷| V| ∑ C_i, WhereV=V_e ∪V_s Therefore, the **Total closeness index, c=0.93**

TABLE 5: The closeness index mean score of the Middle Achievers

Middle Achievers	1st Gp	2nd Gp	3rd Gp	Mean scores
Total closeness index scores	0.95	0.91	0.95	0.937

TABLE 6: Comparing nodes of 1st group lower achievers' to the teacher (expert) concept map as a sample of the 2nd and 3rd groups.

U	Nn(E)	Nn (S)	In	Un	C n
	{B,C,D}	{ B,C,D}	{B,C,D }	{B,C,D }	1
B	{A,M,X,R}	{A,M,X,R }	{ A,M,X,R}	{AM,X,R }	1
C	{A,E}	{A,E }	{A,E }	{A,E }	1
D	{A,E,F}	{A,E,F }	{A,E,F }	{A,E,F }	1
E	{C,D}	{C,D }	{C,D }	{C,D }	1
F	{D,J,G,I,H}	{ D,J,G,I,H }	{ D,J,G,I,H }	{ D,J,G,I,H }	1

G	{F,L}	{F,L }	{F,L }	{F,L }	1
H	{F,L}	{F,L }	{F,L }	{ F,L}	1
I	{F,K}	{F,K }	{F,K }	{F,K }	1
J	{F,K}	{F,K }	{F,K }	{F,K }	1
K	{I,J}	{I,J }	{I,J }	{ I,J}	1
L	{H,G }	{ H,G }	{ H,G }	{ H,G }	1
M	{ N,P,B}	{N,P,B }	{N,P,B }	{N,P,B }	1
N	{M,O }	{M }	{M }	{M ,O}	0.5
O	{ N}	{Φ }	{Φ}	{Φ }	0
P	{Q,M }	{Q,M }	{Q,M }	{ Q,M}	1
Q	{P }	{P }	{P }	{P }	1
R	{ B,S,T,U,W}	{ B,S,T,U,W}	{ B,S,T,U,W }	{ B,T,U,W,S }	1
S	{R }	{R }	{ R}	{R}	1
T	{R }	{ R}	{R }	{R }	1
U	{R,V }	{R,V }	{ R,V}	{ R,V}	1
V	{U }	{U }	{U }	{U }	1
W	{ R}	{ R}	{ R}	{ R}	1
X	{ B,Y,Z}	{B,Y,Z }	{B,Y,Z }	{B,Y,Z }	1
Y	{X,Mt}	{X,Mt }	{X,Mt }	{MT,X }	1
Z	{ X,Pt,Nt,}	{ X,Pt,Nt }	{ X,Pt,Nt }	{ X,Pt,Nt }	1
Mt	{Y,Pt }	{ Y,Pt }	{ Y,Pt }	{ Y,Pt }	1
Nt	{Z }	{Z }	{ Z}	{Z }	1
Pt	Z,Mt	{ Z,Mt }	{ Z,Mt }	{ Z,Mt}	1

C (G_e, G_s) = 1÷| V| ∑ C_i, WhereV=V_e ∪V_s Therefore, the **Total closeness index, c=0.933**

TABLE 7: Mean closeness index score of the lower Achievers

Lower Achievers	1st Gp	2nd Gp	3rd Gp	Mean scores
Total closeness index scores	0.95	0.91	0.94	0.933

DISCUSSION

The ability levels of Low, Middle and High Achievers on the cell structure, components and their functions were calculated using the Closeness Index (CI) marking scheme developed by Goldsmith, *et. al.* (1994), as shown in Tables 3, 5 and 7. The Tables 2, 4 and 6 are samples of the various ability levels from which the Mean Closeness Indexes were calculated

A closeness index mean score of 0.953 obtained from the three groups of the high-scoring students indicates that a high level of conceptual understanding was achieved by that group. On the other hand, mean scores of 0.937 and 0.933 obtained by the middle and lower achievers' respectively also prove that they really understood the concept on cell theory and the concept map construction principle in spite of their extremely low achievement mean scores of 43.2%, 34.0% and 28.0% obtained by high, average and low achieving levels respectively in the pre-intervention test. Again, the levels acquired by the students in concept mapping construction ability do not differ much among the nine groups of students. This suggests that an individual ability to construct a good concept map is not limited to any ability group, therefore, students should be encouraged to improve upon their understanding of concepts using concept mapping.

CONCLUSION

In concluding, the concept encourages students to represent their vision of how a knowledge domain such as the Cell Theory is structured and foster reflection of how nodes are interrelated. It gave an avenue of expression for the students to transfer their visual representations into diagrammatic interpretations with the Closeness Index (CI) calculation tool edging out the different ability levels of the achievers.

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