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Correlation between Assessment of Concept Maps Construction and the Clinical Reasoning Ability of Final Year Medical Students at the Faculty of Medicine, Suez Canal University, Egypt

Ahmed Radwan[1], Asmaa Abdel Nasser[1], Shaimaa El Araby[1,2], Wagdy Talaat[1]

[1]*Department of Medical Education, Faculty of Medicine, Suez Canal University, Ismailia, EGYPT*

[2]*Medical Education Department, Fakeeh College for Medical Sciences, Jeddah, KINGDOM OF SAUDI ARABIA*

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ABSTRACT

There is a resounding resemblance between concept maps and illness scripts described in the knowledge structure theory of clinical reasoning. Despite the growing interest in concept mapping, few studies have been done on its relationship with clinical reasoning. The aim of this study is to examine the relationship between 6th year students' (n = 55) ability to construct concept maps and their clinical reasoning skills and to improve the understanding of concept maps' use in medical education curriculum in the Faculty of Medicine, Suez Canal University. Analytical cross-sectional study was used and a workshop was conducted in 2017 to teach final year medical students how to construct a concept map in paediatrics discipline. Then, the developed concept maps were scored by four raters according to the Kassab and Hussain scoring system. Then a Script Concordance Test (SCT) in paediatrics was taken by these 6th year students. Correlation analysis between concept maps' scores and SCT scores was done. The results showed a mean and SD of 14.76 ± 2.79 for the total score in concept map assessment. In clinical reasoning evaluation using SCT, 6th year students recorded a mean score of 37.2% (11.16 ± 3.55). There was a statistically significant correlation between mean scores of the total concept map assessment scores across all raters and the total scores in SCT for those 6th year students with a correlation coefficient of 0.51 (p value < 0.05). The study concluded that there is a significant correlation between the 6th year medical students' ability for constructing concept map and their clinical reasoning skills. This is considered as a starting point for the application of concept maps as an assessment tool for evaluating clinical reasoning skills in health professions education.

Keywords: *Concept mapping, Correlation, Clinical reasoning, Script concordance test*

CORRESPONDING AUTHOR

Dr. Asmaa Abdel Nasser, Department of Medical Education, Faculty of Medicine, Suez Canal University, Ring Road, PO Box 41111, Ismailia, EGYPT | E-mail: dr.asmaashraf@gmail.com / asmaa_mohamed@med.suez.edu.eg

INTRODUCTION AND RATIONALE

Concept mapping is used to mainly represent clinical knowledge structure. This is done by illustrating the relevant relationships between each concept in a particular subject or domain (1).

The concept map was developed by Novak and Gowin (2), and their work was based on the assimilation theory of learning by Ausubel (3). They were able to describe a concept map as "a schematic device for representing a set of concept meanings embedded in a framework of proposition" (4). This means that the students would be able to draw the related concepts and link them in a framework that is organised hierarchically (1). In this sense, students attain new knowledge by linking new concepts to what they already know. Moreover, to learn with concept maps, the student has to make an intentional effort to differentiate, relate and link hierarchically with one another (4).

Creating a concept map is an active process, which includes multiple steps. First, the student recognises the general concepts and places them at the top of the map. Second, the student recognises more specific concepts in relation to the general concepts. Third, the general and the specific concepts are tied together with linking words that pertain to the student. Finally, the student looks for cross-linkages to tie the concepts from one side of the map to the other side. It can be constructed by hand or using a computer programme (4).

Concept mapping is frequently applied to a multitude of classroom and professional practices. However, it is seldom used for assessment purposes. This is perhaps because information regarding its validity and reliability is scarce, especially in medical education (5).

Kassab and Hussain were able to develop a concept mapping assessment tool. It is a modified version of Novak et al. (6). Scoring is based on five criteria: valid selection of concepts, the hierarchical arrangement of concepts, integration between concepts, relationship to the context, and the degree of student creativity (1).

Expertise development is a complex process that involves not only acquiring more knowledge and skills but also structuring the knowledge (1). This structuring allows for the development of critical thinking, clinical reasoning, and clinical judgement. Those three terms are interrelated concepts. Each is a vital process that leads physicians to sound, evidence-based practice. Critical thinking is the cognitive processes physicians use to analyse clinical knowledge (7).

Clinical reasoning is also a cognitive process, but it is used to analyse knowledge relative to the presenting clinical problem or a specific patient (8). Finally, clinical judgement is "the cognitive, psychomotor, and affective processes demonstrated through action and behaviours" (7). The main reason for clinical reasoning testing is to differentiate between novice and expert. This is why the definition of an expert is very important (9).

The earliest theory of clinical reasoning focuses on different cognitive stages an expert goes through to solve a problem. The expert can create clinical hypothesis and evaluate each deductively. This is called the hypothetic-deductive reasoning. The need to test clinical reasoning – according to this theory's definition – led to the multi-stages, single-question tests like the Patient Management Problem (PMP), Clinical Reasoning Exercise (CRE), and Clinical Reasoning Practice (CRP). Those tests revealed the extent of similarity between the cognitive steps that an expert and a participant take to solve a problem (10).

Illness scripts were introduced by the knowledge structure reasoning as a cognitive framework to organise and apply medical knowledge to a specific clinical situation. Expert physicians have much of the rich illness scripts. This enables them to successfully deal with different clinical situations in their respective fields (9). Therefore, clinical reasoning tests were created to investigate the similarity of illness scripts of participants and those of experts. Moreover, multi-stages, single-question assessment tools were shifted to multi-questions, one-stage assessment tests. The most prominent of those assessment tools is the Script Concordance Test (SCT) (11).

Concept mapping is used to represent knowledge structure. There is a resounding resemblance between concept maps and illness scripts described in the knowledge structure theory of clinical reasoning. Despite the growing interest in concept mapping and their application in medical education, limited research work has been done on its relationship with clinical reasoning.

Therefore, this study aimed to explore the possible relationship between the score of concept mapping construction and clinical reasoning skills based on the knowledge structure theory and the work of Novak and Gowin (2). It also aimed to explore for an evidence for the construct validity of the assessment tool of concept map. Investigation of this relation could have implications on teaching, learning and assessment in medical education.

SUBJECTS AND METHODS

A cross-sectional analytical study was performed to assess the correlation between concept mapping construction and clinical reasoning skills for final year medical students at the Faculty of Medicine, Suez Canal University (SCU).

The target group was final or 6th year medical students. Via random cluster sampling they were divided into four clusters according to their clinical rounds; then one cluster was chosen. All paediatrics clinical round students were included in this research work.

Data were collected in two successive sessions; in the first session, workshop was conducted to instruct students on how to develop a concept map for a specific domain in the paediatric field. Then the concept maps were scored according to a quality scoring assessment system. Scoring is based on five criteria: valid selection of concepts, the hierarchical arrangement of concepts, integration between concepts, relationship to the context, and the degree of student creativity (1). Each criterion was scored based on a Likert-type scale of 1–5, 1 being poor and 5 being excellent. An overall score – out of 25 – was given from the total scores of all five criteria.

In the second session, students were examined through a SCT in paediatrics. It comprised 10 clinical vignettes and 30 test items to assess different aspects such as clinical diagnosis, investigation, and management plan, as well as ethical consideration in certain clinical situations (12).

DATA ANALYSIS

Data entry and analysis was performed using the Statistical Package for the Social Sciences (SPSS Version 22). Data were presented in tabular and graphic forms. Pearson's correlation coefficient was used to correlate the concept maps scores and the clinical reasoning scores. Independent sample *t*-test was used to compare mean scores of male and females in concept maps and clinical reasoning tests.

RESULTS

The results of this study revealed the following: the gender distribution of the study population (n = 55) was 20 (36.4%) were males while the remaining 35 (63.6%) were females.

Table 1: Concept map scores by each rater in each category and total score in the concept map assessment (n = 55)

Concept map assessment category	Mean ± SD				
	Rater 1	Rater 2	Rater 3	Rater 4	Total
Validity	4.27 ± 0.62	4.58 ± 0.60	3.73 ± 0.45	4.36 ± 0.59	4.24 ± 0.41
Hierarchy	4.11 ± 0.86	1.76 ± 0.88	3.11 ± 0.76	3.11 ± 1.24	3.02 ± 0.70
Integration	2.91 ± 1.31	1.40 ± 0.78	1.78 ± 0.90	2.04 ± 1.19	2.03 ± 0.79
Context	2.45 ± 0.94	4.73 ± 0.56	2.93 ± 0.72	3.31 ± 1.36	3.35 ± 0.67
Creativity	1.96 ± 1.96	1.96 ± 1.11	2.24 ± 0.76	2.29 ± 1.29	2.11 ± 0.85
Total	15.71 ± 3.87	14.44 ± 3.28	13.84 ± 2.59	15.05 ± 3.59	14.76 ± 2.79

Note: Each category was graded for a maximum of 5 points with a total of 25 points

Table 2: Inter-rater reliability coefficient for each concept map assessment category (n = 55)

Concept map assessment category	Reliability coefficient (r)	95% confidence interval	*p* value
Validity	0.69	0.53–0.81	0.000
Hierarchy	0.72	0.57–0.82	0.000
Integration	0.73	0.59–0.83	0.000
Context	0.67	0.51–0.79	0.000
Creativity	0.73	0.58–0.83	0.000
Total score	0.85	0.78–0.91	0.000

Table 1 showed the mean and SD scores of each rater for each category of concept map assessment and also the total scores. Rater one recorded the highest mean in hierarchy and integration while recording the lowest mean in context and creativity categories. Rater two recorded the highest mean in validity and context categories, while the lowest mean in hierarchy and creativity. Next, rater three recorded the lowest mean score in the validity category and the highest score in creativity. In terms of the total scores, rater one had the highest mean (15.71 ± 3.87), rater three had the lowest mean (13.84 ± 2.59), and the total mean score for all raters was 14.76 ± 2.79.

Table 2 shows high inter-rater reliability coefficient for each category of concept map assessment scores. In the validity category, the inter-rater reliability coefficient (r) was 0.69 (p value < 0.05), while in the hierarchy category, it was 0.72 (p value < 0.05). Moreover, in both integration and creativity categories the reliability coefficient was 0.73 (p value < 0.05). Finally, in the context category it was 0.67 (p value < 0.05). The total score shows the highest inter-rater reliability coefficient 0.85 with significance (p value < 0.05).

Table 3 showed no statistically significant difference between male and female students in the SCT total scores ($p > 0.05$). However, females showed a higher mean (11.66 ± 3.51) than male students (10.30 ± 3.56).

Table 4 shows a statistically significant correlation between mean total concept map scores across all raters and total scores in SCT for 6th year student with a correlation coefficient of 0.51, with a p value < 0.05. This concludes that there is a statistically significant correlation between students' concept map creation and their clinical reasoning skills in paediatrics discipline.

Table 3: Comparison between male and female SCT total scores (n = 55)

SCT scores	Mean ± SD			*p* value
	All students	Males	Females	
Total scores	11.16 ± 3.55 (37.2%)	10.30 ± 3.56 (34.3%)	11.66 ± 3.51 (38.9%)	0.176

Note: Scores are reported from a maximum of 30 points based on experts' answers.

Table 4: Correlation between mean concept map assessment scores in each category and total score in SCT for 6th year students (n = 55)

Concept map assessment category	Total score in SCT	
	Pearson correlation	*p* value
Validity	0.38	0.005
Hierarchy	0.54	0.000
Integration	0.41	0.002
Context	0.31	0.020
Creativity	0.44	0.001
Total score	0.51	0.000

DISCUSSION

Expertise development is a complex process that involves not only acquiring more knowledge and skills but also structuring of the knowledge. This structuring allows for the development of critical thinking, clinical reasoning, and clinical judgement. Concept mapping is used to mainly represent knowledge structure. This is done by illustrating the relevant relationships between each concept in a particular domain.

Although the limited research work on concept map assessment scores correlation and students' abilities in clinical reasoning has been reported in the literature internationally, there is one study on assessment of concept map conducted in Bahrain on undergraduate medical students by Kassab and Hussain (1), and another study conducted to use SCT to assess clinical reasoning ability of final year medical students in paediatrics at Faculty of Medicine, SCU by Abouzeid et al. (12). Therefore, the current study is considered as one of the earliest trials to measure the correlation between the concept map assessment results by validated scoring system (1) and the clinical reasoning skills ability by SCT in paediatrics (12).

This concept map scoring system is used due to its feasibility and high-reliability analysis results (1). The test uses a quality scoring system with higher inter-rater reliability and test-retest reliability than the structural scoring system. Also, this scoring system was developed upon problem-based learning (PBL) medical curriculum at the Arabian Gulf University in Bahrain which is similar to the educational strategy used at Faculty of Medicine, SCU. There is also a similarity between the cultures of both countries, in terms of the Arabic language being the mother tongue, which made it feasible to be used in our study.

Students in this study were given the task to construct maps guided by the intended learning outcomes of paediatrics rotation, Faculty of Medicine, SCU. On the other hand, the paediatrics SCT is used also due to its feasibility, ease of administration and collection. Furthermore, experts from the SCU faculty were used to develop this SCT test (12). This contributes to the validity of this study results as opposed to using a test based on another school's curriculum and context.

The results of our study showed a mean and SD of 14.76 ± 2.79 for the total score in concept map assessment for 6th year students. This is lower than Kassab and Hussain's study, in which the mean and SD was 19.03 ± 2.44 for 4th year students (1).

In integration, the mean score in our study was 2.03 ± 0.79 lower than the results of Kassab and Hussain's study, which was 3.64 ± 0.52. In addition, in creativity category the mean score of 2.11 ± 0.85 was lower than in Kassab and Hussain's study results in this category, which was 3.55 ± 0.67. The lower results in scores may be attributed to: first, the small sample size (n = 55) of our study; second, the use of concept map in one discipline (paediatrics); third, due to the difference in the knowledge level of students between the two samples; and last, may be due to the use of different number of raters in each study.

In studying gender influence on concept mapping ability, our results showed no statistically significant difference between male and female students' scores in concept map assessment (p value > 0.05). This is consistent with Bello and Abimbol's study (13). They needed to determine gender influence on student's concept-mapping ability. In their results, there was not identified gender influence on students' concept mapping ability.

The results of our study showed a high interclass correlation coefficient (ICC) of 0.85 (95% CI, 0.78–0.91) for 6th year students. This is higher than the results of Kassab and Hussain study, that showed an ICC of 0.69 (95% CI, 0.59–0.77) for 4th year students and 0.75 (95% CI, 0.67–0.81) for 2nd year students (1). The difference between the results of our study, and Kassab and Hussain's study can be attributed to the use of four raters in our study compared to five raters in Kassab and Hussain's study. Another contributing factor for the high ICC in our study is the consistency between raters in the level of knowledge about the disciple cognitive domain and concept map assessment.

We did a generalisability (G) study analysis for the concept map assessment. We used a fully crossed single facet design (Students × Raters) using four raters and one domain based on the decision (D) study analysis of Kassab and Hussain's method (1). G-theory was used to estimate the reliability of concept map assessment scores. G-theory estimated the variance due to between-student differences in concept map scores (universe score variance) and the variances due to differences in raters (four raters).

In our study, a high G-coefficient (0.85) was produced using four raters with one domain. This is consistent with the D-study analysis of Kassab et al. (14), which predicted a G-coefficient of ≥ 0.80 if at least four raters were used. However, our results are higher than a study by Srinivasan et al. (15), which proposed another quality scoring system for concept maps. In their study, 52 senior residents (paediatrics and internal medicine) and 4th year medical students at the University of California created separate concept maps about two different subject domains (asthma and diabetes) on two separate occasions each (four total maps). The authors produced a G-coefficient of 0.77 for a system of two domains, two occasions, and two raters. The use of more domains and occasions increases the number of interactions between facets and could explain the lower G-coefficient in their study than ours.

The results of our study also showed that the largest estimated variance component (6.66) was for students and represented 56% of the total variance. This variance component is the estimated variation in the students' scores when the score for each student represents his/her mean score across all raters. This is consistent with the results of Kassab's G-study, which showed that students are the largest estimated variance component (15.18) representing 47% of the total variance (14). Our results are also consistent with G-study of Srinivasan et al., which showed that students are the largest estimated variance component representing 41.3% of the total variance (15).

The second largest source of variance in our study was the interaction between students and raters (4.66) representing 39% of the total variance. This indicates gives a good explanation for the concept map scores of students that differed across the four raters. This is again consistent with Kassab's G-study results, which showed that student-rater interaction represents the second largest sources of variance (7.92) and 25% of the total variance (14). However, this was inconsistent with Srinivasan et al., which showed the interaction between students, domains, and occasions to be the second largest source of variance representing 20.2% of total variance (15). The difference in results in the percentages of the total variance for student-rater interaction and in students' scores can be explained by the number of domains used in each study. In our study, we used only one domain. Kassab et al. (14) and Srinivasan et al. (15) used three and two domains, respectively, which contributed to the total variance in their study.

A D-study was also done to make it possible to determine the optimal numbers of raters necessary to obtain a satisfactory G-coefficient (e.g., ≥ 0.8). Our study's results showed that any increase in the number of above two raters results in a high level of reliability. To reach a generalisability coefficient of 0.80, at least three raters would be needed in its evaluation. Further improvements in reliability can be achieved by increasing the number of raters, however, improvement in dependability appeared to diminish beyond four raters. This is consistent with the results of Kassab et al. (14), D-study concluded that increases in the number of concept map domains were not necessary and any increase in the number of raters above two resulted in a marked increase in reliability. However, this was inconsistent with Srinivasan et al. They modelled their D-study for a single rater, two domains, and multiple occasions. They concluded that at least four occasions of testing are needed with a single rater and two domains to achieve a G-coefficient of 0.80 (15).

In clinical reasoning evaluation, in our study's results, 6th year students recorded a mean score of 37.2% (11.16 ± 3.55). The low students score can be explained by the individual level of clinical reasoning in the students. This score is indicative of the difference in experience level between the students and the subject matter experts. Among female students, the mean score was 38.9% (11.66 ± 3.51). Meanwhile, among male students, the mean score was 34.3% (10.30 ± 3.56), with no statistically significant difference between male and female students. This result is consistent with Lee et al. (16), which showed that there was no difference in overall clinical reasoning score between male and female students. In their study, they aimed to determine if a workshop that uses "illness scripts" could improve students' clinical reasoning skills when making diagnoses of patients portrayed in written scenarios.

Our study demonstrated a statistically significant correlation between mean total concept map assessment scores across all raters and total scores in SCT for 6th year students with a correlation coefficient of 0.51 with a p value < 0.05. A correlation coefficient of 0.38 was found between validity category scores and total scores in SCT (p value < 0.05). The hierarchy category was found to have the highest correlation coefficient of 0.54 (p value < 0.05). In integration category, the coefficient was 0.41 (p value < 0.05) while in the context category, the coefficient was lowest at 0.31 (p value < 0.05). Finally, in creativity category, it was 0.44 (p value < 0.05). This concludes that there is a statistically significant correlation between students' concept map construction and their abilities in clinical reasoning. The fact that concept mapping is used to represent knowledge structure and the resounding resemblance between concept maps and illness scripts described in the knowledge structure theory of clinical reasoning could explain our observation.

While there is scarce literature on the relationship between concept maps constructions and clinical reasoning ability, there are multiple studies done on concept maps and critical thinking. One study was by Wilgis and McConnell (17), whereby they explored whether concept mapping improved critical thinking skills in graduated nurses in Jacksonville University, Jacksonville, Florida. Their study concluded that concept mapping was a valuable teaching and evaluation strategy that could be used by nursing educators to improve critical thinking skills of their students.

Another study by Daley et al. (18) also supports this conclusion. In their study, they explored whether improvement in concept mapping ability would lead to an improved critical thinking in a clinical setting. Their results indicated that an increase in concept mapping construction was significantly correlated with an increase in conceptual and critical thinking skills.

CONCLUSION

This research work proved that there is a correlation between concept map construction and clinical reasoning skills of final year medical students. This opens the door for application of concept map as an instructional tool to enhance clinical reasoning abilities and as an assessment tool for measuring clinical reasoning abilities of the clinical year students in health professions education.

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