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The Effect of Concept Map Strategy on Academic Achievement and Student Retention in Biology Education

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ABSTRACT

The present study aimed at the effect of concept mapping strategies on learners' achievement and retention in biology teaching. A pretest/posttest quasi-experimental research design was adopted with one control and experimental group. The target population was male students who studied in second grade of high school in 2023-22 educational year in Iran. Simple random sampling technique was used to select the sample of students. Considering the Cohen tables and statistical assumptions, a sample size of 40 participants was estimated. They were then randomly assigned to each group. The experimental group made use of concept mapping strategies, while the control group was taught using the traditional methods. An academic achievement teacher made test was administered to all groups as a pretest / posttest and biology achievement retention teacher made test, a separate delayed posttest was administered after three weeks to the learners of the groups. The obtained data were analyzed using one-way Ancova test. The results indicated that concept mapping strategies had a significant effect on learners' achievement. Analysis of the data using t-tests revealed that the retention of biology teaching by using concept mapping strategies was significantly higher in comparison to the traditional methods.

Keywords: *Biology, Concept mapping, Achievement, Retention*

Introduction

As soon as the child comes into contact with the environment, learning is founded, so students must be prepared to face challenges through education and to keep with the advancement of science and technology. Unfortunately, today, in order to pass the exam, students memorize the content of a course and repeat it. In such situations, problem-solving skills, creative thinking, interest in research activities, and collaboration skills cannot be developed. It seems to be appropriate to use concept maps to motivate and other skills mentioned above in students (Dhaaka, 2012).

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One of those techniques in which concepts, as well as the relationships among these concepts, can be defined or represented in clear and concise forms is concept-based knowledge representation. Conceptual mapping is one of the educational strategies that has a profound effect on learning. It was first proposed in 1960 in Cornell University by Novak to represent knowledge. Concept mapping is a tool to depict the relationship between concepts in an organized way (Novak, 1998). According to the result of Stewart et al. (1979) study, concept maps is a structural way of representing relationships among concepts of a discipline, or a part of a discipline. Stewart et al. (1979) revealed that concept maps, due to its flexibility, are utilized as curricular tools, instructional tools, or as evaluation tools. Research tool and instructional technique that can be employed for an effective meaningful learning is concept maps (Novak et al., 1983). This approach is based on Ausubel's theory, according to which new concepts are learned by making connections with other previously known knowledge (Novak, 1991). Novak and Canas (2006) reported that in concept maps, knowledge was represented by graphical tools. In this method, concepts, usually endorsed in circles or boxes of some type and relationships between concepts are revealed by a connecting line linking two concepts. Words on the line, referred to as linking words or linking phrases specify the relationship between two concepts. Some scientists use concept mapping as a tool to demonstrate the relationship between concepts in an organized way (Chularut & DeBacker, 2004). Muijs and Reynolds (2005) introduced concept mapping as an educational strategy that can be used to create a structure of concepts in students' minds.

Kaddoura et al. (2016) in a study on the effect of concept mapping on the development of critical thinking skills in nursing students, showed that students in the mapping group had a higher grading concept than the control group. In this regard, Chen et al. (2011) examined the effect of teaching using concept mapping compared to traditional lectures on students' critical thinking, concluded that students in the experimental group performed better than the control group. However, there was no statistically significant difference.

Hwang et al. (2014) showed that combining concept mapping in the learning process, a web-based problem-solving approach, can increase students' cognitive level. The researchers of this study justified that this could be the result of not accepting the low-tech concept map that was tested in the dissertation study (Hwang et al., 2014). In another study, Hu and Wu (2012) found that conceptual mapping reduces students' cognitive load by helping them integrate curriculum knowledge. This result is agreeing with the results obtained by Gerchak et al. (2003) that concept mapping can be a valuable tool for assessing academic achievement and assessing students' understanding of a particular field.

Nedungadi et al. (2015) integrated concept maps with online labs (Olabs). The results showed that the students' scores in the concept map group were higher than in the control group, while there was no significant difference between the two groups. Martinez et al. (2013) showed that there is a statistically significant difference between the concept map group and the control group in terms of the "effect of using concept maps in teaching physics concepts." Students in the concept map group performed better than the control group.

Findings by Yousef and Mansour (2012) showed that adopting a conceptual mapping strategy in nursing education can make significant progress in student learning. Chiou (2008) concluded in

a study that mapping the concept could help students understand and integrate accounting concepts as well as increase students' interest in learning more about accounting than traditional teaching methods. Similarly, in an experimental field study conducted by Attia et al. (2009) to investigate the effect of using a conceptual mapping tool called ICTOOL on comprehension. Students and improve learning learn the life cycle of the process.

Although there has been an attempt to improve teaching in recent years, and various educational strategies have been used in this area, the effect of concept map strategies have not been investigated.

The present study is an attempt to investigate the effect of concept mapping strategy on learning and retention of biology concepts among the second-grade high school students. Accordingly, the aims of this study are as follows: 1) the effects of concept map strategy in improving the learners' performance in biology, and 2) the effect of this strategy on retention rate of biology concepts among the learners.

Research hypotheses

The following hypotheses were formulated and tested base on the gathered data:

1: There is a significant difference between concept mapping strategy and traditional methods in students' achievement in biology.

2: There is a significant difference between concept mapping strategies and traditional methods in students' retention of biology lessons.

Method

In this quasi-experimental study, a pre-test and post-test was used to investigate the effect of concept mapping on learner achievement in biology. A pre-test and a post-test were administered before and after education to measure the learner achievement. The pre-test was also used to measure the homogeneity of the groups. In addition, the results of the pre-test were compared to the results of the post-test to investigate the effect of the strategies on learners' achievement.

Population and sampling

The target population included all high school male students in the Salmas area (N=1254) in northwestern Iran. A sample of 40 students were selected from two intact classes from two different high schools. Simple Random sampling was used to select the two high schools. They were also randomly assigned to the concept mapping and control groups. All schools were located in northwestern Iran. Most people in this region are farmers or have cattle farms and only a small percentage of the citizens are government employees. The rationale for selecting this region is that different kinds of families, with literate and illiterate parents, live there.

Instrument

The instrument used to collect the data was academic achievement test teacher made that was used as a pre-test and post-test. The results of the pre-tests and post-tests were compared to measure the learners' achievement in the two groups. In addition, in order to measure the learners' retention of

the content, a separate delayed post-test was administered after three weeks to the learners of the both groups. Academic achievement test included 12 essay type questions. The validity of the questions was checked by the teachers, experts of the biology department, and educational science professors, and the necessary revisions were made in the questions. The retention test comprised of 12 questions, 5 of which were multiple choice and 7 were essay type questions. They were administered to the students after they were checked and confirmed by the experts of the biology department and educational science professors.

Experimental design and data collection

Data was collected in two stages. In the first stage, the researcher visited the selected schools to obtain the necessary permissions from the school principals to use the facilities and the students as participants in his study. This was followed by administration of a biology achievement test which served as a pre-test as well as a test of homogeneity for the participants in two groups. In the second stage, the students in the experimental group were taught using concept mapping strategy. The control group were taught using traditional methods. Biology lessons were taught simultaneously to groups in 16 weeks. Afterwards, an achievement test was given to the learners as the post-test to two groups. In the third stage, a delayed post-test was given to the participants after three weeks to measure their retention of the lessons.

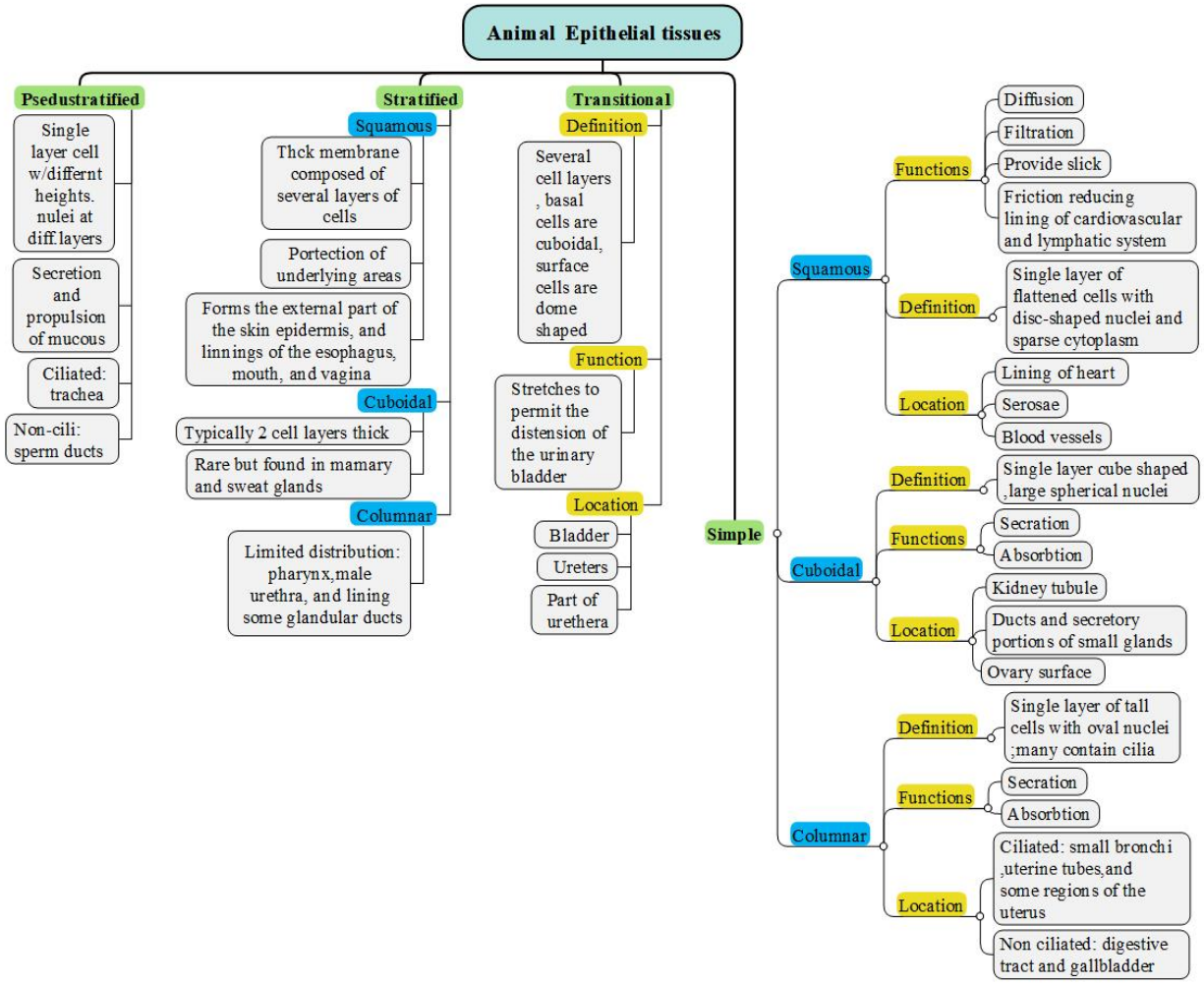
The scores obtained from the pre-test, post-test, and delayed post-test were analyzed using ANCOVA and independent samples t-tests. ANCOVA was used to analyze the mean differences of the pre- and post-tests. It was also used to check the significance of these differences. Independent samples t-test was used to compare mean scores of delayed post-test of the groups.

All of the participants of the study had a previous knowledge of biology and related subjects. It was important that the participants of the study be selected in a way that they all had same level of previous knowledge about the subject. To do so, the researcher visited the target schools and had an interaction with the biology teachers. In addition, he administered a pre-test to check the homogeneity of the participants in the two groups. Moreover, the same biology teacher taught both groups, so that the participant would be taught by the same teacher, but with different educational strategies. The teacher's had a relevant university degree (i.e. teaching biology) and had passed training courses in his own major. He was particularly skilled in teaching and taught the content to each group with the intended strategies.

Examples of concept mapping

Figure 1 is an example of a concept map created by a student using a computer. Figure 1 shows that the main tissue of animals is four, each of which is divided into sub-branches, and for each tissue, samples are written on the animal's body. In this map, the students did not use any images and the content was presented only as a branch. In this way, the concepts, which are usually confirmed in some kind of loop or box, and the relationships between the concepts, are revealed by a line of communication that connects the two concepts. The words in the line, as connecting words or connecting words, define the relationship between the two concepts.

Figure 1. An example of a student's concept map (created by experimental group)



Results

Differences in achievement test scores

In order to evaluate the homogeneity of the participants, a pre-test was conducted. The results of the data analyses of the pre-test scores of the participants in the groups are presented in Table 1.

Table 1. ANOVA analyses of pre-test scores

Source	Sum of Squares	df	Mean Squares	F	Sig.
Between Groups	1.314	1	1.321	0.87	0.35
Within Groups	57.43	38	1.51		
Total	58.74	39			

As it is shown in Table 1, there is not a significant difference between the two groups ($F=0.087$, $P>0.05$). This is to say that F values are not meaningful in $P<0.05$ level. The results also indicate that between the two groups, the mean of squares is not significantly higher than the sum of squares. In other words, there is not a significant difference between the pre-test scores of the two groups. This confirms the homogeneity of the participants before the teaching.

a) Investigating normal distribution of the scores

The results of the Kolmogorov-Smirnov test showed that the significance level of the distribution of academic achievement test scores is greater than 0.05 ($p \geq 0.086$), it can be claimed that the distribution of scores is normal and parametric tests can be used for the data analyze.

b) Testing the assumption of homogeneity of regression slopes

As it can be seen in Table 3, the F value in the interaction between independent and the covariate is 0.03, which is not significant ($P>0.05$). Consequently, it can be concluded that homogeneity of regression assumption has been met.

Table 3. The interaction between the independent variable and the covariate

Source	Type III Sum of squares	df	Mean Squares	F	Sig.
Pretest×groups	0.027	1	0.026	0.03	0.86

c) Testing the assumption of homogeneity of variances

Leven's test was used to check the homogeneity of variances. The results showed that the significance level of the test is 0.9, which is higher than 0.05. That is to say that the assumption of homogeneity of variances is met.

H_1: There is a significant difference between the effects of educational strategies concept mapping, and traditional instruction method on learners' achievement in biology.

In order to test this hypothesis, the scores of the post-test in two groups were compared and analyzed using ANOVA and Post-Hoc tests with significance level of 0.05. Results of the test are presented in Tables 5.

Table 5. Analysis of covariance for the achievement test of the groups

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	63.635	2	31.818	38.899	0.00	0.678
Intercept	62.955	1	62.955	76.966	0.00	0.675
pretest	1.135	1	1.135	1.388	0.24	0.036
group	58.636	1	58.636	71.685	0.00	0.660
Error	30.265	37	0.81			
Total	6906.000	40				
Corrected Total	93.900	39				

According to the table 5, the effect of group association by removing the variance variable, the hypothesis of the research was confirmed and it was detected that teaching by concept mapping strategy method was effective in the increasing the academic achievement of students and its effect rate was 66%.

H_2: There is a significant difference between the effects of concept mapping on students' retention in biology.

An independent samples t-test was used to compare the delayed post-test scores of the learners' in the groups. The results are presented in Table 6.

Table 6. Independent samples t-test for the delayed post-test

Test	Group	N	Mean	Std. Deviation	T	df
Retention (delayed post-test)	Control	20	11.8	0.89	0.253	38
	CMS	20	14.3	0.92		

CMS=Concept Map Strategies

As it can be seen from the table, there is a significant difference between the results of the two groups. The mean score of the learners in the concept mapping group (14.3) is higher than the mean score of the learners in the control group (11.8). This is to say the concept mapping helps the learners better in retention of the knowledge than traditional method. Thus, the second hypothesis is also confirmed.

Discussion

Students' academic success prepares students to solve various problems in life. Students achieve this success in school, and the impact of using teaching methods is undeniable. On the other hand, the results of several studies have shown the usefulness of using the educational strategy of conceptual maps in various fields. Therefore, in this study, the effect of concept map strategy on academic achievement and retention of biology in students of of Salmas of Iran was investigated. The research findings in relation to the first hypothesis of the research showed that teaching by conceptual method has been significantly effective on students' academic achievement compared to traditional education. Based on the results, it can be argued that the use of conceptual-based teaching increases learners' performance in believing in their abilities in terms of biological concepts. These results are in terms of the effect of teaching by concept map on students' academic achievement according to the results of causal studies. As students continue to engage in classroom activities, their efforts to continue and respond will be strengthened. The pleasure that students gain from teaching through concept mapping increases their motivation to find answers to difficult questions. The result of the study showed that the learner's enjoyment resulting from direct learning experience paves the way for her to learn difficulties and this ultimately leads to an increase in their success. This finding is in line with the findings of Tanriseven (2014), Abi-El-Mona and Adb-El-Khalick (2008), Adodo (2013), Mahasneh (2017), Dhindsa and Anderson (2011), Ismail et al. (2010), Farrand et al. (2002), Rooda (1994), Singh (2004), Rao (2001), Zoller (2000), Alarcon (2005).

The results of the independent samples t-test revealed that there was a significant difference in the retention rate of the biology between the experiment groups in compared to control. The retention rate in the concept mapping group was significantly higher to that of the control group. A similar result was obtained by Bawneh's (2019) and Adodo (2013). The results of bawneh (2019)

revealed that using concept maps helps students perform better in immediate access and retention of electrical energy concepts.

Conclusion

The findings of the present study indicated that concept mapping strategy was more effective in improving learner achievement than traditional teaching strategy. That is to say that concept mapping grants the learners the ability to think creatively and communicate more effectively, which are missing in the traditional method. Teachers should identify the individual differences of the learners and design their curriculum based on those differences to address the learners' needs. It is also recommended that the learners use conceptual map strategy in teaching biology and encourage learners to use. That is to say that concept mapping grants the learners the ability to think creatively map strategy in learning biology to enhance the learning outcomes. Biology teachers should also attend workshops on how to teach biology using these strategies.

This research had limitations; For example, this study was conducted only on second-year male students in the experimental field; therefore, caution should be exercised in generalizing the results to female students. The study was also conducted on high school students and was not conducted at other levels of education; therefore, other precautionary measures should be taken in generalizing the results of this research. Given the above limitations, it is suggested that a similar study be conducted for female students in disadvantaged areas and students in other educational levels.

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