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META-ANALYSIS OF THE EFFECTIVENESS OF CONCEPT MAPPING AS A LEARNING STRATEGY IN SCIENCE EDUCATION

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Technical Editor's Note: The authors supplied enlarged versions of several tables. These appear at the end of the article.

The learning of a subject matter on the students` part depends not only on how the material is organized and presented but on the learning strategies they use. Some research studies back the idea that in many situations the difference between the students who are achievers and the non-achievers lies in the fact that the achievers have developed learning strategies adequate to the learning task presented to them (West, Farmer and Wolf, 1991). One of the strategies to which special attention has been placed in science learning is concept mapping (Novak and Gowin, 1988) The strategy consists in the development of a graphical representation of the conceptual structure of a subject. Such representation is bidimensional and it has a hierarchic structure in which the most general and inclusive concepts occupy the upper levels. Every two concepts are intertwined through propositions that indicate the relationship between them.

This learning strategy is derived from the Theory of Meaningful Learning by Ausubel (1968). According to this researcher, the concepts are organized in hierarchic form in the cognitive structure, with the more specific concepts intertwined with the more general and broad ones. In order to learn with meaning, it is necessary to intertwine the new concepts with those that exist in the cognitive structure, while maintaining their hierarchic order. The benefit of concept mapping lies in the fact that it makes the process of knowledge integration explicit. Concept mapping can be used in any subject and any level within the subject. The maps are somewhat subjective since any subject can be represented correctly in various ways; however, the maps that a student generates can be used to organize the student's ideas and are suitable for the teacher to provide feedback on them.

Although the first studies on the effectiveness of concept mapping as a learning strategy appeared approximately fifteen years ago (Bodgen, 1977; Moreira, 1979), it was not until recently that research using experimental or quasi-experimental designs became popular. As with other learning strategies, the results of the research have not been consistent, there being an almost perfect balance between the studies where a significant effect can be found and those where a positive significant effect is found. The purpose of this study is to carry out a quantitative synthesis of the research on the effectiveness of concept mapping in science learning.

METHODS

Sample

The studies used in this research were mainly found through a computerized search using the Dialogue system. The data banks used were ERIC, Psychological Abstracts and Dissertation Abstracts International. In every case the search was limited to 1980 and subsequent years. Forty-one empirical studies on the effectiveness of concept mapping were found. Of these, sixteen were eliminated because they used descriptive or pre-experimental designs. It was also found that three of the references were duplicated in other sources. The analysis presented here includes seventeen studies in which nineteen effect sizes could be calculated.

Procedures

The procedures used for the meta-analysis are those described by Hedges, Shymansky and Woodworth(1989) and Hedges and Olkin (1987). In general,the effect size for each study was calculated using the equation;

$$g = Jd$$

where **d**, the Glass estimator, is the difference between the average of the experimental group and the control divided by the standard deviation of the control group, and **J** is the correction factor provided for removing the bias of **d** which is approximately;

$$J = 1 - \frac{3}{4m-1}$$

In this last equation **m** represents the degrees of freedom associated with the standard deviation of the control group. The global effect of concept mapping was reached by obtaining a pool average where the weight consisted of the reciprocal of the variance with each effect size.

To determine whether there is consistency in the results of the studies the statistic $Q = \Sigma(d_i - d..)^2$ was used where d_i is the average of the effect size calculated per study and d.. is the global effect size.

RESULTS

Achievement

Seventeen of the studies found in the computerized search had enough information to calculate the effect size. It has been possible to calculate more than one effect size in two of them, whereby nineteen is the total. Table 1 shows, for each study: whether the results obtained by the author were significant or not, the science discipline, the academic level of the students who participated, the number of weeks for the duration of the study, the training time in weeks, the values of the effect size and the standards deviation of each effect size.

Table 1. Significance, academic level, study length, training length, effect size and standard deviation for the studies included in the achievement analysis.

Authors	Sig.	Disc.	Level	Study Length (weeks)	Training duration (weeks)	d	s
Abayomi (1988)	n.s.	ES	M	5	1	0.05	0.166
Bodolus (1986)	s.	ES	M	8	2	0.06	0.129
Cliburn (1985)	s.	B	U	26	3	0.31	0.225
						1.19	0.267
Cliburn (nklin (1991)	s.	B	M	1	5	0.12	0.168
Gurley (1982)	n.s.	B	H	36	4	0.01	0.233
Heinze-Fry & Novak (1990)	n.s.	B	U	2	2	0.61	0.340
Lehman, Carter & Kahle (1985)	n.s.	B	H	6	1	0.06	0.130
Okebukola (1990)	s.	B	U	6	3	1.73	0.224
Pankratius (1987)	s.	Ph	H	8	6	0.39	0.334
Pankratius (1990)	s.	Ph	H	6	6	0.15	0.390
Sherrys & Kahle (1984)	n.s.	B	H	8	2	0.06	0.087
Soyibo (1991)	s.	B	U	4	2	1.60	0.274
						1.19	0.249
Spaulding (1989)	n.s.	B	H	3	1	0.13	0.197
Stensvold (1989)	n.s.	Ch	M	4	1	0.28	0.200
Wanchu (1991)	n.s.	Ch	U	4	2	0.94	0.197
Willerman & MacHarg (1991)	s.	Ph	M	2	2	1.20	0.410

ES=Earth Sciences
B=Biology
Ph=Physics
Ch=Chemistry

U=University
H=High school
M=Middle school

As can be seen, nine of the seventeen studies reported significant results; five were carried out at a university level, seven at a high school level, and five at a middle school level. The duration of the studies fluctuated between one and thirty six weeks. As to the effect size, it varied from -0.28 to 1.73. The average effect size was 0.57, which is statistically significant ($p < 0.011$). This effect size is equivalent to an average increase in percentile from 50% to 72%. The average standard deviation was 0.14. The homogeneity test revealed that there is a lack of consistency between the results of the different studies ($Q = 148.40$, $p < 0.005$). To explain the lack of homogeneity between the studies, four variables were considered: the academic level at which the study was carried out, the science discipline, the duration of the study, an the training time on the concept mapping technique.

Effect of the academic level

Table 2 shows the mean effect size and the mean standard deviation for each of the three levels considered

Table 2. Effect size and standard deviation for the studies grouped by academic level.

Level	n	d	s
University	5	0.92	0.248
High School	7	0.75	0.237
Middle School	5	0.10	0.215

As can be seen, the effect size increases with the academic level. The effect at university level is equivalent to an average increase in the percentile from 50% to 82%; at high school level an average increase of 50% to 77%; and at the middle school level it is equivalent to an average increase in the percentile from 50% to 55%. In all three cases, the effect size is significantly different from zero ($p < 0.01$). The analysis of variance (ANOVA) revealed that the differences between academic levels is significant ($Q_B = 177.86$, $p < 0.01$).

Effect of the science disciplines

Table 3 shows the average effect size and the average standard deviation for the different science disciplines. As can be seen, the effect size is higher in biology and lower in earth science. The homogeneity analysis revealed that the biology and chemistry results are not consistent. On the contrary, the physics and earth sciences results are consistent. The analysis of the variance revealed that the differences between the disciplines is statistically significant ($Q = 142.23$, $p < 0.01$)

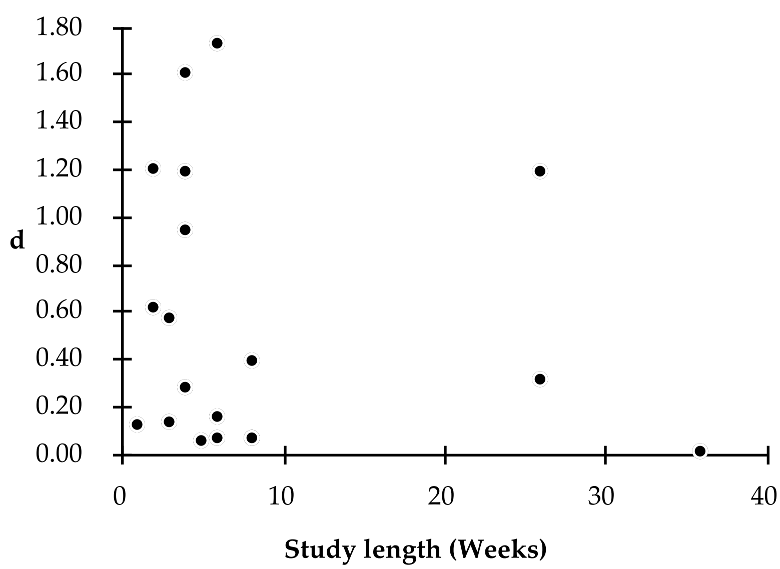
Table 3. Effect size and standard deviation for the studies grouped by science discipline.

Discipline	n	d	s
Biology	10	0.74	0.239
Physics	2	0.33	0.200
Chemistry	3	0.54	0.378
Earth Sciences	2	0.13	0.148

Effect of the length of the study

Figure 1 presents the relation between the effect size and the duration of the study.

Figure 1. Relationship between the effect size and the duration of the study.

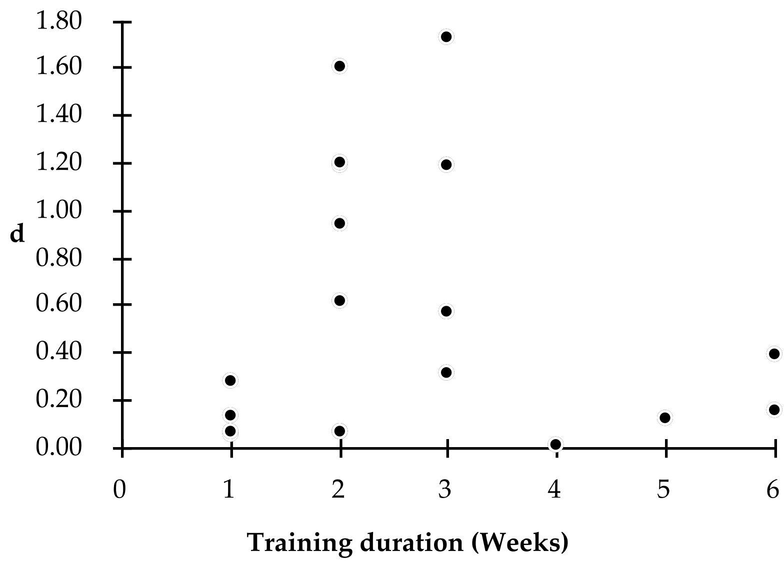


The correlation between the effect size and the duration of the study is equal to -0.13, which is not statistically significant. Therefore, there is no relation between the effect size and the duration of the study.

Effect of the training time

The relationship between the effect size and the training time is illustrated in Figure 2.

Figure 2. Relationship between the effect size and the training time.



The correlation of the effect size and the training time of the students on concept mapping strategy is equal to r = -.06, which is not statistically significant at the a = 0.01 level.

Attitudes toward learning science content

Five studies contained data on attitudes towards learning science content. Table 3 presents the authors, significance, effect size and standard deviation for these studies. In four of the five studies a significant effect of the use of concept mapping upon the attitudes of the students was reported. The average effect size was 0.87, wich is significant at the 0.01 level. This effect size represent an increase in the percentile from 50% to 80% on the attitude measure. The heterogeneity test revealed that the results were not homogeneous. It can be seen that there are noticeble differences in effect sizes between the studies by Bodolus (1986), Cliburn (1985) and Gurley (1982), and Okebukola and Jegede (1988 and 1989).

Anxiety

Three studies presented data on the effectiveness of concept mapping upon anxiety. All of them reported significant reductions on anxiety for the group of students using the concept mapping strategy. The average effect size was -0.68, with a mean standard deviation of 0.13, which is significant at the 0.01 level. This effect size is equivalent to an decrease from 50% to 25% in the mean percentile of the students. The heterogeneity test revealed that the results were heterogeneous. As can be seen, great differences exists between the effect sizes of the three studies.

Table 4. Significance, effect size and standard deviation for attitudes towards science learning.

Authors	Sig.	d	s
Bodolus (1986)	s.	0.05	0.129
Cliburn (1985)	s.	0.47	0.243
Gurley (1982)	n.s.	0.47	0.236
Okebukola & Jegede (1988)	s.	1.85	0.201
Okebukola & Jegede (1989)	s.	2.07	0.168

Table 5. Significance, effect size and standard deviations for anxiety.

Author	Sig.	d	s
Alaiyemola, Jegede & Okebukola (1990)	s.	-0.55	0.300
Franklin (1991)	s.	-0.06	0.167
Okebukola & Jegede (1989)	s.	-3.75	0.360

DISCUSSION

In nine of the seventeen considered, the authors informed that they did not find significant effects in the use of concept mapping in science learning. However, the meta-analysis revealed a significant mean effect size of 0.57. This effect size is equivalent to an increase of 50% to 71% in the mean percentile of the students. The homogeneity test, revealed a lack of consistency between the results of the different studies.

To explain the lack of consistency between the studies, four independent variables were considered: the academic level at which the study was carried out (university, high school and middle school), the science discipline, the number of weeks of training time in the concept mapping technique, and the duration of the study.

With respect to the academic level, it was found that the higher the academic level, the higher the effect size ($d_u = 0.92$, $d_h = 0.75$ and $d_m = 0.10$). As to the science discipline, significant differences were found between the effect size and biology, chemistry, physics, and earth science. Two correlation studies revealed that there is no relation between the effect size and the duration of the training time study and the duration of the treatment.

To summarize, the literature examined indicates that the students who learn to use concept mapping as a learning strategy tend to better profit from their courses. Apparently, the effect of this strategy is higher in the higher academic levels. It is possible that the students' age would be a determining factor in the effectiveness of concept mapping since this strategy requires the capacity of abstraction characteristic to the stage of the formal cognitive development. On the other hand, the benefit of using concept mapping seems to be immediate since its effectiveness does not depend on the time that the students have been using the strategy. We should point out, however, that all of the authors coincide in that it is necessary to train the students in the use of this technique so that they can use it adequately.

Two other dependent variables were examined: attitudes towards learning science content and anxiety. In both cases a significant global effect size was calculated. For the attiudes, the mean effect size was of 0.87 and for anxiety -0.68. Thus, the effectiveness of the concept mapping strategy seems to have an important effect, not only upon learning the different science contents, but also on the students’ attitude towards learning those contents, and in reducing their anxiety while learning science.

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