Mediated learning experience and concept maps: a pedagogical tool for achieving meaningful learning in medical physiology students

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Submitted 2 April 2007; accepted in final form 24 September 2008

González HL, Palencia AP, Umaña LA, Galindo L, Villafrade M LA. Mediated learning experience and concept maps: a pedagogical tool for achieving meaningful learning in medical physiology students. Adv Physiol Educ 32: 312–316, 2008; doi:10.1152/advan.00021.2007.—Even though comprehension of human physiology is crucial in the clinical setting, students frequently learn part of this subject using rote memory and then are unable to transfer knowledge to other contexts or to solve clinical problems. This study evaluated the impact of articulating the concept map strategy with the mediated learning experience on meaningful learning during the cardiovascular module of a medical physiology course at Universidad Autónoma de Bucaramanga. This research was based on the ideas of David Ausubel (meaningful learning), Joseph Novak (concept maps), and Reuven Feuerstein (mediated learning experience). Students were randomly allocated to either an intervention group (mediated learning experience articulated with concept mapping) or a control group (traditional methodology). The intervention group constructed concept maps related to cardiovascular physiology and used them to solve problems related to this subject. The control group attended traditional discussion sessions and problem-solving sessions. All students were evaluated with two types of exams: problem-solving and multiple-choice exams. The intervention group performed significantly better on the problem-solving exam, but the difference was not significant in the multiple-choice examination group. All students were evaluated with two types of exams: problem-solving and multiple-choice exams. The intervention group performed significantly better on the problem-solving exam, but the difference was not significant in the multiple-choice exam. It was concluded that intervention promoted meaningful learning that allowed the students to transfer this knowledge to solve problems. The implemented strategy had a greater impact on the students who came into the study with the lowest cognitive competence. When they can do this, it is possible to say they “understand” knowledge is structured in memory determines the ability to retain, recall, and use it to solve problems (16). Meaningful learning occurs when the learner interprets, relates, and incorporates new information with existing knowledge and applies the new information to solve novel problems. Meaningful learning, then, involves building multiple representations (mental models) of knowledge (10, 12).

In medicine, meaningful learning implies that knowledge acquired by the students makes sense in their future medical practice and allows them to solve different problems (12, 15). This is easier in the clinical setting than during basic science instruction. During the latter, students receive a great amount of information, some of which does not have direct medical application. Thus, many students in the first semester use rote memorization to acquire a large amount of information that they will forget after the exams.

In physiology, meaningful learning means that the students are able to predict and explain the responses of a physiological system if it is disturbed and sometimes to solve quantitative problems (calculate something). In other words, they are able to apply what they know about physiology to novel situations. When they can do this, it is possible to say they “understand” physiology (9, 12).

In this study, we addressed the following research question: does the concept mapping methodology, articulated with the mediated learning experience, increase meaningful learning in students attending to the cardiovascular module of a medical physiology course?

Concept mapping is a pedagogical tool initially proposed by Joseph Novak as a method to represent the relationships between relevant concepts within a given subject area. This tool not only allows organizing and presenting the knowledge but also promotes meaningful learning (1, 2, 13, 14). As Novak (14) states:

Knowledge stored in our brain consists of networks of concepts and propositions. As meaningful learning proceeds, new concept meanings are integrated into our cognitive structure to a greater or lesser extent, depending on how much effort we make to seek this integration, and on the quantity and quality of our existing, relevant cognitive structure. If we learn strictly by rote, essentially no integration of new concept meanings occurs, and existing cognitive structure is not elaborated or reconstructed.

This research also uses the theoretical foundations of Reuven Feuerstein’s cognitive modifiability theory and the me-
The mediated experience describes a special quality of interaction between a learner and a teacher, in this case, called a “mediator.” The intention of the mediator is different from that of a teacher or tutor. The mediator is not concerned with solving the problem at hand. Rather, the mediator is concerned with how the learner approaches the problem. The problem at hand is only an excuse to involve the mediator with the learner’s thinking process. For the process to be successful, at least four important qualities must be present in the interaction:

- Intentionality. The mediator concentrates on understanding and helping the learner to understand how he or she is using his or her brain.
- Reciprocity. The learner and mediator need to consider one another as on the “same level.” That is, the mediator does not pretend to know the answer as to how the learner should be thinking.
- Mediation of meaning. The mediator interprets for the learner the significance of what the learner has accomplished. In various ways, the mediator causes the learner to reflect not just on the solution to the problem but also on how the solution was obtained and the generalizations that flow from it.
- Transcendence. The experience and lessons learned in the current situation must be “bridged” to new situations. Human beings differ from other species in the way they can transfer lessons, rules, and methods learned from one experience to another situation (3, 6, 7).

METHODS

We conducted a randomized controlled study with students enrolled in the third semester of medicine at Universidad Autónoma de Bucaramanga (UNAB; Santander, Colombia). In Colombia, students go to medical schools directly from high school. UNAB is a private university, with a medical curriculum characterized by a basic cycle (semesters 1–5) followed by the clinical cycle (semesters 6–12). During the basic cycle, students approach the foundations of structure and function of the normal human body (semesters 1–3) and its alterations (semesters 4 and 5). This plan is achieved through a simultaneous approach of different basic disciplines (anatomy, histology, biochemistry, physiology, genetics, molecular biology, microbiology, pathology, and pharmacology) around each of the human body systems. The first semester includes the study of subjects related to general and cellular physiology, the second semester introduces the nervous and endocrine systems, and the third semester includes the study of digestive, cardiovascular, respiratory, and renal systems.

At the beginning of the study, an index was obtained based on the following information from each student: 1) total score on the national high school graduate exam [called the Instituto Colombiano de Fomento de la Educación Superior (ICFES) exam], 2) cumulative average grades of the previous semesters, and 3) the grade obtained for the construction of a conceptual mentifact (defined as graphical instruments to represent thoughts and human values). This mentifact helps to define how knowledge and mental operations are organized and represented in the human mind (20).

Based on this index, students were divided into quartiles as follows: quartile 1, students classified below percentile 25; quartile 2, students classified between percentile 25 and 50; quartile 3, students classified between percentile 50 and 75; and quartile 4, students classified above percentile 75. Thus, students allocated to quartile 1 were considered to have the lowest competence at the outset, and students in quartile 4 had the highest competency level. Students in each quartile were randomly allocated to the control or intervention group. To increase the possibility of finding significant differences between groups, researchers established approximately a 2:1 ratio of intervention students to control students.

Students in the intervention group were organized in small subgroups (4–5 students/group). They attended four 2-h mediated sessions to develop an approach to study the cardiovascular module (specifically cardiac output, arterial pressure, and their determinants). These sessions were distributed as follows: session 1, cardiac output (definitions and concept map construction); session 2, problem-solving activity using the cardiac output concept map; session 3, arterial pressure (definitions and concept map construction); and session 4, problem-solving activity using the arterial pressure concept map.

Students received reading material related to cardiac output and arterial pressure 1 wk before the first session. At the beginning of each session, the mediators (a role assumed by the professors, as defined by R. Feuerstein) briefly explained the activity and its importance in medicine. Students were also given instructions regarding the principles and construction of concept maps. Each subgroup received two sets of cards: one with propositions reflecting concepts and the other with definitions (see the example shown in Fig. 1). Students matched each concept with its corresponding definition. After discussing and clarifying doubts about concepts and definitions, students were prepared to elaborate the specific concept map.

Mediators intentionally observed the cognitive performance of the students and helped them to analyze and correct their own cognitive difficulties in organizing the concepts. To do this, a cognitive map was elaborated, in which each activity was planned and the required cognitive operations plus the possible difficulties for the construction of the maps were anticipated. After students had finished the maps, each of the concept maps was presented to their classmates and mediators (see an example of a concept map shown in Fig. 2).

In the other two mediated sessions, students used their concept maps to solve problem situations presented by the mediators. Again, mediators helped the students to recognize the mental processes needed to solve the problems.

The control group attended the same number of sessions and also received the reading material. These sessions were conducted by the same teachers, but, in contrast with the mediated sessions, the teachers assumed the role of the “traditional” teacher. (The qualities described by R. Feuerstein—intentionality, reciprocity, mediation of meaning, and transcendence—were not manifested.) The pedagogical methodology used traditionally in our medical school consists of discussion sessions focused on specific topics, in which teachers ask questions and students clarify doubts. Control students also participated in sessions to solve the same problems used by the intervention group. The other activities of the course were identical for both groups (theoretical classes, laboratories, etc.).

During every session, two researchers from the school of education acted as observers to record academic, cognitive, attitudinal, and

![CARDiac OUTPUT](minute volume) The amount of blood that goes through the circulatory system in one minute

![Systolic VOLUME](The volume of blood ejected from a ventricle with each beat (systole) of the heart)

Fig. 1. Students received a set of cards with propositions reflecting concepts and definitions that they had to match.
behavioral performances of both students and mediators. Mediators (who also acted as “traditional” teachers in the control group) were physicians from the physiology department who had a background in medical education, concept maps, and the theory of the mediated learning experience.

Two types of exams were used to evaluate students. First, multiple-choice exams with only one correct answer were used. In this type of exam, the students had to recall the precise information related to the question that could or could not be related to a specific problem (see the example shown in Table 1). Second, problem-solving exams were used. In this kind of exam, the students were asked to resolve specific problems using hierarchical structuring, sequencing, or proposing alternatives (see the example shown in Table 1).

Additionally, at the end of the cardiovascular module, both groups were required to evaluate themselves to assess their perceived changes in their cognitive processes.

Control and intervention groups were compared based on the following variables: 1) average grades on the exams, and 2) percentage of students who failed the exams (on a scale from 1 to 5, a grade below 3.0). Data are presented as averages (means) and SDs for continuous variables and as a percentage (%) for discrete variables.

Significant differences between the groups were determined with a t-test (for a comparison of two means) and a Mann-Whitney test. A P value of <0.05 was used to determine statistical significance. All statistical comparisons were done using Stata 8.0 SE software.

This project was approved by the Institutional Review Board for Human Experimentation and was considered without risk for human health.

RESULTS

The study groups were distributed as follows: intervention group (n = 83, mediated learning experience articulated with concept maps) and control group (n = 39, traditional).

The grade averages were generally higher for the intervention group than for the control group, but only the problem-solving exam grades showed a statistically significant difference between the groups (P = 0.0013; Table 2).

When student performance was compared according to the initial distribution by quartiles, it was observed that the grade average on the problem-solving exam was higher for the intervention group than for the control group, but this difference was statistically significant only in quartile 1 (students with the lowest competence at entrance, P = 0.008; Table 3). The grade average on the multiple-choice exam was higher in

Table 1. Examples of questions in the multiple-choice and problem-solving exams

Example of a question from the multiple-choice exam

When a patient suffers a hemorrhage, the first cardiac output determinant that is affected is:
A. Preload
B. Contractility
C. Afterload
D. Cardiac frequency

Example of a question from the problem-solving exam

A patient suffers a hemorrhage. Try to create a logical sequence of events starting with a reduction in blood volume until the arterial blood pressure changes. For each altered variable, indicate its change (increase or decrease).

Table 2. Results of the exams in the cardiovascular system module

<table>
<thead>
<tr>
<th></th>
<th>Problem-Solving Exam</th>
<th>Multiple-Choice Exam</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Mean</td>
</tr>
<tr>
<td>Control group</td>
<td>39</td>
<td>2.79</td>
</tr>
<tr>
<td>Intervention group</td>
<td>83</td>
<td>3.60</td>
</tr>
</tbody>
</table>

n, Number of students per group. P values were determined by a nonpaired Student’s t-test for homogenous variance. Results were also determined using the Mann-Whitney test.
all quartiles of the intervention group, with exception of quartile 1, but this difference was statistically significant only between the students allocated to quartile 3 (that is, those classified between percentile 50 and 75, \( P = 0.0063 \); Table 3).

Additionally, there was a significant difference between the groups in the percentage of students who failed the problem-solving exam (grades below 3, 40.96\% in the control group and 19.23\% for the intervention group; Fig. 3) but not the multiple-choice exam.

Qualitative information was also gathered from the self-evaluations of students and from the researchers who acted as observers. Students pointed out that mediation in the construction of concept maps helped them to develop some metacognitive strategies, such as to be more conscious about their weaknesses and strengths when organizing and applying their knowledge. In addition, when they presented the concept maps to their mediators and classmates and had to justify the concepts and the relationships, they were able to recognize and analyze distortions in their own understanding of the contents. Additionally, students remarked that the active role in their own learning was very motivating. These kinds of comments were less frequent in the control group students, although they mentioned they were motivated by the topics studied. Most of the students agreed that a weakness of the intervention was the short time they had to construct the maps. Additionally, some of them expressed certain resistance to assume a more active role in their own learning.

Some difficulties observed by the researchers in the cognitive performance of students were problems in concept categorization, selection of the right concept links, and impulsiveness. However, some improvements could also be implemented throughout the intervention process.

### Table 3. Results by quartiles on the problem-solving and multiple-choice exams

<table>
<thead>
<tr>
<th>Quartile 1</th>
<th>Quartile 2</th>
<th>Quartile 3</th>
<th>Quartile 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean of the Grades in the Intervention Group</td>
<td>4.31</td>
<td>4.04</td>
<td>3.60</td>
</tr>
<tr>
<td>Mean of the Grades in the Control Group</td>
<td>2.88</td>
<td>4.00</td>
<td>2.53</td>
</tr>
<tr>
<td>( P ) Value</td>
<td>0.008*</td>
<td>0.8255</td>
<td>0.1774</td>
</tr>
</tbody>
</table>

\( P \) values were determined by a nonpaired Student’s \( t \)-test for homogenous variance. *Statistically significant difference.

**DISCUSSION**

It has been previously demonstrated that concept maps can be an effective learning tool in a variety of classroom settings including the education of health care professionals (5, 15, 16). This pedagogical tool is a metacognitive strategy that assists learners to develop a self-appraisal of their own individual cognitive processes (5) and also stimulates critical thinking and meaningful learning in students (19). Knowledge stored in our brains consists of networks of concepts and propositions. As meaningful learning proceeds, new concept meanings are integrated into our cognitive structure to a greater or lesser extent. What is commonly observed is that learners often cannot transfer what is learned in one context or setting to another context or setting, and, hence, learning is situated in the original learning context (14).

In this study, we intended to amplify the advantages of concept maps by combining this methodology with the mediated learning experience based on the cognitive modifiability theory. Through this experience, a new learning atmosphere was presented to the students that facilitated their cognitive performance in the construction of concept maps and stimulated changes in students’ mental structures and learning styles. Mediated learning occurs when environmental events are selected, ordered, filtered, and invested with specific meaning by mediating agents. In this way, significant cognitive modifications produce a structure by which the organization and elaboration of the transmitted information will become increasingly complex and function more efficiently (7). Thus, it was expected that students were prepared to reach meaningful learning by articulating concept maps with a mediated learning experience.

The statistically significant differences found between the control and intervention groups on the problem-solving exams show that the intervention facilitated the development of meaningful learning. This can be explained because these kind of exams demand a greater level of cognitive functions and mental operation than multiple-choice exams. To solve a problem, it is necessary to recall, transfer, and apply knowledge using mental processes such as identification, comparison, proposition, and argumentation. It is possible that the intervention facilitates in students the skills to identify and evaluate the significant and hierarchic relationships between concepts and to transfer the knowledge to the resolution of problems related to the discipline (11).

No significant differences between the groups were found on the multiple-choice exams. One explanation is that this kind of test does not challenge the students in the same way as the problem-solving exams. Although multiple-choice exams have
been the most common tool used to evaluate medical students, in fact, they are generally designed to recall rote memory more than to assess transference of meaningful learning (4).

Even though the intervention group globally benefitted from the implemented strategy, the results showed a greater impact on the students allocated to quartile 1, those with the lowest initial competence. It is possible that intervention stimulated the development of cognitive functions that already were present in the rest of the students in this group.

It is also important to mention that a mediated learning experience stimulates metacognition in students. For many years, psychologists and educators have recognized that, in addition to learning subject matter knowledge, students can also acquire knowledge about learning or the nature of knowledge. Metacognition was coined to label “learning about learning.” This includes the ability to learn to plan, monitor success, correct errors, recognize unsuccessful problem approaches, etc. (18). In this experience, students had the possibility of becoming more conscious about their own learning style and the mental operations needed to organize concept maps and solve problems.

Qualitative analysis suggests that the intervention increases students’ motivation and stimulates a better attitude to actively participate in the construction of personal knowledge.

In summary, the results suggest that mediation through concept maps is an effective alternative for learning physiology (at least in the module of the cardiovascular system) that can also be used in other disciplines related to medicine.

A caveat of this research is that it does not allow us to draw conclusions on the impact of the intervention on the permanence of meaningful learning and in the ability to transfer knowledge to other and more complex contexts. This could be studied by tracking the student participants through subsequent semesters.

ACKNOWLEDGMENTS

The authors thank Paul Camacho for help with the statistical analysis and Victor Mauricio Herrera for help with the study design and statistical analysis.

GRANTS

This work was supported by a grant from Universidad Autónoma de Bacaramanga.

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