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A TEACHING-LEARNING METHOD ENHANCING PROBLEM SOLVING AND MOTIVATION IN SECONDARY SCHOOLS

MÉTODOS DE ENSEÑANZA –APRENDIZAJE PARA MEJORAR LA SOLUCIÓN DE PROBLEMAS Y MOTIVACIÓN EN LA ESCUELA SECUNDARIA

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Abstract

The author presents a teaching-learning method for enhancing problem solving and motivation towards studying science in secondary schools. This research emerged from a former survey, which found that the motivation of 14-18 year-olds as measured by the Kozéki-Entwistle test was at a rather low level – especially so on the "interest" subscale. Because interest is known to correlate with problem solving positively, we should ideally use teaching-learning methods that have a positive effect on both motivation and problem solving at the same time. A novel approach to teaching and learning in biology is described briefly.

Keywords: problem solving, motivation, teaching methods

Resumen

El autor presenta el método de enseñanza y aprendizaje para el mejoramiento de la solución de problemas y motivación en la educación en ciencias para la escuela secundaria. Esta investigación es el resultado del trabajo anterior donde se encontró que la motivación de los estudiantes de 14 a 18 años medida con la prueba Kozéki-Entwistle está en bajo nivel especialmente en la subescala de intereses. El interés hacia los estudios

está en la correlación directa con la capacidad de resolución de problemas. En el trabajo se utilizó el método de enseñanza y aprendizaje que tuvo efecto positivo en la motivación y las capacidades de resolver problemas. Está escrito el enfoque innovativo para la enseñanza y aprendizaje de biología.

Palabras Clave: Resolución de problemas, motivación, métodos de enseñanza.

Introduction

In our time both highly gifted and ordinary people are expected to be able to recognize and solve problems so the development of problem solving has become a central issue in the methodology of science subjects. Intellectual capacity, including problem solving, is an integral part of the general ability of giftedness (Gagné, 1985). This way of thinking represents one of the highest levels of learning, whose psychological procedure has been examined by several researchers around the world. After several studies on the stages and strategies of problem solving (Wallas, 1926; Pólya, 1971; Lénárd, 1978) the interest of researchers has shifted to the connection between problem solving and creativity, to insight, analogy, transfer and the computerized modelling of the memory process in problem solving. (Gick, Holyoak, 1983; Sternberg, 1984; Davidson, 1986; Bejar, 1991).

Nevertheless, it is probably worth looking into the problem of strategy again as it may offer the algorithm for thinking and the research methodology in science subjects. We carried out an experiment in biology in a secondary grammar school in order to examine the development of the problem solving strategy. This involves the identification of the problem, the setting up of different hypotheses, the testing of those hypotheses through researching new material and through comparing the new material to previously acquired knowledge and through planning experiments to facilitate the testing of those hypotheses. It is important that the teacher presents problems so the children have the opportunity to prove or disprove their hypotheses by the end of any one lesson. This sets the time limit. Problem solving applied in schools is the same as that applied by researchers for solving and disclosing problems during research, also called the research method. Thus when the research method is applied during lessons in schools problem solving develops as a matter of course.

The problem solving abilities of 14-18 year-olds are influenced by motivation. According to Kulcsár T. (1982) school performance including intellectual abilities and problem solving are connected with motivation, teaching methods, and the personalities of teachers and learners alike.

There are three important correlating factors, which affect problem solving (Fisher, 1987): -

Attitude: interest, motivation, self-confidence

- Cognitive skills: knowledge, memory, thinking ability

-Experience: knowledge of content, connections, problem solving strategies, background.

Kozéki and Entwistle (1986) investigated the motivation towards studying, which they divided into three fields and ten subscales (See table 1).

According to Balogh L. (1998) independent learning and problem solving skills can only be developed if we steadily make our students practise all the procedures of problem solving. The road leading to the solution should be shown to those who are not able to find it themselves (Skinner, 1973).

Given the above, the aim of our experiment was to examine the connection between problem solving and certain dimensions of motivation towards studying as well as to identify the weakest subscale within motivation. A further goal was to work out a teaching method that would develop problem solving and motivation as well. The two main hypotheses were: 1., There is a strong connection between motivation and problem solving. 2., The regular and systematic application of the problem solving strategy in the process of acquiring knowledge enhances the development of students' motivation towards studying and their problem solving, too.

Methods and experiment

The experiment included 302 students aged 14-16. The survey method was chosen as a means of data collection. The level of motivation was measured with the Kozéki-Entwistle test (1986) within 60 questions could be divided into three fields and ten different subscales (Table 1.) Each pupil of a class was given the test, and was asked to answer 60 questions in 45 minutes at the same time.

Table 1. Fields, subscales and some questions of motivation towards studying based on the Kozéki-Entwistle questionnaire.

Fields	Subscales	An example for questions related to subscales
	M_1: Emotional warmth: need for care, affection	I am happy to talk to my parents about what happened in the school.
	M_2: Identification: need for accepted, mainly by teachers	Most teachers treat every student fairly.

Affective	**M_3: Affiliation:** sense of belonging (mainly to peers)	Being friendly with my parents is more important to me than competing them.
Cognitive	**M_4**: **Independence:** need to follow one's own road	My parents never disturb me when I am engaged in something.
	M_5: Competence: need for acquisition of knowledge	Sometimes I get so interested in what we study at school that I want to deal with it outside school as well.
	M_6: Interest: responsiveness to novelty	School is boring.
Moral	**M_7: Conscience:** need for being trusted and valued, self-esteem	I feel ashamed of myself when I am not doing well at school.
	M_8: Need for order: need to follow values	It is important to me that my teachers should know that they could trust me.
	M_9: Responsibility: need for self-integrity, moral personality and behavior	Punishment at school is always unfair.
	M_{10}: Feeling of pressure: feeling that teachers set unachievable high demand without understanding	Adults expect too much of the young and they offer very little in turn.

Students chose one answer to each question from a 5-grade scale (a, b, c, d or e), the meaning of which was the following:

a., „I fully agree"; b., „I agree more or less"; c., „I partly agree"; d., „I don't quite agree";

e., „I don't agree at all".

We relied on the Hungarian translation of the original English version.

The possible responses were written on the blackboard by the teacher before the pupils began to answer the questions and remained on the blackboard until they had finished.

Evaluation: The letters denoting the responses to each question were then converted into points: a= 5 points; b=4 points; c=3 points; d=2 points; e=1 point. Such conversion seems to be in line with the five-grade scale used in the study. E.g. if a subject fully agreed with “Most teachers are fair towards their students” (See table 1.) he/she marked ’a’ on the answer sheet. Because this item reflects positive influence on motivation 5 points were allocated. The items reflecting a negative influence, however, were marked inversely on motivation (a=1 point; b=2 points; c=3 points; d=4 points; e=5 points) where the choice of ‘e’ on the answer sheet (I do not agree at all) was worth 5 points, and so on, since disagreement with these items reflects a positive influence.

After allocating the appropriate points to the answers, the score was calculated for each subscale (Table 2.), after which, the values of the subscales were added so that we should have the total score of the three different fields. Finally, we added all of the children’s score within subscales and fields and divided them by the number of students. The mean of these factors can be seen in Table 2 (except for the value of the fields which seemed irrelevant). The means and standard deviations (SD) (Table 2.) were calculated with the SPSS computer program, which completed the evaluation. The standard deviation measures the spread of the individual responses around the mean (Table 2.).

Table 2. Means and standard daviation of subscales within motitivation towards studying for 15 –year-olds in Hungary, 1998.

Subscales	Means	Standard daviation
Emotional warmth	24,72	4,08
Identification	20,03	3,89
Affiliation	23,57	3,39
Independence	21,31	3,41
Competence	20,88	3,94
Interest	20,06	4,05
Conscience	23,89	3,59
Need for order	22,65	3,78

Responsibility	23,47	3,82
Feeling of pressure	17,29	4,57

Performance of problem solving was measured with a test in biology (Table 3.), which was based on previous studies. Pupils had 45 minutes to complete the test, which proved rather difficult.

The test consisted of two parts and thirty items. In the first part, students were supposed to identify the type of the nutritional net, which would help them give the answers to the questions (the nutritional net vas previously covered at lessons). Correct answers were worth 2 points (part 1: five items x 2=10 points). The main point in this part was the identification of the nutritional net. The second step then, was to set up hypotheses and test them through trial and error to eliminate faulty ones, and to find the correct solution. The second part tested problem solving abilities more. The problem here was how the quality of the water in the pond could be judged. Students were expected to rely on their prior knowledge and to gain the necessary new information through research. They had access to books and a description of the possible indicators (their composition and the constituents they indicate). Given the relevant information students were expected to set up hypotheses, which were to be tested through planning and carrying out the measurement (experiment) in their mind. While they were trying to verify their hypotheses they were to note down the expected results on the basis of the equation of the chemical reaction. These results and the available resources (books and tables) made it possible for them to judge the quality of the water. The maximum of 20 points were broken down as follows:

-The presence of which substances may be indicated by Nessler-reagent, phosphoric acid and potassium iodide (KI)? (3 points)

-The experiment planned and described (3 points)

-Results (observation described) (3 points)

-Conclusion, assessment (3 points)

-Equations of reactions (3 points)

-Assessing the table showing the quality of water (2 points)

-Showing the results in a table (3 points)

The second part was more difficult (and was worth more points accordingly). It is impossible to cope with such a task without good problem solving skills and the ability to carry out individual research.

Table 3. Questionnaire for measurement of problem solving in biology.

1., We examine different associations. Each association includes 4 species. The species in every association are in different nutritional connection but one species of each association is only a consumer. This species is not nutrition for other species.

Answer the following questions:

a., How many nutritional connections may there be in the association which contains the fewest connections? (2 points)

b., How many nutritional connections may there be in the association which contains the fewest nutritional levels? (2 points)

c., How many nutritional connections may there be in the association which contains the most connections? (2 points)

d., How many nutritional connections may there be in the association which contains the most nutritional levels? (2 points)

e., Which organism (herbivorous, predatory or omnivorous animal) can be found on the highest level of the nutritional net in the association that contains the maximal nutritional connection? (2 points)

2., The environment of a pond is examined. On one coast there is reed, marsh and swamp. The other coast of the pond is partly cultivated, partly used as a pasture. Sample is taken out of the water of the pond and analysed. How would you examine this sample with the following agents: Nessler-reagent, Phosphor-acid and KI-solution? (20 points)

Write down the procedure planned by you

the results expected and possible explanations.

Total: 30 points

Further tests for the measurement of the development of problem solving were similar to this first test (30 points each, based on the material dealt with in the lessons of biology).

After measuring motivation and problem solving new teaching methods aiming at the development of these two factors were outlined. A workbook was compiled to cover the biology syllabus. At the beginning of each unit in the workbook the main problem is identified and students are invited to

make up their hypotheses. The new material is revised through questions and answers, after which students can conclude whether their hypotheses prove right or wrong. An example from the workbook can be seen in the Table 4.

Table 4. An example from the workbook for development of problem solving in biology.

Diffusion and osmosis

Problem: In rain the skin of the ripening fruit is easily split open. If we put an egg without its calcerous shell into water it soon swells and its soft shell is split open. Examining human blood sample, which was treated with a thinner solution than blood, we can see a red mass without cells in microscope. These are different problems but the reason is the same. What can it be?

Hypotheses:……

Carry out the following experiments. Put a tea bag into a glass of cold water and another one into hot water.

Observe: Where did water become coloured earlier? Observe how the process of colouring starts, and what its direction is like. …….

Explanation:……..

What general process is the background? Define it!

……..

Write another example for diffusion in biology! ……..…

Can the problems at the top of the test be explained with diffusion or not? Why? ……

Another experiment If you put concentrated sugar-solution into a cellophane bag and close it, the bag will swell and water out of it won't be sweet. Why?

Study and define the background process! ……

…….

Test your hypotheses again!…….

The development is effective if at least the biological syllabus of one school year is covered. We relied on the textbook used with 14-16 year-olds when compiling the workbook. The tests included several interesting, exciting exercises and experiments, which require the students' creative and abstract thinking. Sometimes the workbook applies the project and mind-map methods. Sometimes students and teachers work together, but at other times children are expected to work on their own or in groups without the assistance of the teacher.

Further studies are carried out with the workbook. At the end of the research problem solving abilities will be assessed again with a similar test presented here (Table 4). Motivation will also be measured with the Kozéki-Entwistle test (1986).

Results

Table 5. represents the rank order of subscales as measured by us (Revákné) and calculated on the basis of the means in Table 2. Table 5. includes the data of another researcher, Dávid I. for comparison.

Table 5. The rank order of factors affecting motivation towards studying based on Kozéki - Entwistle Test

Order	Revák's data – age: 15 in 1998	Dávid's data in 1997-1998	
		age: 12	age: 14
1.	Emotional warmth	Emotional warmth	Emotional warmth
2.	Conscience	Conscience	Affiliation
3.	Affiliation	Responsibility	Responsibility
4.	Responsibility	Need for order	Conscince
5.	Need for order	Affiliation	Independence
6.	Independence	Identification	Need for order
7.	Competence	Competence	Competence
8.	Interest	Interest	Interest
9.	Identification	Independence	Identification
10	Feeling of pressure	Feeling of pressure	Feeling of pressure

As far as the different factors are concerned care and emotional warmth seem to be the most important ones for school achievement, learning and the development of abilities in every age group in

school and family as well. The position of interest (responsiveness to novelty) in every age group should be more carefully examined because it seems to be lagging behind other factors and does not seem to get into a higher position with time either, which may constitute a major disadvantage in the development of students' abilities. This factor may play an extremely important role in the development of gifted and average children alike, so it is worth looking into the problem more closely in the future. The last factor is the feeling of pressure (feeling that teachers set unachievable high demands without understanding) because it is the most negative factor in motivation towards studying and learning. But teachers should not be blamed for this fact. Maybe it would be a good idea to reconsider the huge requirements of the national curriculum.

The results of the test measuring problem solving (Table 3.) cannot be seen in a separate table. We added the students' score within problem solving test and divided them by number of children's. So the mean for the whole sample was 15,21 points (max:30 points), 50.7%, which unfortunately is rather low, showing the need for the development of problem solving.

For correction, the values for problem solving abilities and those for motivation were compared. The sample was the same. The correlations between means of each subscale of motivation towards studying and problem solving can be found in Table 6. Correlations were calculated by entering the scores on the tests measuring motivation and problem solving into the computer and using SPSS program. The results showed how much these factors were connected.

Table 6. Correlation between the subscales of motivation towards studying (age: 15, in 1998)

	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}
M_1										
M_2	,343**									
M_3	,336**	,294**								
M_4	,284**	,156**	,112**							
M_5	,216**	,336**	,349**	,187**						
M_6	,220**	,383**	,193**	,175**	,460**					
M_7	,423**	,291**	,299**	,167**	,255**	,301**				
M_8	,276**	,498**	,332**	,223**	,547**	,445**	,424**			
M_9	,276**	,166**	,169**	,169**	,216**	,113**	,445**	,290**		

M_{10}	,.362**	-,147**	-,236**	-,199**	,218**	,069**	-,192**	-,155**	-,218**
P	-,361	-,061	,028	,001	,105	,226*	,053	,017	,027	-,050

(Explanation: M_1: Emotional warmth; M_2: Identification; M_3: Affiliation; M_4: Independence M_5: Competence; M_6: Interest; M_7 : Conscience; M_8: Need for order; M_9: Responsibility; M_{10}: Feeling of pressure; P: Problem solving;

*: signification 0.05 level ;

**: signification 0.01 level)

Emotional warmth (need for care, affection) correlates with statistical significance at 0.01 level with all the factors of motivation towards studying, except for the feeling of pressure. So it is a dominant factor in learning and the development of abilities. Emotional warmth is connected with interest (responsiveness to novelty), too (Table 6.). An important correlation is between affiliation (sense of belonging, mainly to peers) and competence (need for acquisition of knowledge). Consequently, working and learning in groups make it possible for young people between 14 and 18 to develop their problem solving thinking. The high correlation between competence and interest indicates the importance of working together in a group, too. Problem solving does not seem to correlate with any of the subscales on a high level, except interest. Thus, the hypothesis that motivation at school and problem solving abilities are closely related to each other was not proved, though there seems to be a connection between problem solving and interest.

This seems to be because teaching methods influence school achievement, which is determined by motivation and intelligence, teaching methods in turn develop interest and problem solving thinking as well.

Conclusions

Currently it is a worldwide problem that students are under-motivated to study science subjects, so it is important to find and develop factors that contribute to school achievement. Our experiment sheds light to a rather low level of motivation. Problem solving proved to be at a similarly low level (50.7%) Emotional warmth and care play a very important role in cognitive development. Problem solving turned out to correlate with the subscale of interest the most. Thus, each teaching method boosting interest develops problem solving as well. One possible method may be the more flexible teaching-learning method presented here, which helps students learn and solve problems in each age group, individually and in groups alike.

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