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DEVELOPMENT OF LOGICAL THINKING IN SCIENCE SUBJECTS TEACHING

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Abstract

The paper presented summarises the most important principles of problem - based teaching realised through problem - based tasks. A basis of the research, carried out in this area, are problem – based tasks from science subjects – mainly from biology and chemistry – for pupils of elementary schools and students of secondary schools. Solutions to these problems are presented as models realised through a problem- based programme expressed by a flow chart. This chart - designated for teachers - represents a design of micro-regulation that expresses a supposed structure of thinking activities of students and controlling activities of teachers in search for solutions to the respective problem - based tasks. The use of the programme in the teaching process widens a scope of individualised activities of teachers.

Within this research, 148 problem – based tasks have been gradually developed. In experimental classes of the eight and ninth grade of elementary schools and in the first and second year of secondary schools, practical verification of these tasks have been carried out. The most significant outputs of the research are referred to in the conclusion to this paper.

Key words: science teaching, model of the activity, problem tasks, development diagrams, problem-solving.

Introduction

At present it is necessary to pay attention to not only the selection and arrangement of science knowledge in teaching materials for elementary and secondary schools but also to the way of their acquisition and to the development of thinking activities of pupils from the first grade/year of teaching science subjects. From this point of view, the present state of teaching in the Czech Republic is not satisfactory. A considerable extent of science knowledge and a decreasing number of teaching hours, mainly for laboratory exercises, often makes teachers use mostly monologues, where students are in the position of passive recipients of information with a little emphasis laid on logical thinking. One of the up – to – date trends that can enhance effectiveness of teaching and increase activity, independence and creativeness of students in the teaching process is a problem - based teaching. Problem – based teaching can be realised in specific conditions of the teaching process at two levels. Either to base the whole teaching of the subject on problem solving approach where scenario and case methods are mainly used, or – with the existing arrangement of teaching material being maintained – to apply a problem solving approach to only partial phases of materials and set the problem - based tasks (they assist to develop ideal conditions for productive thinking that leads to active approach and creativeness. The latter seems to be optimal at present.

Therefore our goal was to design a set of problem – based tasks from science subjects - biology, chemistry and physics with a maximum use of interdisciplinary relations and to set pedagogical and psychological conditions and a model for solving the individual tasks that would reflect a controlling activity of the teacher and supposed activities of pupils.

Proposed tasks and a proposed procedure of how to solve them were verified in practice at elementary and secondary schools in the Czech Republic. The course of verification of each task was recorded and used for optimisation of setting the task and for a supposed search for solutions.

Starting points for creation of problem teaching tasks

In general, teaching tasks can be divided into assignment tasks and problem tasks. An assignment task is one in which the student is to attain a certain target and knows how to do this. We can characterize an assignment teaching task as one where the activities carried out in the work are algorithmic and algorithmic processes are not creative (unless the process of creating algorithms is involved).

A problem teaching tasks is the most difficult type. This is considered to consist in a task where the students know the target (revealing an unknown feature, knowledge, activity), but are, at the given moment, not aware of the means through which this is to be achieved. The internal structure of the problem (the nucleus of the problem task) differs from an assignment (the nucleus of an assignment task) in that, for a problem, the student does not have "everything required" for the answer. (S)He must first obtain the necessary information through a thought process, supplement the problem and then arrive at the correct result.

The degree of use of creative thinking is considered to constitute the borderline between the two types. It is, however, necessary to emphasize that the exact borderline between an assignment and a problem task cannot be laid down unambiguously, as it depends on the specific conditions, i.e. the phase in the whole subject matter or stage in the teaching process in which the task is included, and the initial knowledge, awareness, capabilities and habits of the students. Thus, it follows that it is impossible to decide on the basis of the task alone whether an assignment or problem task is involved.

An important precondition for the creation of problem tasks and work with them consists in meeting the following requirements:

- setting the targets of the task;
- respecting the individual and age characteristics of the students (based on the level of development of their knowledge);
- inclusion of the motivation aspect;
- guiding the work of the student in solving the task.

The first step consists in clarification of the teaching and educational targets of the prepared tasks and content analysis. The content of the teaching material is one of the most important factors affecting the possibility of formulating the task. Not every science subject in the teaching material is of the same importance in relation to inclusion of problem tasks.

In addition, it is necessary to determine the initial knowledge and capabilities of the students. Problem tasks must be appropriate to the overall maturity of the students, and the degree of development of their learning abilities. The students must discover by themselves, or with appropriate assistance from the teacher, which information is missing and how it can be obtained. The task must not be too simple - it would lose the nature of a problem, or too complicated - a problem situation is not created as the students are resigned to not finding a solution. It is also necessary to consider the phase of the subject matter to which the task belongs.

An important step in the creation of problem tasks consists in thinking through and selecting suitable motivation. Psychology indicates that output in any area, i.e. also in solving problem tasks, is a function of abilities and motivation. While abilities can be changed only slowly and gradually, a person can be motivated much faster. It follows from the laws of psychology that high motivation is required especially for activities that place high demands on the thinking of the student and problem tasks undoubtedly fall in this category.

From the standpoint of effectively fulfilling the requirements on guiding the activities of students during solving problem tasks, we attempted to utilize information obtained from cybernetics, which is concerned with the general properties and laws of management in

biological, technical and social systems. For effective management of an arbitrary process, i.e. also solving of problem tasks, it is necessary to know or provide for, in accord with the theory of management:

- the initial state of management of the system (state of psychological and knowledge preparedness of the students in relation to the teaching);
- the final state of management of the system (the specific targets of the teaching tasks);
- the model of the transformation from the initial state of the managed system to the final state (model of the transformation states of the psychological activity of the students, i.e. the optimal complexity of the structure of the solution);
- regulation of the solving process through suitable supplementary and elaboration questions in the proper order - the regulating factor is not only the teacher, but also the collective of students;
- feedback (control and verification of gaining the knowledge is practically the only means enabling determination of the degree to which the students approach the set target. This phase is, however, important not only for the requirements of evaluation of the students, but also provides valuable information and a foundation for further management).

Model of the activities of the teacher and student in solving problem tasks

In order for the teacher to be able to direct the students in solving tasks, (s)he need to know how their thinking works. We have attempted to prepare a certain model of student activity, containing concepts of the order and structure of the operations carried out (from the psychological point of view, this model is based on the work of Gaĺperin, Piaget, Kalošinová, Leonťjev and Rubinštejn). In directing the work of students, it is very important to transform the students' mental activity to the stage of external speech and the stage of material and materialized activity, which enable direct monitoring of the progress of the students' thinking (i.e. the opposite process in the sense of the Gaĺperin theory - exteriorization).

In order to emphasis the regulative aspect of teaching in solving problem tasks, we attempted to integrate problem and programmed teaching by preparing a model of problem programs. We are of the opinion that this is one of the possible approaches to bringing into harmony the requirement of development of activity and creative thinking of students with the principle of individual guiding of the teaching, with simultaneous retention of the greatest possible independence of the students.

The model of the activity of the student in solving problem tasks and the model of the guiding activities of the teacher with expression of their mutual relations was created with the assistance of the development diagrams normally used in programming. They are defined in the technical literature as schemes depicting the structure and connections of operations in the program.

If management is understood as a set of qualitative changes from setting to solving the task, then this is expressed as the development diagram. The basic feature of management is regulation, directing the activities of the student in solving the task (expressed the quantitative aspect). This is a subordinate concept and corresponds in the development diagram to the individual introductory questions, recommended observations or experiments carried out. The regulation activity of the teacher is ensured through feedback.

Example of problem tasks with development diagrams

Topic: Damage to skin

VVC: Students should be able to provide the first aid in case of skin chemical burn caused by acid and substantiate the methods used.

Setting of problem situation – motivation:

When working in a chemical laboratory, one of the students poured acid over his hand. His fellow students wanted immediately to provide him with first aid. One of them proposed to apply a weak solution of vinegar on the effected area, the other to apply a solution of sodium bicarbonate.

Setting of problem task:

Which of the students was right and why?

Initial knowledge required:

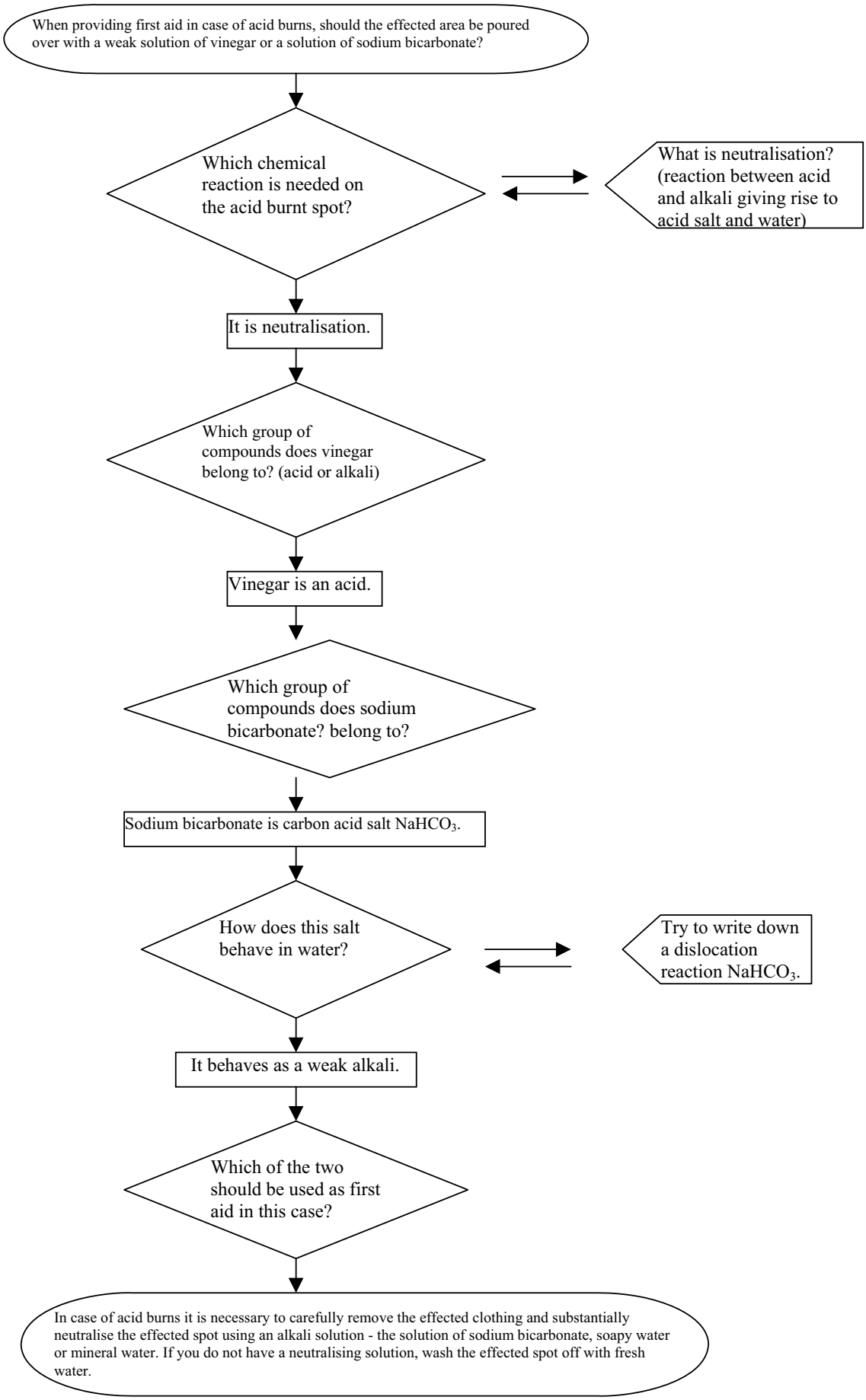
Reaction between acid and alkali – neutralisation, chemical composition of vinegar – acetic acid solution - CH_3COOH, chemical composition of sodium bicarbonate – $NaHCO_3$.

Positioning of task in teaching process:

8th class when dealing with principles of first aid, topic Damage to skin. The task can also be set in the eight class in chemistry lessons when dealing with neutralisation.

Table 1. Solving of problem task.

Phase of solving	Thinking activities of students	Teacher's control
Introduction	Analysis	Motivating and setting up the task
Search for solutions	Analysis	Which chemical reaction is needed on the spot burnt by acid?
	Analysis Comparison	Which group of chemical compounds does vinegar belong to?
	Analysis Comparison	Which group of chemical compounds does sodium bicarbonate belong to?
	Analysis	How does this salt behave in water?
Conclusion	Synthesis Generalisation	Which compound should be used as first aid in our case?


When providing first aid in case of acid burns, should the effected area be poured over with a weak solution of vinegar or a solution of sodium bicarbonate?
Which chemical reaction is needed on the acid burnt spot?
What is neutralisation? (reaction between acid and alkali giving rise to acid salt and water)
It is neutralisation.
Which group of compounds does vinegar belong to? (acid or alkali)
Vinegar is an acid.
Which group of compounds does sodium bicarbonate? belong to?
Sodium bicarbonate is carbon acid salt $NaHCO_3$.
How does this salt behave in water?
Try to write down a dislocation reaction $NaHCO_3$.
It behaves as a weak alkali.
Which of the two should be used as first aid in this case?
In case of acid burns it is necessary to carefully remove the effected clothing and substantially neutralise the effected spot using an alkali solution - the solution of sodium bicarbonate, soapy water or mineral water. If you do not have a neutralising solution, wash the effected spot off with fresh water.

Results of the research

We proposed 148 science problem tasks for elementary schools and secondary schools. For each task, we prepared a model of the activity of the teacher and students containing concepts of the order and structure of operations carried out in solving these tasks. We attempted to integrate the problem and some tasks of the program teaching of problem programs with the assistance of development diagrams. Development diagrams are an expression of management as a set of qualitative changes from the setting of the task to the solution, as they contain the expected structure of the thought processes of the students and simultaneously the series of directing steps of the teacher.

The proposed model introduces ***differentiated management of problems*** into problem teaching. The individual introductory questions (regulation elements) contained in the development diagram are employed as required. Simultaneously, this can be a means for determining and affecting the difficulty of the given tasks. They enter the development diagrams especially in the decisive steps and the teacher can use them according to the individual needs of the student. This does not mean that every student must necessarily go through every proposed step, as a number of variants can occur in the solution. For example, an excellent student can solve the task instantly, on the basis of his (her) knowledge, insight or previous experience. For such a student, the teacher uses the development diagram only to control his (her) ability to carry out the expected thought processes and to control the correctness of the individual answers and solving of the given task. A good student will solve the task independently or with minimal assistance from the teacher. For an average student, the development diagram will serve the teacher as a basic axis according to which (s)he will gradually direct the work of the student as required, especially at decisive points in solving the task. For sub-average students, the diagram is used to its full extent to reach the right answer.

The proposed model cannot, of course, be considered to be the only possible one. It is accompanied by a certain degree of subjectivity and does not take into account the occurrence of unusual situations. It is a certain axis for the teacher, an ideal route that (s)he may (must) modify in a creative manner according to the specific teaching conditions. It can be a useful aid, especially for new teachers.

In addition to use by the teacher to direct the work of students, for example through conversations (frontal, individual, group), there is another potential for use by the students themselves. By leaving out the text of the answers in the processing part of the diagram (the rectangles in the development diagram), a working sheet is obtained that the students can fill out themselves. The third possibility is conversion of the development diagram to the form of a computer program.

The proposed model has the advantage that it increases the scope for individual action by the teacher and an individual tempo of the students. The teacher can devote him(her)self more to those students who need his (her) personal assistance.

The prepared tasks were tested on 8 elementary school classes and 4 secondary school classes in the framework of yearly repetition, that was not specified beforehand to the students. The testing was carried out by the teachers of the relevant schools. We recorded in writing and then evaluated this in each class. We employed the results of the testing for the final form of the development diagrams.

Conclusions

The work was concerned with the aspect of carrying out teaching of science through solving problem tasks. First we prepared the concept of problem teaching at a theoretical level, reflecting

new knowledge in pedagogy, psychology and didactics and we concluded that fulfilling of the following requirements constitutes an essential precondition for the creation of problem tasks from the standpoint of their function in the educational process:

1. clarification of the educational target of the task
2. carrying out content analysis of the subject
3. determining the expected knowledge, skills and habits of the students
4. respecting the individual and age characteristics of the students
5. inclusion of motivation aspects
6. provision for directing the work of students in solving these tasks
7. provision for feedback and evaluation
8. formal and stylistic correctness of the task.

We also attempted to prepare a model of directing the work of students in solving these tasks.

In conclusion, we consider it essential to point out that theoretical preparation of problem tasks is a very important phase, but constitutes only one aspect of research. In their application in teaching, tasks enter a new level representing new conditions, that are variable. They depend on a number of factors, especially the level of the students in the class, the personality of the teacher, previous experience, time, material equipment, etc., and these all affect the form of the theoretically prepared model. Thus, it is also necessary to evaluate, on a sufficiently large sample of students under various conditions, the other aspect, consisting in the actual implementation in teaching. Thus, further work on the use of problem tasks in science must be oriented primarily towards practical testing, the results of which can then affect work in creating a theory of problem tasks both in teaching science and in general didactics.

All this requires that the teacher be flexible, alert, adaptable to changing conditions and not only mechanically apply a set form. This means that emphasis on creativity is placed not only on the work of the students but also on the work of the teacher.

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Резюме

РАЗВИТИЕ ЛОГИЧЕСКОГО МЫШЛЕНИЯ В ОБУЧЕНИИ ЕСТЕСТВЕННОНАУЧНЫМ ПРЕДМЕТАМ

Вера Чижкова, Гана Чтрнацтова

В статье обсуждаеться вопросы осуществления учебы естественных наук посредством решения проблемных задач. Прежде всего в теоретическом плане авторы обработали понятие «проблемной учебы», которое отражает новые сведения по педагогике, психологии и дидактике и пришли к выводу, что неизбежным условием для творчества проблемных задач является выполнение следующих требований: определение педагогико-образовательной цели, задачи, исполнение смыслового анализа темы, определение предполагаемых знаний, грамотности и навыков учеников, соблюдение индивидуальных и возрастных особенностей учеников, включение мотивационного аспекта, обеспечение управления деятельностью учеников при решении этих задач, обеспечение обратной связи и оценки, формальная и стилистическая правильность задач.

Было составлено 148 задач, их решение заключается в разработке моделей в проблемную программу изображенную в блок-схема программе. Эта диаграмма, предназначенная для преподавателя, является проектом микрорегулирования, и передает предполагаемую структуру мыслительной деятельности ученика и руководящую деятельность преподавателя при решении данной проблемной задачи.

Очевидно, что теоретическая обработка проблемных задач очень важная стадия, но представляет всего лишь одну сторону исследования. Поэтому были задачи удостоверены и практически в опытных классах (в 8 и 9 классах начальной (основной) школы а также в 1 и 2 классах средней школы). При применении в учебе задачи исполняют и другой план, представляют новые условия, переменные условия. Они зависят от ряда факторов, в особенности от уровня учеников в классе и личности преподавателя, и определяют процесс (действие) теоретически подготовленной модели. Поэтому нужно исходить не тольно из достаточно большого образца учеников при разнообразных условиях, но и также из другой стороны - собственной реализации во время учебы.

Ключевые слова: обучение естественнонаучным предметам, модель деятельности, проблемные вопросы, блок-схема программы, решение проблем.

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