Motivation and Hands-on Experiments

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Abstract. *The main objective of the paper is to show the relationship between simple experiments and motivation of students in science education. The first part presents a psychological base of cognitive motivation. Outcomes are cognitive motivational teaching techniques. One of these techniques is the use of simple experiments. Next, the author presents simple experiments as incentives of cognitive motivation, prevention against misconceptions and a source of creativity. Presentation is supplemented by original simple experiments. The last part deals with science teacher skill to motivate students by experimenting. It describes the role of simple experiments in teacher training.*

Keywords. Cognitive motivational teaching techniques, simple experiments, preconceptions and misconceptions, creativity.

1. Cognitive motivation in science education

Motives are the psychological characteristics of a personality [1] which we consider to be the internal cause of behavior. Motives are factors which awake, keep going, and focus the behavior. Motives consist of elementary structures of consciousness which are called needs. Needs are the elementary motives, which we can imagine as a condition of a lack or abundance in an organism, causing tension in an organism which is directed and starts activity. Motivation is a psychological process, in which motives (needs) are implemented into the behavior and experiences of an individual (by outside factors):

MOTIVES $\mapsto$ MOTIVATION $\mapsto$ BEHAVIOR

At the beginning of the motivational process there is the "inner state of tension" and at the end is the "final action". Motivation is localized intro-psychologically in a human's consciousness, but it is also closely connected to a human's relations with subjects and phenomenon in their environment. Motivation results in certain, aimed activity.

The structure of needs is hierarchically arranged according to development of individual, evolution of humanity, and interaction between an individual and their environment. Important classification [2] of needs according to A.H. Maslow (1954):

- Physiological needs.
- Need of security.
- Need of solidarity and love.
- Need of appreciation.
- Need of self-fulfillment (included cognition need).

Needs develop progressively during the ageing process. If the basic (physiological) needs are not satisfied, it is impossible to satisfy higher needs. It is also important to note that everyone has their own hierarchy of needs which forms the spectrum of motivation. Factors affecting motivation can change during one's lifetime.

There are two ways to increase the need, impulse or incentive of a person. Impulse is an inner initiative marking some change in the body or mind. The example could be the feeling of thirst, the need to drink, when the body's organs signal a lack of liquids. Homeostasis is the condition of an organism when organs do not signal any lack and no impulse is apparent. In the condition of homeostasis (without impulse) the need can be increased by the use of an external initiative - incentive. An example of this situation is when the appearance of something to drink increases our thirst, this occurs without signals from the internal organs indicating the need for liquid. Incentives are very important, especially in the field of education.

Incentives can be positive or negative. Positive incentives increase and satisfy needs at the same time. When we are thirsty, the positive incentive is a soda machine. If we have the coins and we know how to use them, we can get something to drink. The same machine becomes a negative incentive if it doesn't work or we do

not have the money. Negative incentives increase the need, but do not satisfy it.

Incentives are simple, or complex depending on the number of needs they affect. Simple incentives affect only one need. Complex incentives affect more then one need at the same time. Every kind of need has a whole group of incentives which increase the need. However, it is important to notice that certain incentives work individually and have different impacts.

There is usually more then one incentive present at one time. They are influencing each other and this interaction increases and decreases their impact. There is also a possibility of a development of individual by alteration of the efficiency of incentives and their combinations during the development of a student [4]. Teaching provides a typical complex incentive, in this situation for learning, with a variety of interacting needs and other motives.

Interest is an important complex motive, especially from an educational point of view. It is based on a variety of needs. These needs can be innate or acquired. Interest can develop from different groups of needs, while the same groups of needs can become the source for different kinds of interests. A further, important characteristic of interest as a complex motive is the close connection between the motivating and emotional elements. Interest causes inner positive motivation when the activities (objects, phenomenon), which are the subjects of interest, increase and in the same time satisfy that group of needs which is the basis of interest. The entirety of this motivational process is followed by strong positive emotions, experiences of pleasure and self-satisfaction. There is also a connection between the interest and the willing capability of an individual. Interest and will are directly proportional. From an educational point of view, the process of the development of interest is important, especially in general learning, but also in certain subject studies, e.g. science.

Teaching and learning are complicated activities, implemented in schools typically in a social context, when a student reacts to the achievement requests of the teacher and school. In education, we can put forward three special groups of dominant needs in students which are being continuously developed:

(a) Social needs.
(b) Achievement needs.
(c) Cognitive needs.

The group of social and achievement needs usually includes the needs of identification and positive relationships (especially the teacher-student and the student-student relationship), status, influence, competence, realized goal of successful performance, and the avoidance of failure. Social and achievement needs lead to external motivation of the student which has a high motivational impact and which quite often contains a dominant motive. This boosted motivation can be both positive and negative and this is its biggest disadvantage. Luckily this negative motivation isn't included in the group of cognitive needs on which we will concentrate.

Each part of teaching (e.g. undertaking experiments) usually boosts social, achievement, and cognitive needs all together. The teaching is complex incentive which induces these groups of needs depending on the individual structure of the personal sphere of needs.

2. Cognitive motivational teaching techniques

Cognitive needs are the basis for cognitive motivation which is the inner motivation of students and it is always positive. It often leads to development of interest in studying a certain subject. Because this form of cognitive motivation increases student interest so much and appears more frequently, it is important we should use such a technique in our teaching.

Cognitive needs of students exist also in science education at school and also out of school. Science teachers have the possibility to instigate the cognitive needs of students. The students' cognitive needs are induced in the students by the educational process and hence the teacher plays an important role in affecting the students' cognitive motivation [5].

These cognitive needs we compared with students' school activities in science teaching. This led to the set of science cognitive motivational teaching techniques (CMTT) given below through which students can be motivated:

1. Stimulation through unconscious perception and experimentation.
2. Use of models of natural objects and phenomena.
3. Solving problem exercises and projects.
4. Demonstrating simple experiments and toys.
5. Seeing paradoxes and tricks.
6. Watching films, video programs and computer programs.
7. Experiencing humour in science.

The characteristics of each of the mentioned science CMTT have a certain special incentive effect on one or more desired cognitive needs.

We want to get students' interested in science education even though they may be more interested in different school subjects, or in non-school activities (art, sports etc.). Motivational teaching techniques which do this are interdisciplinary CMTT. They are similar to science CMTT (because interdisciplinary CMTT also stimulates internal cognitive motivation), but not using pure science incentives. These techniques use facts or situations which stimulate a student's interest based on the stimulus from different fields of studies.

Classification of interdisciplinary CMTT is based on a spectrum of subjects and activities which can be used for motivation. By comparing these subjects and activities with science components, we discovered interdisciplinary CMTT which can stimulate interdisciplinary cognitive motivation:

8. Use "Science for life" (health, food, energy, environment etc.).
9. Application of science knowledge in technology.
10. Exploitation history related to science discoveries and scientists' lives.
11. Reading sci-fi literature and watching sci-fi films.
12. Application of science and art.

For each interdisciplinary CMTT, there is a certain characteristic interdisciplinary connection.

3. Simple experiments with everyday objects

The distinctive quality of a simple experiment is transparency of presentation of physical phenomenon base. This transparency is given especially by the three following factors:

1. Reduction extra phenomena which may occur within an experiment.
2. Qualitative ness of an experiment when students' attention is not taken away from phenomenon base to unnecessary measure.
3. Easy realization by students who perceive an experiment by every sense.

The significant group of simple experiments is group of experiments with everyday objects. So the transparency of phenomenon base observation is supported thanks to the fact that students know these objects from their daily life, so their attention is not taken away from the demonstrated experiment and they can concentrated on it. These simple experiments with everyday objects can be marked as hands-on experiments.

Also undemanding technical realization of simple experiments with everyday objects is an important quality. This brings students a great opportunity to conduct simple experiment by themselves at school as well as out of school. It also results in development of manual skills of students.

We must not omit economical undemanding ness of a simple experiment with everyday objects. Many schools still contend with insufficient equipment with expensive commercial aids which can be partly substituted by usual low-cost items.

3.1. Motivational incentive

The fundamentals of scientific research are observation and experimentation. In science education, teachers' demonstrations and students' experiments are also very important. It should be obvious that every correctly chosen and appropriately used experiment is valuable for motivation of students. Nevertheless we can still find one group of experiments with even higher motivating potential: simple experiments.

Simple experiments can be a complex incentive in activating cognitive needs such as problem solving, modeling of natural phenomena, the needs of our senses and muscular activity etc. This simultaneous activation of some cognitive needs can result in a strong motivating impact. Qualitative ness of a simple experiment activates students' cognitive need of problem solving and thus its consequent activity leads to the pursuit of problem solving. These cognitive needs are activated particularly by paradoxical experiments, tricks and toys.
A paradox is a phenomenon which creates a conflict between experience and perceptions of reality. It is a multiple incentive which can activate sensory activity (students focus their attention because of the conflict created with their previous experiences) and the need to solve the problem (which is closely connected with the paradox). We can begin to understand it after a deeper study of natural laws.

Paradoxes and other surprising phenomena are often elements of magic and tricks, commercially utilized in entertainment (e.g. equilibrium of bodies, rotation of bodies, and

light reflection in mirrors). It is usually a combination of perceptive illusions and/or demonstrating imitations of our senses. The principle of commercial utilization of tricks is to keep the fundament of paradox a secret. If we use a few tricks, it is necessary to explain the fundamental ideas.

Evidence of the motivational efficiency of toys as simple experiments is their successful commercial utilization in the form of toys for both children and adults. Bubble makers, yo-yos, click-clacks, and kaleidoscopes are example of these toys.

3.2. Preconceptions and misconceptions

From the pedagogical-psychological constructivist view there is significant use of simple experiments with everyday objects known by students from their daily life. Thanks to this knowledge students have often already formed correct preconceptions. In this case we can use these correct preconceptions and base teaching on them.

Significant problems of education in natural sciences are students' misconceptions. They strongly keep from effective teaching and bound understanding of physical phenomena. They are also source of students' motivation loss for science education. There exist several teaching techniques leading to get over students' misconceptions. This contains follow-up therapy which is not much effective while misconceptions are quite stable.

Simple experiment can be important preventive instrument against misconceptions forming. Misconceptions have their matrix in difficult situations when many overlapping or often even contrary phenomena come through. Then it is difficult to find out the simple relation leading to the correct preconception. If a simple natural phenomenon is presented to students in a simple experiment with transparent phenomenon, the correct preconception can be formed and thus we can avert creation of misconceptions. This conclusion leads to use of simple experiments in primary science education in the lowest age.

3.3. Creativity and skills

Simple experiment allows for the creation of alternative variants of an experiment and open space for the creation of new experiments. Use of simple experiments in education therefore supports development of students' skills of experimentation and develops their creativity.

One of other possibilities of use of simple experiments in education is simulation of natural phenomena which helps us survey and verify physical relations without precise measurement with difficult measuring instruments. It is about making changes in specific parameters of an experiment for better cognition of phenomenon base or possibly for determination of dependent character among quantities describing the given phenomenon. In this way we can deduce or verify relations for the given phenomenon within teaching. Experimentation leads students not only to effective cognition but also to the development of manual and intellectual skills.

Teaching aids for the simulation of attributes of buoyant hydrostatic force made from polystyrene (a set of blocks) by author can be used as an example of simple simulative aids:

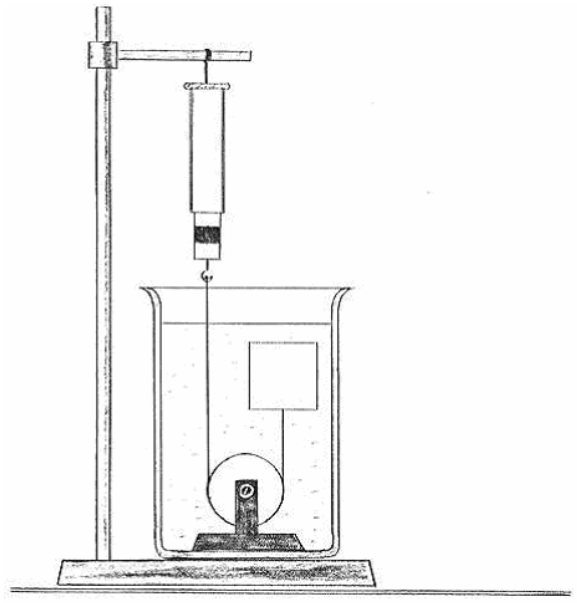

Figure 1. Polystyrene block in liquid

4. Teaching technology using simple experiments

Analysis of a teaching stage and method appropriate for the best implementation of an experiment has to be made for optimization of educational effect of a simple experiment use. A simple experiment can be used in every stage of teaching. For example, paradoxical experiments are best applied in the motivation stage, both in initial and running motivation. In the explanation stage we use simple experiments for initial periods when demonstration of phenomenon

base is needed. Simple experiments can be used also in the fixation stage when we can apply them effectively for students' creativity development. Students can create their own alternatives or even new experiments. These experiments will be integrated also into application and diagnostic stages.

Use of simple experiments is optimal in direct students' experiments. Simple experiments are appropriate also in some special teaching techniques with ICT use:

(a) Videos with simple experiments: Simple experiments can be demonstrated by video projection. Projection of these experiments can be used as:

- initial and running students' motivation,
- supplement of real demonstration experiments (time saving, safety),
- instructing for the students' following experimenting,
- projection without sound with students' comment in fixation and diagnostic stage etc.

(b) Simple experiments on the Internet: many of web pages contain the presentation of simple experiments. This can be used within the fixation teaching stage when students search for these experiments by them selves and then present them in class or use them as an inspiration for the creation of their own experiment modification.

(c) Records of students' experiments: individual students' performance during demonstration of simple experiments can be recorded by camcorder for motivation as well as for the experience stages of teaching. These records thus can be analyzed with students from a physical and technical view.

(d) Experimentation instructions: photos or short videos with descriptions and experimentation instructions can serve students and teachers as simple experimentation instructions and simple aids making instructions. PP presentations on PCs and data projectors are appropriate.

(e) Web presentations: photos or videos with simple experiments can be placed on school web pages. Thus the project of students' presentation in the field of simple experiments can be realized.

5. Resources of simple experiments

The above mentioned ideas of simple experiments use in science education have to be compared with real situation at schools. Can teacher get information about simple experiments as much as necessary and does he use them in teaching?

Methodical publications with simple experiments have been published recently. Simple experiments are a base of some videos, e.g. "Physics in Experiments" [8]. In 2005, "Fair of Inventions", the tenth year of national conference of school physical and science experiments in the Czech Republic will be held. An important part of the conference is formed by simple school experiments and their description is published. Methodical journals publish periodically articles about the use of simple experiments. Some commercial companies are specialized in making simple aids for school experiments. Teaching aids for simulation of principles of flying created from polystyrene by author and made by commercial company as example:

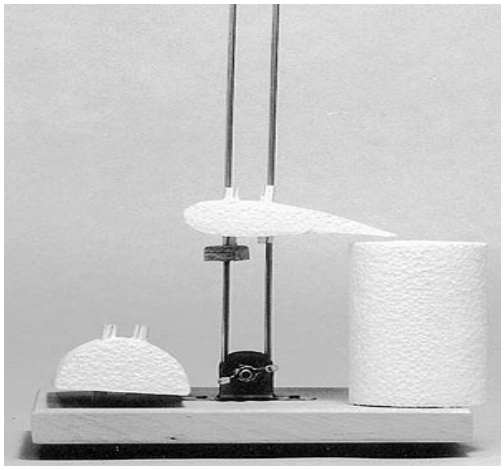

Figure 2. Principles of flying

Attention is paid to simple experiments also on the international level. We can see it on web pages. The international interest is also demonstrated by a three year organized all-European conference "Physics on Stage" where the majority of European countries present their physics and science school experiments. Many of them are just simple experiments with usual things. Documentation from these conferences is available on web pages [7]. Use of the experiments in teaching depends primarily on individual teacher. Our research shows that simple experiments with usual things together with ITC attract more and more attention.

The author of this article created and put together several quite extensive sets of simple experiments and aids exploiting everyday objects

and materials from daily life. These are especially experiments with coins, plastic syringes, toilet paper, polystyrene and matches. These sets of experiments show, among others, that everyday objects and materials can effectively serve for school experimentation in most fields of physics and science. These experiments are recorded on videos [8].

6. Teacher skill to experiment

How is it necessary to prepare science teachers in the field of simple experimenting [6]? The character of science experimenting generally brought us to conclusion on the necessity of acquiring experiment skill in three stages:

1. Scientific experiment skill (skill of 1st order) - complex qualification to carry out scientific experiments.
2. School experiment skill (skill of 2nd order) - complex qualification to carry out school experiments.
3. Skill to teach students to experiment scientifically (skill of 3rd order) – technology to teach students by using school experiments.

The skill to simple experimenting is located into second and third stages. Science teacher have to obtain detailed information about simple science experiments and about their role in science education. Not only knowledge but particularly the acquiring the skill to experiment simply is very important [3]. Five acquiring stages exist in the training of science teacher's skill to simple experimenting:

(1) Motivation stage:
Completing of professional interest and attitudes towards simple experimenting.

(2) Stage of subject orientation in acquired skill:
Acquiring knowledge necessary for the experiment skill (thought item of skill).
Creation of experimental habits (sensual and motor items of the skill).

(3) Stage of "crystallization" of new skill:
Solving of simple applied tasks of simple experimenting.

(4) Stage of completing the skill and its including into wider contextual frame:
Solving of complicated applied tasks of simple experiments.

(5) Integral stage during which the new skill is integrated into skill structure:
Solving of teaching problem situation etc. in school practice.

Completion and integration stages are conditioned by several-year field experience of the teacher and that's why acquiring experiment skill is not possible to finish as soon as pre-gradual training of teachers.

7. Acknowledgements

We acknowledge companies Direct film and Ariane schola which produced videos and aids with our simple experiments. The paper was created in the projects GRUNDVIG, SGE G2-P-2004-15 and GACR 406/05/0246.

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