The New Educational Review

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Development of Technical Imagination as the Effect of Computer-Aided Process of Learning Physics

Abstract

The paper presents results of experimental investigations. The studies were undertaken with the aim to ascertain whether computer techniques, used to assist the process of learning physics, can partake in the creation of conditions leading to the development of technical imagination. The ability to make use of technical imagination is important in the process of knowledge transfer to students as well as in the development of logical, creative and abstract thinking.

The experiments were carried out during laboratory classes with students from the Technical Physics of Poznan University of Technology employing the method of parallel groups with rotations. Students from the experimental group learnt a physical experiment using appropriate computer programmes, while students from the control group worked without computer support.

Key words*: learning of physics, computer-aided, technical imagination, logical, creative and abstract thinking, natural pedagogical experiment*

Introduction

The process of teaching students requires appropriate conditions and actions, which will allow them to acquire suitable competence and proficiency, so that, in the future, they will be able to carry out new tasks and perform professions which are still unknown today. Future requirements contribute to the current tasks facing high education institutions: the transfer of knowledge to students, development of their abilities for logical, creative and abstract thinking and the organisation of the environment allowing to apply students' own knowledge to life. Another responsibility of education is to combine research with technology, production activities, everyday life and human activity. The effective and fulfilling participation of young people in contemporary societies requires modern methods of education including: the application of methods intended for both group and individual education, self-study, development of individual skills, talents, and imagination. One of the most important tasks of education should be to intensify assistance in this area.

The objective of the performed experiments was to verify whether computer techniques assisting the process of learning physics can participate effectively in the creation of conditions for the development of technical imagination. The validity of this assumption is apparent from earlier performed investigations, which indicated that computer techniques contribute to the conditions of subjectivity and motivation (Kozielska 2000, 2003) as well as to the development of students' research and creative activities during the process of learning physics (Kozielska 1996, 2004).

1. Physics and technical imagination

Imagination combines various forms of intellectual activity and constitutes a creative component of human psyche. A deliberate and conscious human effort in developing knowledge and its imaginary contents is important in the process of education. Imagination is examined in combination with philosophy, psychology, sociology as well as pedagogy, aesthetics and art. Philosophers examine the relationship of imagination and knowledge because knowledge is one of the elements of learning reality. Psychologists explore functioning mechanisms of imagination because they view it as this capability of human beings which takes part in their perception, memory, thinking and activities. Pedagogues emphasise the instructive and educational aspects of imagination and, hence, examine it in the context of its development by students.

Both human imagination and mind allow us to get to know and transform the surrounding environment. Methods and activities associated with the creation of material goods by man together make up technology. It can be defined as the human activity leading to the creation of objects, constructions and transformation of reality. Man needs imagination to further and support him-self in these activities. Imagination can, therefore, be understood as the capability of human beings to know, understand, predict or create new knowledge.

People equipped with technical imagination possess many valuable capabilities, among others: spatial imagination, foresight of consequences of realised projects, appropriate selection from many possibilities, prediction of mutual effects of elements, development of technical solutions, also those which were unknown earlier, construction of dynamic images of technical elements on the basis of theoretical information, perception of technical problems in the environment.

The development of technical imagination can take place in the course of intellectual work to solve problems in the field of physics, especially at the university level. Physics encourages a scientific attitude to technical problems and builds powers of association and abilities of observation. Through observations and the analysis of the course of the observed phenomena, physics teaches how to take note of elements of the observed process, it seeks their interrelationships and draws appropriate conclusions, leading to theoretical models. It also happens that scientific conclusions drawn from experiments lead to theoretical generalisations.

Physics acquaints students with inanimate matter in its various forms and which, in turn, constitute the object of engineers' activity. An engineer should know and understand basic laws governing matter as well as its principal features such as: its symmetry, quantum character, probabilistic and relativistic properties. Physics combines macro- and microelements of the world and reconciles classical and quantum approaches because that is what matter is like. Physics understood in this way can provide a good content basis for the development of students' technical imagination.

2. Influence of computer technology on the for development of technical imagination

Computer techniques assist technical design. Simulations imitating the operation of various technical equipment are useful in teaching during the transition from theory to practice. They provide effective help, which allows to combine knowledge and technical activity. Moreover, computer techniques create possibilities for the development of individual capabilities of human imagination and activity. Computers are systems intended for the processing of information. They can, therefore, supplement certain psychic traits of the human brain.

Educational computer programmes, especially dynamic presentations of natural phenomena, enable simultaneous involvement of students' perceptive, conceptual and constructional capabilities. That is why they are particularly important in technical education, since they stimulate and encourage students' technical imagination, motivate them for the development of their technical interests and arouse their creative and inventive powers. Therefore, it is quite understandable why computer assisted software must comply with very high requirements. These kinds of programmes need to present clear simulations, which will contain a certain amount of simplifications facilitating familiarisation with the construction and functioning of even very complex and complicated equipment used in practice. It appears that the presented constructions and process dynamics encourage students to think logically, creatively and abstractly. Furthermore, they stimulate students' creative involvement in the learning process by putting forward their proposals for construction or aesthetic changes as well as innovation ideas within the framework of the presented simulations (Kozielska 2004).

3. Experiment and results

Purpose of experiment: Observations made in the course of the application of the computer-aided process of learning physics require experimental verification. The purpose of the performed experiments was to ascertain *if students' activities during physics laboratory classes and the quality of their intellectual involvement in the course of their application of computer software found their reflection in their achievements indicating a higher level of technical imagination.*

Parameters of experiment: Bearing in mind the earlier-presented characterisation of the technical imagination, *when determining its level among students, the following parameters were assessed in the course of the performed experiments*: 1. spatial imagination, 2. prediction of the consequences of the realised tasks, 3. appropriate selection from among many possibilities, 4. the capability to envisage the impact of some factors on other ones as well as on technical solutions, 5. the capability of dynamic images formation on the basis of theoretical information, etc.

Indexes: *The level of students' technical imagination was assessed on the basis* of their achievements connected with their ability to solve problems associated with the earlier-mentioned capabilities and based on the physics from the field of optics.

Assessment: The final index of students' knowledge and competence was evaluated using appropriate assessment consisting of tasks and problems. They were expected to demonstrate the above-mentioned capabilities in the area of optics. The groups under comparison shared the following common factors: the syllabus and the time of its execution, knowledge base, and uniform conditions of work in the students' physical laboratory.

Sample and method of experiment: 64 students of Technical Physics participated in the performed research. They were divided into two equal groups. The experiments were carried out in the course of laboratory classes, which were conduced in accordance with the programme of studies, three hours a week during one semester. In the performed experiment the method of parallel groups and the technique of rotation was used.

Coding: In the case of the experimental group *"E"*, a computer programme assisted the learning process, while the control group *"K"* (blank) worked without any assistance. The groups were swapped at the second stage of the experiment and renamed for *"E'"* and *"K'"*. Control assessment covering the material presented during laboratory classes was applied after each stage of the research.

Scoring: For the assessment ten exercises were prepared. It was possible to achieve ten points for all exercises.

Procedure of experiment: *How did students from the computer-aided group work during the physics laboratory classes?* Their work involved independent execution of a given experiment and elaboration of the results under the supervision of the teacher. The employed computer software helped students prepare and execute a given experiment and then to elaborate its results. The computer programmes were strictly connected with all the experiments, the presented the required physical contents, simulated courses of studied phenomena, laws and interrelationships. They also showed the construction and action of pieces of equipment and stands used to carry out individual experiments. The most valuable programmes concerned the structure of pieces of equipment known from drawings, charts and descriptions.

The students prepared appropriate equipment for work, got familiar with their measuring potentials, put forward their proposals for changes in laboratory stands and new approaches to research methods. The employed computer software allowed them to carry out experiments in computers prior to their executions using real equipment. They also allowed them to examine the effects of the proposed changes as well as to carry out model experiments and study phenomena in relation to parameters established and changed by themselves. In addition, the applied programmes also indicated favourable experimental solutions and helped students to prepare mathematical elaboration of results.

The students utilised educational computer programmes in their demonstration or dialogue forms or in forms co-operating with the laboratory stand, i.e. allowing their direct involvement in physical measurements.

In a particular exercise each student used the same computer programme during the classes in study schedule. The PC programmes used in the educational research had been financed by the State Committee for Scientific Research. These programmes are not available commercially.

4. Analyses of Results

For the studied groups of students, on the basis of the obtained experimental results, the following values were determined: mean values $\overline{X}$, S^2 variances and standard deviation S. Additionally, the following tests were applied: χ^2 test for evaluating the conformity of empirical and normal distribution, F_0 test for evaluating the significance of differences among the variance of empirical distributions obtained, and "t" – Student test used for the estimation of the difference between the means of the results for examined groups of students (Guilford 1960; Ferguson, Takane 1989). These results are presented in Table 1.

The following formulas were employed:

$$\bar{x} = \frac{\sum n_i x_i}{N}, \tag{1}$$

$$S^2 = \frac{\sum n_i (x_i - x)^2}{N-1} - \frac{1}{12}h^2, \tag{2}$$

$$S = \sqrt{S^2}, \tag{3}$$

where: n_i denotes the frequency of occurrence of results in individual class intervals for x_i – a given group; – a numerical value of the interval centre of a given class; $N = 32$ – number of persons in the examined group; h – width of a class interval.

In order to ascertain if the experimental results had a normal distribution, the function of the random density of variable $\varphi(x_i)$ was calculated and the frequency of occurrence of theoretical results n_i was determined on the basis of the following formulas:

$$\varphi(x_i) = \frac{1}{\sqrt{2\pi S}} \exp \frac{-(x_i - x)^2}{2S^2}, \tag{4}$$

$$n_i^{'} = \frac{Nh}{S}\varphi(z_i), \tag{5}$$

where the φ (z_i) value, at the given $z_i = \frac{x_i - \bar{x}}{S}$, was read from tables (Guilford 1960; Ferguson, Takane 1989).

The following zero hypothesis $\boldsymbol{H_0}$ was suggested: the experimental results obtained in class intervals do not differ significantly from the theoretical results of the appropriately selected normal curve. In order to verify the above hypothesis, Pearson's test of goodness of fit was applied:

$$\chi_0^2 = \sum_{i=1}^{N} \frac{(n_i - n_i^{'})^2}{n_i^{'}}, \tag{6}$$

When $\chi_0^2 \leq \chi_{0,05}^2$, then it is possible to maintain – with 5% risk of error, that the $\boldsymbol{H_0}$ hypothesis is true, i.e. the experimental results can be approximated with the help of normal distributions. $\chi_{0,05}^2 = 5.991$ was read from tables. This result allows the application of the significance test "**t** " – Student to verify the hypothesis concerning the significance of the difference between the means of the examined groups of students.

The significance of difference between S_1^2 and S_2^2 variances of individual groups was verified using the following function:

$$F_0 = \frac{N_1 S_1^2}{N_1 - 1} : \frac{N_2 S_2^2}{N_2 - 1}, \tag{7}$$

where: $N_1 = N_2 = 32$ denotes the number of persons in the examined groups. The boundary value $F_{0.05} = 1.835$ was read from Snedecor's tables (Guilford 1960). Because (in Table 1: $F_0 = 1.29$, $F'_0 = 1.17$, $F_{0.05} = 1.84$), therefore, there is no significant difference between the variances of the two compared groups. Therefore, the author applied a test "t" – Student, which was based, for $\nu = N_1 + N_2 - 2$ degree of freedom, on the function:

$$t_0 = \frac{\left|\overline{x_2} - \overline{x_1}\right|}{\sqrt{\frac{(N_1 - 1)S_1^2 + (N_2 - 1)S_2^2}{N_1 + N_2 - 2}\left(\frac{1}{N_1} + \frac{1}{N_2}\right)}}, \tag{8}$$

The presented statistical methods were used for the analysis of the results of the pedagogical experiment. The results of this analysis are presented in Table 1. The rightness of the proposed hypotheses for both of the stages of experiments was confirmed, i.e.: $H^E > H^K$ and $H^{E'} > H^{K'}$, because, as it was shown in Table 1: $X^E = 7.4$ and $X^K = 6.2$ as well as $X^{E'} = 5.7$ and $X^{K'} = 4.7$.

4. Conclusion

1. **The students who used, in the process of learning physics, computer programmes achieved - at both stages of the experiments – significantly higher results with regard to their understanding and solving technical problems, which required involvement of technical imagination.** They showed good knowledge and understanding of the research equipment used in the course of experiments. After finishing work with the computer programme, they proceeded with measurements with a good deal of understanding how to carry on and knowledge of the laboratory stand. They also created optimal conditions for work, obtained precise results and were able to indicate causes of the errors they made. The questions they asked were concrete, detailed and to the point. They indicated that they developed appropriate ideas of the objects and construction and showed genuine intellectual activity.

2. **It turned out that the simulation from the demonstration programme, illustrating abstract phenomena, technical solutions or interrelationships, was quite important because, frequently, it was the only help to develop students' imagination.** Such simulations facilitated the creation of images, dimensions or proportions of a simulated object, the course of a phenomenon or a technical system, which were known to students only from schematic diagrams. It helped them to unravel many technical problems. Animation of difficult theoretical phenomena, technical solutions and unknown results of the activity of equipment, helped students to develop notions and concepts of technical solutions realised in conditions determined by teaching programmes.

3. **In the case of computer programmes employing dialogue boxes, it was the possibility of 'conversing' with the computer that constituted its highest didactic value.** In such programmes, the 'customer' (student) feeds in his/her questions, answers, parameter values etc. as instructed by the software. In this case, the employed computer programme allowed a student to realise examples suggested by him/her. It facilitated the selection of interesting examples, making appropriate observations and arriving at solutions of difficult technical problems.

4. **The applied computer programmes were found to exert a particularly positive influence in the development of students' technical imagination in the course of their research work in physics.** It is usually difficult to help students in this area. The usefulness of the programmes was especially apparent when watching students' work. They used the programmes enthusiastically at all stages of the experiment; when preparing for exercises, in the course of the experiment itself and during the elaboration of results and conclusions. They also used the programmes to find examples or confirmation of their own ideas about what how a given piece of equipment looked like or operated. Using the programmes, they

worked actively, trying to discuss problems whose correct interpretation was the result of their intercourse with the computer. It can, therefore, be said that they experienced satisfaction from their own technical activity. The programme indicated a proper method to proceed forward, so the students were not discouraged by failure. They repeated their work with scientific curiosity, richer with the experience learnt as the result of the cooperation with the programme.

5. **The performed investigations showed that computer education programmes from the field of physics can find application in the transfer of ready-to-use technical contents. They are useful in the solving of both theoretical and practical technical problems in the process of learning physics by assisting productive thinking.** In the process of transferring technical contents, these programmes stimulate and encourage notions and associations concerning the operation and construction of equipment, i.e. they help shape and develop technical imagination.

Total conclusion. The performed detailed analysis of the research results allowed drawing the conclusion that, in the field of physics, even without making radical organisational or programme alterations, there are possibilities of development and formation of students' technical imagination by the appropriate application of modern informatics techniques.

Acknowledgements

This work was supported in part by Research Project TB-62-176/05/DS of the Poznan University of Technology.

Bibliography

Ferguson, G. A. and Takane, Y., (1989): *Statistical Analysis in Psychology and Education,* New York: Mc Graw-Holl.

Guilford, J. P. and Fruchter, B., (1978): *Fundamental Statistics in Psychology and Education* New York: Mc Graw – Hill.

Kozielska, M., (1996a): "Educational computer programmes in teaching physics" *Teaching the science of condenser matter and new materials, Forum, Udine, Italy* (ed.) M. Michelini, S. J. Pugliese and D. Cobai.

Kozielska, M., (1996b): "Stimulation of students' investigative activeness in the computer-aided process of learning physics", *Eur. J. Phys.* **17** p. 164.

Kozielska, Mm, (2000): "Educational computer programs in learning of physics by action", *Educ. Media Inf. Media Inf. Technol.* **37** p. 161.

Kozielska, M., (2003): *Computer – assisted education*, TWP, Szczecin, (in polish).

Kozielska, M., (2004): "Developing creativity of students in a computer-assisted learning process." *Eur. J. Phys*. 25, p. 279.

Table 1. Characteristics of experimental groups.
Source: data in Table 1 come from the author's own calculations.

Symbol	Stage of investigations	*E* *E'*	*K* *K'*
$\overline{X}$	I	7.40	6.20
	II	5.70	4.70
S_2	I	2.80	3.70
	II	3.70	5.20
S	I	1.70	1.90
	II	1.90	2.30
F_0	I		1.29
	II		1.17
$F_{0.05}$	I i II		1.84
T_0	I		2.60
	II		2.10
$T_{0.05}$	I i II		1.99
Statement	I	$H^E > H^K$	
	II	$H^{E'} > H^{K'}$	