EDUCATIONAL METHODS OF ENGINEERING TRAINING

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Abstract

The choice and the appropriate combination of methods used in the teaching-learning (education – knowledge-acquisition) process in technical higher education depends to a large extent on the personality of the lecturer, his/her pedagogical culture, personal competences and of course, the technical possibilities at his/her disposal. This study provides a concise overview of the methods as tried-and-tested systems of consciously implemented operations and means that are systematically used by the lecturer to achieve the objectives of training in practical cooperation with the students.

Keywords*: education, method, lecturer, student.*

1. Introduction

When considering the activities of the teachers and those of the students throughout the process of teaching, we can distinguish between four groups of operations [1]:

a) By the teachers:
– communicating complete information verbally or in written form
– directing the solving processes of knowledge-acquisition problems
– highlighting scientific, social, ethical and aesthetic values
– organizing the practical activities of the students.

b) By the students according to the above enumeration:
– acquisition and learning of complete content
– solving of problems, discovery of connections and mastery of the acquired knowledge
– learning and living the values
– creating and/or transforming objects.

2. Grouping of methods

A possible grouping of the methods used in the teaching-learning (training – acquisition of knowledge) process, based on [1, 2] is as follows:

I. Communicative (text-based) methods:
1. lecturing
2. processing of information from manual or lecture notes
3. research of bibliography
4. debate
5. questioning
6. consultation

II. Illustrative (observation-based) methods:
1. modelling
2. simulations
3. processing by means of posters, presentations
4. projections
5. field trips, visiting factories or companies, viewing of exhibitions

III. Practical (activity-based) methods:
1. experiments
2. lab measurements
3. practice
4. professional and production-based exercises

IV. More complex (synthetizing) methods:
1. programmed (distance) learning
2. problem solving (project-based) teaching
3. teaching of algorithms

3. Characteristics of methods

A specific feature of the lecture is the prominent role of the teacher, his/her active role in organizing and directing the teaching process besides the student's "consumer" attitude.

The manual or the lecture note – as a form of "printed lecture" complete with presentations, figures, pictures, diagrams, tables offers ready information to the students. In this case the student passively accepts the knowledge.

Research of bibliography is an important factor in learning, that part of the ever expanding knowledge base that doesn't fit into the framework of the course, and also in preparing the students for autonomous research. Due to the highly specific nature of the sciences, the best opportunities for bibliographic research can be found in institutional or online libraries. A well-organized collection of specialist publications, for instance, can give up-to-date professional information to the researcher.

The essence of debate lies in the teacher raising an issue that has to be solved, and the students formulating their opinions. The teacher acts only as a participant, equal to the others and only plays a directing role. This is mostly typical for seminaries but it can be applied in other situations too.

In the questioning method the activities are conducted by means of an appropriately assembled series of questions. The "moderator" line of questioning can consist of introductory, preparing, directing and concluding questions– that is to say questions that conclude and synthesize the processed topic.

Consultations are a form of aiding the student's work outside the classroom, in the form of advice pertaining to learning, deeper understanding and processing. The environment and the character of these consultations can be very diverse. In the first years of study it is required by the students mostly for understanding the more difficult parts of the curricula, but later it is mostly about scientific tasks (student's conferences, dissertations, theses and such like).

Modelling is an important method for processing knowledge which is in fact a main characteristic of the given branch of science. Complex structures, (sub)microscopic objects and processes, events that happen in an extremely short time can only be followed, understood by modelling. Naturally, the model has to be viewed critically, before applying it we have to establish how much it correlates with reality. A large part of these models can be transformed into physical objects and used as a method of presentation. Mock-ups are such objects and they don't simplify reality, they act more or less as a small-scale projection of reality.

For example, the possibilities of presentation in geometric crystallography can be [3]:

– Two-dimensional models which illustrate the crystal grid as two-dimensional axonometric wire structure, string nodes or ball figures. The advantage is that they are cheap to produce, they take up little space and they are easy to transport. But as beautiful and space-like as these illustrations may be, they are not transparent – especially with more complex three-dimensional cells and grids, they also don't always give a precise indication about the special structure and the possibilities of allotropic transformations.

– Three-dimensional models (mock-ups) which are a more developed version of the previous group. These can be for instance factory-built (typically made of plastic) demonstrative models and building kits. These can be replaced by home-made ball-and-wire (usually metal, plastic and wood) or glued table tennis ball models. Their advantage is that they are much better looking and the students can physically hold them to take a closer look. Their disadvantage is that they can be damaged easily, they can be more expensive and not always accessible to every student.

– Three-dimensional static computer models combine the characteristics of the previous two groups and they appear on the two-dimensional screen as three-dimensional objects, surfaces. They cannot be held physically but they can be rotated, zoomed in and out. A big advantage is that one can save any necessary two-dimensional image from such a model, therefore it can contribute to the creation of the first group. They can be multiplied freely through data storage devices, transferred online which results in a great degree of mobility. They take up relatively little space so they can be used in presentations thus providing excellent opportunities for teaching. The disadvantage is that the rendering of objects that consist of many surface elements (that is the process when the program prepares, calculates the edited media with all the necessary cropping, effects, subtitles and such and then saves the end product) often requires powerful hardware.

– Three-dimensional computer animations are the most spectacular, but they require the most advanced software and hardware background. With these even the most complex grid transformations and distortions can be illustrated very clearly. They can also be transported easily (on pen drive or memory card) even though they take up more space than the static models.

Simulations are also a form of modelling but typically they illustrates processes rather than momentary states. Especially computer-based simulations are popular and multi-faceted, the main steps of which are [4]:

– Formulating and re-formulating the problem (considering, expanding or reducing relevant factors);
– Building and developing the model (progressing from simple to complex);
– Collecting the necessary data (and considering their influence on the problem);
– Preparing and programming the system model (algorithm-writing and programming);
– Verifying (step by step), checking the stability (by means of extreme and exciting parameters too), evaluation (range of validity, precision);
– Planning the series of simulation experiments;
– Using, running the simulation model
– Analysing and evaluating the results;
– Recording and utilizing the results.

Processing by poster or presentation is a concise summarizing of a unit in the curriculum. Its illustrative power is given by the aesthetical, logical structure, the included figures, pictures, diagrams and tables. These posters, that present contemporary themes, can serve not only as a means of illustration in teaching activities but also as decorative elements and in exhibitions.

Projection is a method that contains most of the illustrating methods and the appropriate means. Previously it was achieved through projectors, slide projectors, movie projectors and video recorders. These were replaced by the computer-projector combo. This is the method that allows for the most multilateral, most informative illustration within a given time frame, provided that we use appropriate media files. Therefore, we have to consider the fact that such a large amount of information cannot be regarded as something that has to be learned in its entirety, we need to indicate ways to grab the essentials instead.

Filed trips, visiting factories and companies are also organized forms of teaching therefore they have to be regarded as completely valid learning activities. They cannot be dismissed by replacing them with projecting because even the best pictures or movies cannot give a full image of a factory environment, the spatial reality, not to mention the fact that they are edited to take up less time.

Study [5] gives details about a 15 days long West-European field trip that was organized specifically for students that showed interest in welding. In the course of this trip they had the opportunity to become familiar with the activities of 11 well-known companies (Fronius, Audi, SLV, Oerlikon, Castolin, TWI, Soudometal, RWTH, Cloos, Voest-Alpine, Interweld),and also to broaden their cultural horizons; besides the professional activities there was enough time to visit cities such as Zürich, Lausanne, Paris, Versailles, Cambridge, London, Bruxelles, Cologne, Frankfurt am Main, Nürnberg, Linz.

Practical activities, professional and production-based activities serve first and foremost the developing of specific manual skills (drawing, handling equipment, making and analysing objects etc.). While the practical activities take place in school workshops, labs, the professional and production-based activities are carried out in factories, companies, in real production situations. Classroom and lab activities have a special importance in technical higher education. In an earlier study [6] we gave an overview of its forms, functions, role and content structure.

The most important characteristics of the programmed and the problem solving teaching – compared with those of the communicative method – can be seen in table 1. [1, 2].

The purpose of the programmed (distance) learning method is to individualize and automatize the teaching process. Its essence is the distance learning curriculum itself which is a series of information packages strongly connected both structurally and in a logical manner, which the student has to learn by means of an appropriately structured computer-based „manual".

Problem solving (project-based) teaching is a synthesis of the cooperative, collaborative and autonomous learning, also of the pedagogical directions and methods that build upon student motivation. Through this, in the learning process the student's activity has the greatest importance, the primary teaching activity is different. The teacher switches from a traditional teaching role to a coordinating-moderating one. The projects (problems) that have to be solved are typically inter-disciplinary in nature.

Table 1. *Comparison of some teaching methods*

	Communicative teaching	Programmed (distance) learning	Problem solving (project-based) teaching
Method of transmitting knowledge	The educator transmits ready information. The focus is primarily on the curriculum and the topics which „obscures" the students.	The method of information transmission forces the students to be active at all times. The students themselves are the center of the activity.	Students acquire knowledge by means of solving theoretical and practical problems.
Degree of student activity	Deficiencies, obstacles and difficulties can occur during the transmission of information, often due to the fact that the students temporarily „log out" of the process.	The structuring of the curriculum is such that there are no deficiencies or difficulties. In order to progress, students must overcome every barrier.	While solving problems, the students have to overcome every obstacle, therefore this method yields the largest degree of student participation and autonomy.
Pace of knowledge acquisition	The pace of information transmission must adapt to both the good, the average and the less capable students.	The pace of learning depends entirely on the students, since they work individually.	The pace of learning depends on the individual students or on the teams. Weaker students gain more from team work.
Scope of verification	Verification of the results of teaching is only partial, not an integral part of the transmission of informations.	Verification is complete and a part of the learning process. Students cannot proceed to the next step without verifying that they have mastered the previous information.	The larger degree of student activity and the development of the positive motifs of learning means that there is less need for overall verification.
Succesfulness	One hundred percent success cannot be achieved by all students, but students find it easiest to apply the information acquired by this method than those learned through programmed (distance) learning.	Due to the systematic verification the results are better than in the case of communicative teaching but the applicability of the learned information is not so good.	The results are relatively good. Students acquire a great amount of knowledge and they can apply those in new situations with ease. Their learning competences and professional interests are also developing.

Teaching algorithm is a methodical teaching process in which every step has its determined place within the framework of the whole system in such a way that if one starts from any of these steps, following a given decision he or she can get in every case to the next step of teaching.

The teaching of algorithms is especially important when the students are confronted with a large number of problems (and often with unknown end result) and it's not easy to discover the appropriate solving algorithm of these problems which in turn creates serious difficulties in the acquisition of knowledge.

4. Conclusions

The process of technical higher education, and more specifically the formation of new engineers has to be directed in such a way as to allow the students to understand the aims of the training and their own responsibility in their realization; to support the development of positive motivation and of self-control so that they will not be simply passive consumers of ready-made information but also active creators of knowledge. That is why we need to be familiar with the different methods and to apply especially those that favour student activities.

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