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On the problem of motivation of technical university students in the case of group implementation of an interdisciplinary term project

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Abstract. The authors consider the problems concerned with the mathematical constituent of implementation of interdisciplinary semester projects by groups of students. Significance of using the method of projects for creation of the innovative environment in a technical university, as well as for formation of professional competences of future engineers is demonstrated. The authors have analyzed the techniques of student groups' work on term projects and reflected the role of a teacher in the process of implementation of such projects. It is stressed that one of the major components of technical university education is fundamental training of engineering students based on deeper and wider cycle of mathematical and common engineering disciplines. It provides close interdisciplinary relations between the mathematics course and engineering disciplines, increases the motivation to master mathematics, helps the students to recognize the need to gain profound mathematical knowledge, and forms the skills of creative application of the gained knowledge to successful mastering their engineering professions chosen. It is demonstrated that, in a technical university, an interdisciplinary term project is in essence a task that unites various scientific and technical disciplines and demands engineering and technical knowledge as well as mathematical methods of task solution: applied methods of mathematical modeling, methods of probabilistic and statistical analysis of data, and various types of mathematical packages.

1 Introduction

Training of specialists with a higher technical education necessitates development of students' creative skills, stepwise promotion of each student from his/her personal starting level of development to the certain necessary level of qualification, that is obligatory for all graduates. Creativity is an independent work; therefore, it is necessary to pay close attention to students' independent work and to supervise their work. However, any supervision is concerned with imposing certain restrictions on the supervised person's activities. This necessitates regulation of education and creativity, but the regulation, in its turn, must not impede development of the person's creative skills. Thereby, we face the challenge to optimize the supervision of the students' independent work in the process of development of their creative skills; elaboration of the qualification requirements for graduates of universities, and for graduates of technical universities, in particular. A young engineering specialist must be

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able to organize an effective work of the production team under his/her management, must have skills of organization and innovative development, must be familiar with the methods of scientific and practical organization of labor. Therefore, a specialist with a diploma of mechanical engineering must be independently able to construct certain parts of machines, to assign an economically viable technological processing, to perform necessary calculation of strength, to plan and perform a technical experiment, and to make a report.

Every engineer needs the aforementioned skills since the first days of his/her work at factories, design bureaus, technological departments, workshops, or laboratories. These skills are also necessary for performing scientific research, design and producing new articles, and technological processes. The special characteristic of all these skills is creativity. Therefore, one of the general purposes of education, and of technical education in particular, is development of cognitive and creative skills of students. Learning from creative experience is possible only via practical activities of the person. Hence a student's personal activities on the training material and his/her individual independent work or work in a group play the crucial role in development of his/her creative skills.

One of the most important components of technical university education is fundamental training of engineering students based on deeper and wider cycle of mathematical and common engineering disciplines. The mathematical curriculum in a technical university is an example of harmonious combination of pure and applied mathematics. It provides close interdisciplinary relations between the mathematics course and engineering disciplines, increases the motivation to master mathematics, helps the students to recognize the need to gain profound mathematical knowledge, and forms the skills of creative application of the gained knowledge to successful mastering their engineering professions chosen.

Since junior years, it is necessary to motivate students to gain mathematical knowledge and to associate it with future professional activities, stressing its practical significance. For this purpose, it is necessary to actively apply *term projects* in mathematical disciplines built into consolidated interdisciplinary *individual* or *group projects* [1–3]. The subject of such a project, especially of a group project, ought to be directed to stimulate cognitive interest during education, in order to make the student conscious of the need of such activity and its practical feasibility. An unfortunately chosen subject of a term project (with results which students do not know in advance in general terms) often leads students to implement it formally and blankly and does not arise their considerable cognitive interest.

During implementation of group projects, students must learn to analyze and systematize materials of the subject, to construct the logical reasoning leading to the result, to formulate purposes and conclusions adequate to the task posed. All this leads to formation and development of competences, such as determining the status of the problem posed, independent elaboration of the statement of work, planning the stages of its implementation, and forecasting its results.

2 Technique of group exercises

Working together in a group is one of the forms of education process. Such form of work is often applicable during implementation of various term projects [4, 5]. Uniting persons into groups is a natural phenomenon.

In recent years, the forms of working in groups are quite widespread, so that there is no doubt about their attractiveness and usefulness. However, students working together in a group are not always optimistic about such kind of unification, due to the following reasons: many of the students have no experience of working in groups; they may have negative experience; there may be opinion that discussions in groups are useless; individual problems concerned with activity in a group, etc.

It is clear that working in groups has both positive and negative aspects. As benefits of working in groups, one can regard e.g. that unification is purposed to achieve certain common goals that are more difficult and expensive to achieve individually. In a group, a person satisfies several needs instead of one, performs several tasks instead of one. In the other hand, e.g. it is known that in groups, it is comfortable for a weak student and it is hard for a strong one. The former may use the group's resource to compensate his/her weakness; the latter has to waste energy for other members of the group.

In a group, the quantity of communication acts increases. Often it makes the process of group decision making longer and more difficult. The so-called effects of "groupthink" sometimes arise in groups: the group members feel total confidence that the group is right and its opinion is unshakable, and absence of doubts and interest to alternative opinions. In such situation, he group disengages itself from development. In unbalanced groups, some conflicts may arise and become obstacles to implementation of the tasks. The students' inner tension may arise and cause irritation towards the teacher or against the tasks given by the teacher.

Along with other factors, effectiveness of working of the group depends on its size, and this dependence is not uniform. The only is inevitable—a large group splits into several smaller ones.

Another peculiarity lies in the fact that sometimes activity of those who were working better decreases during working in groups. In one hand, the spirit of collectivism and competition makes the members of the group to increase productivity of their labor. In the other hand, there is a tendency to work in the group slightly less than in the case of individual work.

There is no unanimity of opinions concerning the optimal quantity of group members. Any group is considered to include at least four persons. In this case, one can organize operational work in the group. However, a group of five to seven students is optimal. Groups of such size are the most effective when solving *interdisciplinary tasks* of term projects. At the same time, such group is small enough in order to recognize the contribution of each student. If the number of group members is odd, it is easier to make group solutions.

The teacher stands in the center of group formation and its character. The most significant is the teacher's role in formulation of *group aspirations*, i.e. stating the problem and the purpose, and control of their implementation. The teacher must motivate the students to achieve the purposes stated.

The teacher's significant role consists in creation of the *group mood*, which is to facilitate joint efforts and success of the group. It should be noted that typically group moods are more dynamic than individual ones, hence the former are more convenient to manage.

Elaboration of the *group opinion* is another important constituent part of the teacher's work. The group opinion is the integrated opinion shared by all the group members; it is generalization and unification of individual opinions during the work on the project. The teacher ought to pay attention to the students' statements and remarks and to monitor the process of formation of the group opinion closely.

List the complex of measures that can provide increase of education outcomes of group implementation of term projects.

1. Elaboration of the "bank" of term project tasks of applied nature, taking the specific of professional interests of future engineers in account.
2. Specification of purposes of implemented term projects from the viewpoint of qualification requirements to graduates of the certain university, and delivering the message of these purposes to the students.
3. Supporting systematic independent students' work on the project and their sufficient training for its implementation.

4. Alignment of the students' activities at implementation of the term project, and optimization of their working time.
5. Increasing the teacher's productivity.
6. Increasing educational influence onto the students, and systematical parenting skills to them, in order to provide successful work on the project.
7. Monitoring of the educational effect of the project implementation.
8. Organization of group activities and interaction between its members.
9. Using innovative methods and technologies during implementation of term projects, in order to make the students' work more active and systematic and to increase their motivation to achieve results of practical significance.
10. Evaluating each student's contribution in the group outcome.
11. Accountability of the outcomes obtained.

3 Mathematical constituent of a group interdisciplinary term project

A group term project is a means of goal achievement via elaboration of the problem and obtaining a concrete practical and applicable result by students working in a small group.

In a technical university, an interdisciplinary term project is in essence the task that integrates various scientific and technical disciplines and demands engineering and technical knowledge as well as mathematical methods of task solution: applied methods of mathematical modeling, methods of probabilistic and statistical analysis of data, and various types of mathematical packages [6].

An important constituent of such a project is its subject. The authors have elaborated a large "bank" of such tasks having applicable nature [7–10] and concerned with professional specific of the university graduates. As the research, they have chosen air and space technical units, e.g. various types of motors, turbines, and flying machines.

Interdisciplinary term projects, due to their large volume, from the very beginning, are to decompose into project modules, and the latter are to split into several submodules to practice in small groups. The members of each project group are constantly interacting and hence, there is interaction among members of the small groups.

Implementation of term projects in groups takes place under supervision of teachers belonging to both mathematical and specialized departments, quite independently. In time determined by the agreed plan, they deliver information about the work accomplished. Quantity of students in the groups is determined based on the technical task of the term project.

Usage of innovative methods and techniques [4, 11] and various types of mathematical packages in the process of implementation of term projects allows enhancing and systematizing the students' work, to increase their motivation to achieve outcomes of practical significance.

Another serious motivating stimulus is a student's individual (*cumulative*) rating introduced by the authors [12]. The rating aims at differentiation of evaluation of results of the student's work. The cumulative rating plays a special role in the situation where students implement a term project in a small group, and it is important to evaluate each performer's contribution into the outcome.

Implementation of a term project starts from drawing up a detailed plan of solution of the problem posed; hereby it is necessary to involve the students of the group. Such kind of plan must contain the stages of implementation of the project; moreover, from the teacher's viewpoint, it must be able to realize the methodical objectives of the students' group work, i.e., use of theoretical knowledge, abilities and skills achieved. From the experience of the authors' elaboration of such projects (with mathematical constituent including probabilistic and statistic methods) the plan may include the following items.

1. *Construction of the mathematical model.* Students must be independently able to compose the equations describing the physical phenomena of the problem, to compare the dependencies in order to establish qualitative correctness of the chosen model. Herewith the students obtain the skills of independent search and systematization of information, of analysis and choice of integral-differential equations describing the mathematical model of the problem, and the capability to use interdisciplinary connections between mathematics and mechanics.

2. *Construction of the estimate using maximum likelihood.* It is required to compose the likelihood function and to use it in order to calculate the values of the estimates.

In this item of the plan, the students use the method of maximum likelihood and the principle of invariance, the skills of analytical and numerical calculation of estimates of parameters of distributions.

3. *Comparison of the estimates obtained.* It is necessary to make qualitative and quantitative comparison of the results obtained and to explain the connections discovered.

Herewith the students obtain the skills of systematic analysis of the phenomena under consideration, of formulation and argumentation of the patterns identified, to pay attention to particular phenomena of the results obtained.

4. *Constructing the confidence interval for the model parameters.* Students ought to be capable of using the well-known formulas of regression analysis and the property of Gaussian distribution. In the performance of this task, students obtain the skills of independent search and systematization of information, using formulas of confidence intervals in the Gaussian model.

5. *Statistical analysis of the regression model.* It is offered to students to check the hypotheses of validity of the model (using Fischer's test) and of significance of each individual coefficient by means of the confidence intervals constructed.

In the performance of this item, the students use their knowledge of theory of statistical criteria and the skill of checking statistical hypotheses by means of criteria they know.

6. *Estimating the correlation coefficient.* It is required to calculate the estimate for the correlation coefficient between the biases and to construct its confidence interval; draw conclusion from the results of the research; calculate values of the residuals and create the histograms with various numbers of grouping intervals chosen. Herewith the students acquire the skills of search and usage of known analytical solutions, analysis of the obtained results and drawing conclusions based on them, and checking statistical hypotheses by means of the confidence interval constructed.

7. *Account on the mathematical constituent of the project.* It is necessary to draw up the report with formulation of the problem posed, mathematical methods of its solution and the conclusions.

4 Organizing laboratory work in a small group

A great importance for successful technical creativity of an engineer is capability of organizing and carrying out experiments. When studying a range of engineering courses, students carry out laboratory works (workshops) purposing to reinforce and advance their theoretical knowledge and to get acquainted with the equipment and its handling. However, often the workshop does little to obtain the goals mentioned: the students are not trained enough in theory and have no skills of handling the equipment; they are not able to process the results of their experiments and prepare the reports, their work is devoid of proper systematic.

Often students' attitude to the workshops is formal and blank. One of reasons of such attitude is unfortunate task subject, which does not encourage creative approach and interest in the outcome. The situation compounds by the fact that the students' attention does not usually direct to the search for the causes of outliers of values of the parameters they found from the values given in tables in handbooks. Without understanding that the values of physical constants given in the tables are results of statistical processing of results of huge series of thoroughly implemented measurements, some students try to modify results of an individual experiment "to make it fit the correct answer". This causes direct harm to training of future specialists by forming their distorted view of the purposes, methods and possibilities of laboratory studies.

In fact, the educational result obtained by the workshop is not clear, it does not undergo analysis, but only the fact of defense of the report of the work accomplished is marked. Later, as a rule, the written reports received are not used anywhere, instead they are being destroyed. All this produces students' formal and blank attitude to the important practical part of the educational process, which requires much energy and time expenses.

These facts imply that it is necessary not only to improve subjects of the workshops, but also to increase educational effectiveness of the students' work. To the same extent, it is true with respect to term projects of future engineers.

The complex of measures directed to the following can provide increase of educational outcomes of the term projects and workshops of technical university students.

1. Practical concretization of purposes of the works from the viewpoint of their subject and qualification requirements for graduates of a certain university.
2. The students' theoretical preparedness for accomplishing the certain works.
3. Strengthening educational influence on the students, systematic promotion of their skills, helping their successful work.
4. Providing further practical usage of the results obtained by the students.
5. Control of educational effect of accomplishing he work.

Consider an example of organizing of the workshop "Numerical solution of boundary value problems for one-dimensional equation of heat conduction" for the third year students of Bauman Moscow State Technical University (BMSTU) [13], training on the specialty "Applied mathematics". The purpose of the work is to study the integral-interpolation method of constructing difference schemes for solution of boundary value problems for one-dimensional equation of heat conduction. Performance of the work is suggested to a small group of three to five students.

On the first stage, the students have to choose a one-dimensional mathematical model describing heat conduction in a thin rod of fixed length with thermally insulated side surface, with given thermal regime on its ends. Next, they have to compose the differential equation of parabolic type describing the process of heat conduction with several variants of boundary conditions. For solution of the stated problem, it is required to construct difference schemes using the integral-interpolation method, and to write a program or numerical solution of each problem. Herewith, they consider the two cases of dependences of coefficients of heat conducting: on the spatial co-ordinate and on the temperature. On implementation of the work, it is required to find the point in time, when the temperature in the middle of the rod would be the largest. The calculation is to perform with the required degree of accuracy. The calculation results are to be illustrated with animation or a series of graphs, to make it possible to observe evolution of heat distribution in the rod.

The report shall contain the following items.

1. Stating the problem.
2. Description of the mathematical model, justification of its choice.

3. The difference scheme.
4. Description of the solution method.
5. Test examples demonstrating operating capability of the program.
6. Analysis of the difference scheme under consideration, including research of its monotonicity.
7. Research of stability of the method of solution of the system of difference equations.
8. Analysis of the results, comparison of solutions obtained by the direct scheme, the indirect scheme and the symmetric scheme, justification of the choice of a spatial step and a time step, comparison of effectiveness of the schemes under consideration.
9. Presentation of the results by graphs and animation.
10. Description of the group's and each student's contribution in accomplishing the laboratory work.

For each laboratory work, the teachers, for their part, must provide methodological guidelines containing the necessary general theoretical material, practical recommendations concerning the choice of a certain method for solution of specific tasks, the list of control questions to prepare the students' work defense, examples of allocation of tasks and duties in the group. The teachers must organize the defense of the laboratory work so that each student in the group would have to demonstrate knowledge of the theory of numerical methods to the extent necessary and the skill of applying this theory in practice.

5 Discussion and conclusion

Group implementation of an interdisciplinary term project should be preceded by preparing the complex of teaching methods and materials, educational guidelines, calculation patterns etc. When preparing the materials, it is important to use modern information and communication technologies, and various types of mathematical packages necessary for students in their future engineering activity.

The mathematical constituent of a group interdisciplinary term project in a technical university involves a serious fundamental mathematical training of future engineers, in order to provide integration with engineering disciplines. It is necessary to increase the students' motivation to mastering and practical application of mathematical knowledge in engineering calculation, for successful mastering their future profession.

Active application of *term projects* in mathematical disciplines built into consolidated interdisciplinary *individual* or *group projects* is necessary. Hereby, subjects of these projects should purpose to stimulate cognitive interest during the education, in order to make a student conscious of the need of such activity and its practicality.

As the result of accomplishing these tasks, the students are to learn the following.

1. Analysis and systematization of thematic materials.
2. Independent choice from alternative methods of solution of the problem.
3. Mathematical modeling of objects and processes according to templates, including usage of standard application packages.
4. Applying the suitable mathematical apparatus for solution of the problems stated.
5. Composing reports on the subject of the research accomplished.

All these lead to formation and development of the following competences: identification of the state of the problem, independent elaboration of the technical task, planning the stages of its implementation, and forecasting its results.

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