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Self-regulating in higher education: a psychological and pedagogical framework

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Abstract. This paper describes the psychological and pedagogical (methodological, motivating, organizational, and content-related) conditions for developing the students' ability to self-regulate, within the framework applied to the mathematics education designed for students at the technical university. The paper gives the results of the experiment indicating the efficacy of these conditions. Groups of students studying at Tomsk Polytechnic University participated in the educational experiment. Tests, observations, questionnaires, techniques of mathematical statistics were used for assessment. The experiment makes it possible to conclude that the self-regulated learning of students on the basis of the Modular Object-Oriented Dynamic Learning Environment 'Moodle' together with the project–related activities, performed by students in the existing production environments, leads to a higher level of the students' ability to self-management.

Introduction

Sharp contradictions of our society, expressed in a change of moral values and norms, as well as ambiguous judgments of the past, the obscurity of the present and the uncertainty of the future actualize the problem of young people entering the adult world to manage their own activities and their own lives. In any sphere of life under modern conditions a person must be able to make important decisions on her/his own, define tasks required to reach her/his goals and successfully complete such tasks. A recent graduate of a technical university at the workplace is required to set specific tasks in the context of company's activities and find her/his own ways and tools to address them, often acting in response to lack of time and to excessive or incomplete information.

A skilled and competitive engineer must be competent in all of the latest technologies, have knowledge of mathematics and research methods recognized and widely used in modern science and technology [1, 2]. Such engineer must acquire necessary skills of doing independent research activities. Thus, the self-regulatory ability becomes a significant professional competence for a future expert, and in this regard the teaching activities are mainly intended to provide a background and assist every student in starting the personal development, to support and stimulate this development during the classroom work and extracurricular activities, to improve student's learning techniques for self-actualization, self-organization, self-education and self-regulation development.

Literature review

Already G. Hegel, R. Descartes, I. Kant, L. Feuerbach, F. Nietzsche and others recognized development as the basic form of existence of all living things. According to Socrates, the fate of a human being depends on self-cultivation, and her/his ability of self-improvement with managing self-development as a driving ability for a man. Principles for active work, independence and self-development as an actor or owner of life activities are formulated in works of B.G. Ananiev, B.F. Lomov, I.S. Kon, V.A. Petrovsky, S.L. Rubinstein, V.A. Yadov and other works. In many works one can trace the statement that self-assertion, self-improvement and self-actualization are considered as the basic forms of self-development. A set of works and studies of G. Sh. Gabdreeva, N.M. Peysahov and other scholars is devoted to the ability to self-regulate as an essential element for self-development.

Many authors, namely J. Khol, L. Plunkett, G. Hayes, S. Cassidy [3] and others were involved in investigating the processes relating to self-regulation in different spheres of life.

Self-regulated learning (SLR) is recognized as an important condition of student academic motivation and achievement [4]. The works of S. Jarvela and

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H. Jarvenoja [5] are devoted to self-regulation and its importance for the process of self-regulated learning.

According to L.S. Vygotsky, the development of skills primarily means an acquisition of abilities by an individual. The development of the ability to self-regulate should result in acquiring by students 'the ability to react to the situation, to see a problem and analyze contradictions, to set a goal, to plan and predict the result of activity, to design quality criteria, to self-control and correct'.

Psychological and pedagogical conditions to develop the student's ability to self-regulate their learning activity

In our opinion, there are four groups of psycho-pedagogical conditions to ensure the effective development of the ability to self-regulate: methodological, motivating, organizational and content-related.

The methodological conditions are: the student-centered, activity-based, context-dependent and competence-based approaches to learning; the principles implemented with the fundamentality, profession-oriented education, creative initiatives, self-reliance and adaptive learning environments being combined in the optimum way.

The motivating conditions are: the building of a creative learning environment, where an individual is active and given freedom to choose actions, activities for acquiring internal and external information in the context of subject knowledge and the education system as a whole [6]. *The creation of situations involves freedom of choice* in order to strengthen and realize motives of their own subjective position by students in the cognitive process. *A score system is used to self-assess and evaluate* student's learning activities. There is a *positive openness* on the part of teachers toward students.

The organizational conditions are: different learning methods combined with a gradual involvement into problem-based learning, taking into account the individual experience of students; psycho-pedagogical monitoring; the use of the learning management system (LMS) 'Moodle' (Modular Object-Oriented Dynamic Learning Environment) (https://moodle.org), technical teaching aids.

The content-based conditions include a methodical complex (a program complying with the requirements of state educational standards, course flow charts, score sheets, student self-assessment sheets, training aids with task variants for self-evaluating by using an automated control device 'Simvol-Vuz'); diagnostic tests for psychological and pedagogical monitoring.

We shall consider the bolded psychological and pedagogical conditions for the development of self-regulation skills in the students' learning process in more detail. The task to develop the self-regulation ability requires a transition to active student independent and self-regulated learning activities and ongoing governance (slowly shifting to coordination) of these activities by teachers. Continuous organizational and motivating actions of teachers are carried out by means of the modular object-oriented dynamic learning environment 'Moodle', which is widely used throughout the world. Organizational documents include course flow charts containing the instructions required for the study of every branch of mathematics, score plans on each module of a subject, student self-assessment sheets; all information resources are freely available via the Internet for students enrolled in courses. A course flow chart (CFC) outlines topics of lectures and workshops that the course cover, the quantity of hours required to work through each course component, dates of lectures, workshops, checks of home individual assignments, presentations, exams as well as a brief description of self-assessments, home assignments that can be checked using the automated control device 'Simvol-vuz'. CFC gives a wholly structured lesson and students can choose their own way how to learn through this lesson as well as choose a level of complexity of the proposed tasks.

The main stages of CFC are:

1. *Goal setting, planning* of teachers' and students' joint actions and activities. At this stage a teacher gives information on the topics to be studied during a semester, articulates learning outcomes and forms of assessment to monitor student's learning, and appoints dates to check home individual assignments, to do assessment test and credit test related to the course topics. The teacher also gives students score sheets indicating a quantity of points given for a certain type of learning activity. Having comprehensive information to cover during the semester, a student determines objectives of training and learning of the material, actions to be taken to achieve them, frames a plan to achieve objectives, and makes an individual self-assessment sheet based on the score sheet with the purpose to implement the plan in the context of learning activities (a student's self-report).

2. *Coordinating the self-regulated learning of students* (the function of a teacher is to organize and stimulate; the function of a learner is self-regulated activity). Teacher organizes and conducts classroom training (lectures, workshops, consultations) according to CFC, students are aimed at their individual plans to involve in the cognitive process, making notes on fulfillment in the self-assessment sheets to evaluate the results according to their plans.

3. *Evaluative - reflective*. Within this stage on the ground of student's self-evaluation and self-control combined with the governance by the teacher, the difficulties emerged in the process of learning and training are identified and their causes are analyzed. In the case of a gap between the planned outcomes and actual results, a student and a teacher are supposed to make a decision to revise the process of self-regulation and take corrective actions.

The score sheet describes a quantity of points given for a certain type of activity performed by students during the given semester. The self-assessment sheet is a single document with all students enlisted. Students while putting in their scores obtained from learning

activities can see the results of their mates; this provokes a sense of competitiveness, a desire to be 'better', which means to self-improve.

In order to organize the cognitive process of students in the classes and during independent extracurricular work, a learning package has been developed. This learning package is a major component of the teaching and educational materials aimed at developing the ability to self-regulate. This learning package provides a brief theoretical material on topics related to the curriculum, structure and logic schemes, supporting tasks, theory test questions for self-evaluation, problems of different levels in terms of cognitive complexity for self-assessment, a set of home individual assessments on the studied topics.

Self-evaluating tasks given in a problem book suggest using an automated control device 'Simvol-Vuz' for prompt on-line feedback, quick transfer of information relating to independent learning activity of students and the progress, current control and quick correction of training and learning with the purpose to develop skills of students to self-regulate themselves. The example from such a problem book is given below. Task 1(CS).

Given matrices: $B = \begin{pmatrix} -3 & 2 & 8 \\ 2 & 3 & 0 \end{pmatrix}$, $D = \begin{pmatrix} 4 & 3 & -1 \\ -2 & 0 & 1 \\ 0 & 2 & 2 \end{pmatrix}$. Find a_{13} in BD matrix.

After a learner has found the value of a_{13} in the BD matrix, it suffices to enter the response code (CS) (answers are encoded by teachers using the computer program) and press 'Control' on the automated control device. The lamp lights up with the problem solved correctly. When students receive feedback in such a manner, a teacher has more time to individually work with students (especially with low achieving students), and self-regulating students have the opportunity to promptly receive information on whether the problem is solved and, if required, to correct the solution to the problem without delay.

Using Microsoft Excel also helps students perform self-evaluation in solving problems involving matrix operations, numerical integration, the calculation of statistical parameters of distributed random variables, and others.

The introduction of information and communication technologies (ICT) in the learning process facilitates the development of skills to self-regulate and self-correct, with enhancing the students' motivation for the educational activity and developing the ability to familiarize with a situation. Using an interactive whiteboard makes it possible to study a case in a more generalized and systematic way and demonstrate its dynamics. Interactive whiteboards SMART support the atmosphere of a real-life dialogue in the classroom and stimulate debates. This essentially adds to the students' understanding of problems and facilitates their solution, which is necessary for the organization of educational activities aimed at developing of the self-regulating ability.

When organizing learning activities it is appropriate to use a group form of work ('Moodle' enables a learning group to be divided into sub-groups), particularly when working in small groups (2, 3 or 4 students). In this case the motivation for self-regulation increases due to the need of each student to "personalize" his/her learning process (the construct introduced by V.A. Petrovsky). In an effort to include the individual "Self" into consciousness, feelings and will of others through active participation in joint activities by attracting others to one's interests and desires, a student receives feedback information about the success through the perception by other members, and thus satisfies the "need for personalization" [7].

In groups, students with a higher level of education are motivated by means of personalization, i.e. they need to be recognized as an individual by the public, to be of importance to them, and students with a lower level – by means of achieving success through self-actualization. This happens mostly when the learning activities of students are structured on the basis of projects, because implementing projects in the context of production may require special competences, which are often acquired by weak students. A number of scholars in education emphasize the need for the practice-based learning in designing teaching and learning activities to train engineers [8], and teaching physics and chemistry [9].

The project–based method, when students acquire knowledge in the learning process and do not receive ready-to-learn information, implies great potential to develop the self-regulation ability. When implementing a project all the organizational and self-managing efforts of students are aimed at building an object as a combination of developed, well-established and structured ideas. Consequently, it is reasonable to understand the projecting as an on-going process that includes problem analyzing, forecasting, goal setting, designing evaluation criteria, planning actions, decision making, self-controlling and self-correcting, i.e. the process is meant to support the development of self-regulating skills. And the implementation of a project in a real production environment increases the importance of the job and activates all components relative to the ability to self-regulate. Students are engaged in working at the project 'Applications of Mathematics in Manufacturing Processes' during their on-the-job training by taking part in the production processes and activities at enterprises and companies (of any form of property). Within the projects, students explore the possibility of how to apply mathematics in engineering by consolidating and deepening their theoretical knowledge required to work in today's enterprise, and developing the skills to use these theoretical knowledge in practice for the management of production processes and workforce.

The project–based activities create conditions for the development of a reflective component of the ability to self-regulate. A project participant is able to identify and assess attitude to рук.him in relation to the project. The development of reflection as a process of self-actualization through internal mental actions and states helps students understand that they need to study their

individual characteristics and personality traits for further self-actualization, self-development and self-regulation.

The project-based method 'as a source of intellectual initiative, activity and creativity of thought and action' [10] implies a combination of research, searching and problem methods.

We regard a process of the project-based learning as a way of organizing the educational process based on the interaction between a teacher and a student, and the environment aimed at the development of student's personality through the development of the self-regulation ability in the process of building the educational product having objective or subjective novelty.

Methods of research

In order to examine how effective the identified psychological and pedagogical conditions are for the development of the students' self-regulation ability in the case of mathematics education at the technical university, the following methods of research have been used:

1. Theoretical analysis of the philosophical, psychological, pedagogical and educational materials, regulatory instruments and analysis of the practices and experiences relative to the development of the self-regulation ability in the mathematics education;
2. Questionnaires, tests, interviews (free and standardized), analyses of activity products of future engineers in the process of mathematics education;
3. Pedagogical experiments: summative, searching and formative assessments;
4. Statistical methods for the treatment of experimental data.

The experiment and researches were carried out at Yurga Institute of Technology, Tomsk State University Affiliate.

The sampling frame included first year students (18-22 years) of the following departments: 03.22.02 'Metallurgy' (24 persons), 35.03.06 'Agroengineering' (20 persons) for the control group. The sampling frame also included students of the Faculty of Mechanical Engineering departments: 15.03.01 'Engineering' (23 persons), 20.03.01 'Life Safety, Ecology and Physical Education' (22 persons) for the experimental group. The control group and the experimental group were formed in terms of uniformity, levels of performance, age, social status. We analyzed the content of educational programs and curricula in Mathematics within the disciplines of Natural Science and Mathematics taught to students of all departments. The curricula adopted at these departments relating to undergraduates learning are the same and meet the standards of technical general education.

To identify the dynamics that showed how the ability to self-regulate was developing, we used the technique 'the Self-Regulation Ability' developed in Kazan Federal University, Laboratory of Mental Health under the guidance of N.M. Peysakhov. When monitoring the cognitive process and educational activity of students with the purpose of necessary corrections, empirical data obtained using the above mentioned technique were refined and added through individual interviews with students and their parents, teachers, tutors and psychologists of the university.

Results and discussion

The results showed gains in terms of levels of development (low, below average, average, above average, high) as to the ability to self-regulation. The skills to analyze, to plan and to self-assess were significantly developed (see Figure 1).

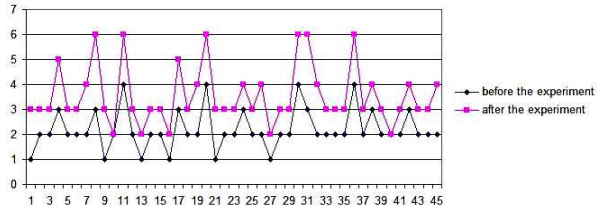
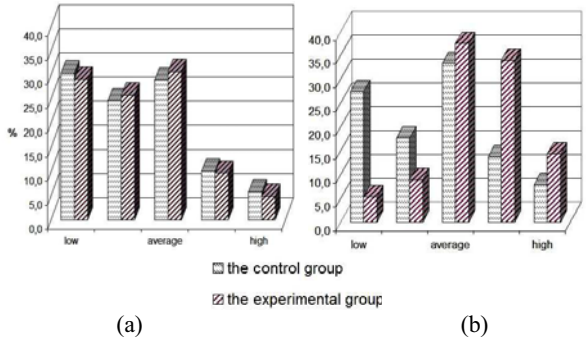


Fig. 1. Levels of the ability to analyze contradictions in the experimental group 'before' and 'after' the experiment

The criterion of signs G showed significant differences at a level of 1%. The result of data processing based on Pearson test showed that the indicators of the self-regulation ability (Figure 2) with the students in the experimental and control groups at the summative stage of the experiment coincided with a significance level of 0,05, ($\chi^2_{emp.}$=0,26; $\chi^2_{0,05}$= 9,49). The significance of differences as to the indicators of the self-regulation ability with the students in the experimental and control groups after the experiment made 95% ($\chi^2_{emp.}$=9,88, $\chi^2_{0,05}$= 9,49).



(a) (b)

Fig. 2. Distribution of students in the experimental and control groups with regard to levels of the self-regulation ability (a) - 'before' and (b)-'after' the experiment

Acknowledgment

From the above stated it can be concluded that the purposeful work of the teaching staff aimed at developing self-improvement ability of students of the technological institute of TPU enhances the effectiveness of the educational process. In addition, in our opinion, the technical university graduates with a higher level of the self-regulation ability have better understanding how

to handle problems, become more adaptive in response to job requirements in rapidly changing environments, and such graduates are the most competitive on the labor market.

This conclusion can be confirmed by opinions expressed by the heads of enterprises where the students performed their project work on subjects in the context of technical fundamental education during their work experience placement.

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