

Collective Subject in Implementation of STEM Technologies in Engineering Education

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Abstract. Provision of quality of engineering education upon implementation of international CDIO initiative (Conceive – Design – Implement – Operate) results in implementation of new education technologies, in particular: STEM (Science, Technology, Engineering, Mathematics). Its implementation allows to solve a set of educational issues concerning motivation of students from the first day by using integrated practically oriented assignments, step-by-step immersion into designing activity. Interdisciplinarity and integration, inherent in the STEM technology, assume moving out of a teacher as a holder of educational situation from his disciplinary area, would demand to be a co-participant of a student activity, his initiative in solving creative tasks. Successful realization of STEM technology depends significantly on new competences of teachers and managers, their capabilities to significant modifications of their occupational activity. Difficulty of implementation of STEM technology is related with unpreparedness of teachers and managers. This work is aimed at substantiation of necessary conditions providing readiness of managers, teachers, and students to implement the STEM technologies characterized as a collective subject. The experimental results serve as theoretical substantiation of the concept of formation of collective subjects (managers, teachers, students), determination of new functionality of managers, teachers, students, stepping of this process to provide implementation of STEM technology. The practical implementation was performed at the Federal innovation platform of Siberian Federal University: Model of system modifications in multilevel engineering education.

1 Introduction

The quality of engineering education is manifested in preparation of competitive graduates, capable to generate and implement original concepts in solution to engineering problems and

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having occupational and personal properties. One of such mechanisms is application of STEM technology.

Analysis of psychological and pedagogical publications reveals description of various aspects of this phenomenon. Russian scientists consider STEM education in Russia as prioritized trend of the governmental policy [1], as a new approach to engineering education [2], as an innovative technology for Industry 4.0 [3, 4]. At international level the interest is observed by recent development of STEM reading audience [5].

Sanders describes STEM as "an approach where learning and teaching are between/among any two or more STEM spheres as well as between STEM subjects" [6]. Integration into STEM is considered as "an attempt to combine several or all four disciplines: science, technology, engineering, and mathematics into one lesson, module, or course, based on interaction between these subjects with real problems" [7]. Other scientists determine STEM as "an approach to studying STEM content in two or more STEM areas interrelated by STEM practices in authentic context, aiming at combination of these subjects to enhance student education" [8]. Some researchers do not see the necessity of clear definition of STEM, it is sufficient to coordinate general principles [9]. At present, global education is aimed at increased involvement of youth in STEM [10]. This leads to numerous STEM modifications: STEAM, STREM, STREAM, and other variants combined by integration of various subjects [11, 12].

While recognizing the value of investigation into separate aspects of STEM technology, it should be mentioned that they more often represent its essence by integration of subjects and importance in education. In fact, the issue of readiness of teachers to its implementation, to management of this problem is not considered, the problems occurring under new interdisciplinary conditions are not analyzed.

This work is aimed at substantiation of required conditions providing readiness of managers, teachers, and students to implementation of STEM technology.

2 Methods

The study is based on multiparadigm approach in consistent combination of systematic, personality oriented, activity, and competence approaches actualized in solution to specific research problem.

Theoretical methods (analysis of publications), empirical methods (surveying, pedagogic observations, self-assessment and peer assessment, expert assessment) were applied.

The Gibbs model of reflective cycle for students and SOAP strategy (Subjective, Objective, Assessment, Plan) for teachers were applied.

3 Results

1. It has been substantiated that a necessary condition of implementation of STEM technology characterized by interdisciplinary integrative essence is creation of collective subject comprised of managers, teachers, and students with modification of their functionality.

2. The functionalities of head, team of managers and leaders were defined upon STEM implementation in learning process, namely: initiation, overcoming resistance, expert assessment.

3. The functionality of STEM teacher was determined expressed in discipline redesign, teamwork, and partnership, realization of distributed situational education process upon forming assessment and expert assessment.

4. The stages of transition of a teacher, autonomous subject, into members of collective subject upon STEM implementation were determined: goal setting, cognitive enrichment, personal development, expansion of spheres and form of interrelation, critical reflection.

5. The functionality of students-tutors in STEM as collective subject was determined, oriented at increase in motivation of first-year students to education and development of occupational skills.

4 Discussion

The presented results of investigation into formation of collective subjects of various levels (managers, teachers, students) were obtained during five years of implementation of CDIO initiative for several areas of engineering education at Siberian Federal University.

Preliminary presentation of STEM to teachers of scientific discipline, described by managers as a meaningful opportunity of their future activities, and integration into education program in the form of three STEM study modules resulted in some difficulties of both cognitive didactic and personal character, as well as natural resistance against added modifications. The presented results in terms of modified functionalities of the participants reveal the activities on transition of previously autonomous subjects into members of collective subject, the content of its activities is disclosed by interaction and interdependence with team participants based on internal motivation and self-reflective practices promoting to maintain motives for joint activities.

STEM technologies essentially vary teacher activity, which proposes two aspects: at first to initiate and to motivate students for educational activity, and then to become a participant in this personally oriented, problem, creative and reflective activity.

Interdisciplinarity and integration of STEM approach orient a teacher to work with students, where applicability and practical implementation of knowledge are highlighted, which assumes both substantial and organizational redesign of each STEM discipline [13, 14, 15]. Disciplinary knowledge is not delivered to a student in ready form but integrated into consultations in request–response structure.

Such format of learning process determines specificity of assimilated content: information is reduced, quality of its perception by students varies. Assessment becomes a forming factor when students obtain assignments not for testing knowledge and skills but for their formation. A teacher becomes a part of the team, he is an adviser, he executes functions of duly assistance and feedback. Herewith, the teacher acts as a supervisor of teamwork, interpersonal communication, he can support them in from of reflective sessions. Their application for students is based on the Gibbs model of Reflective Cycle [16]. Upon critical reflection of teachers, the SOAP strategy is applied: reflection model developed in California University as a part of professional guidebook: Education based on experience.

Activity of first-year students realized in the frames of STEM study modules, Engineering cluster, Engineering start, Engineering lab, throughout the year is new for them and results in some difficulties. The productive and comfortable completion of these modules by first-year student teams is supported by tutor assistance of senior students.

In the course of the studies the criteria were determined for selection of tutors, their tasks and functions, substantiation of number of first-year students for assistance by a tutor, forms of their work, and others.

Reflection of activity of students-tutors demonstrated that it acted as a factor of their development, allowing students the following:

- to enhance personal and interpersonal skills in communications with each other and assisted students;

- to form and to express subjective position upon assistance, decision making concerning learning process in STEM, to propose them to the first-year students, to be responsible for them;

- to systemize and to generalize their productive experience and to present it to other students.

Tutor assistance oriented at common goal of quality improvement provides monitoring of development of team activity by fast data acquisition about team progress in STEM; provides assistance for teachers of STEM modules during preparation of modules and tools for work.

An important result of this activity is that during tutor assistance a team of active students is formed, understanding the essence of STEM and loyal to it.

5 Conclusion

This work presents a variant of solution to the problem of development of staff provision as a necessary condition to implement STEM technology in engineering education.

Functionality of participants was theoretically substantiated and practically verified in the frames of activity of the Federal innovation platform of Siberian Federal University.

As a consequence of implementation of STEM technology into learning process, the community of teachers, managers, and tutor–students was formed characterized by properties of collective subject [17].

Further studies will be devoted to the issues related with development of collective subject, unlocking its potentials, registration of expert communities, and arrangement of expert activity as a part of collective subject.

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