The Development of Student Core Competencies through the STEM Education Opportunities in Classroom

Z. Dedovets, M. Rodionov

Abstract—The goal of the modern education system is to prepare students to be able to adapt to ever-changing life situations. They must be able to acquire required knowledge independently; apply such knowledge in practice to solve various problems by using modern technologies; think critically and creatively; competently use information; be communicative, work in a team; and develop their own moral values, intellect and cultural awareness. As a result, the status of education significantly increases; new requirements to its quality have been formed. In recent years the competency-based approach in education has become of significant interest. This approach is a strengthening of applied and practical characteristics of a school education and leads to the forming of the key students' competencies which define their success in future life. In this article, the authors' attention focuses on a range of key competencies, educational, informational and communicative and on the possibility to develop such competencies via STEM education. This research shows the change in students' attitude towards scientific disciplines such as mathematics, general science, technology and engineering as a result of STEM education. Two staged analyzed questionnaires completed by students of forms II to IV in the republic of Trinidad and Tobago allowed the authors to categorize students between two levels that represent students' attitude to various disciplines. The significance of differences between selected levels was confirmed with the use of Pearson's chi-squared test. In summary, the analysis of obtained data makes it possible to conclude that STEM education has a great potential for development of core students' competencies and encourage the development of positive student attitude towards the above mentioned above scientific disciplines.

Keywords—STEM-science, technology, engineering, mathematics, students' competency, Pearson's chi-squared test.

I. INTRODUCTION

MODERN education is focused on a development of creative initiatives, independence, competitiveness and mobility of future specialists. In his report "Education - a hidden treasure" to UNESCO's International Commission on Education for the 21st Century, the President, Jacques Delors, formulated the four pillars of modern education: "learning to know, learning to do, learning to live together, learning to be". The formation and development of these qualities are (in its' essence) the responsibility, in large part, of education system to the meet the challenges and grasp the opportunities of modern society [1].

Changes in the principles and purpose of education are one of the major and distinctive features of the 21st century. Until fairly recently education concentrated mainly on passive knowledge acquisition not on active student development. This is the traditional informational – illustrative approach to the presentation of educational content. That is, when a teacher presents large volumes of knowledge in readily available forms without relying on independent student's work. But more recently the individual's level of education is defined by the student's ability to solve problems of various complexity based on current knowledge and not by the volume of such knowledge. The problem of traditional education system is that teacher's use only one knowledge function which is informational, while leaving out the equally important the developmental function. These two functions are closely related but are not identical. In the competency building approach, it is possible to utilize these two functions simultaneously and effectively.

II. THE COMPETENCY BASED APPROACH

The competency based approach becomes a strategic priority in the development of education alongside the implementation of information and communication technology for educational purposes. The essence of this approach is that it focuses not only on learning or acquiring skills and knowledge, but on each individual's way of thinking, the development of learning skills and of creative potential. As a result of such a learning process, acquired skills allow students to act effectively in their future professional, personal and community life. The approach was constructed as a result of a simple set of questions on how a student can utilize the results of education outside of school. The key outcome of most of the research work on the subject is that to create a "remote effect" of a school education we must include all studied content in the processes of student's consumption and use. This is especially important for theoretical knowledge which must not stay in idle isolation, but instead become the basis for understanding the wider context of life, and in this way become an aid in life's practical situations and also as a tool for solving practical problems. Therefore, the competency-based method stresses the importance of a student's ability to resolve problems occurring in various scenarios, in particular while:
1) learning and explaining phenomena in real life;

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2) interacting with other people;
3) performing social roles in day to day life;
4) choosing a profession and evaluating personal readiness to study in a professional or vocational institution and to develop a sense of direction in the job market;
5) learning to use new equipment and technologies, and so on.

The critical element of competency-based learning is the student's independent active learning activity. An important result of this approach is the formation of core competencies, to develop the ability to find, establish and use the relationship between knowledge, skill and any particular given situation [2], [3].

A. Learning-Cognitive Competence

Learning-Cognitive competence is an aggregate of a student's competencies in the area of self- education that only appear and develop through his or her learning activity. It assumes that students possess the following skills: the ability to discern and achieve their goal; to plan, analyze and evaluate their own activity; to identify their understanding or non-understanding as it relates to the problem being studied; to formulate questions; to propose a hypothesis; to select experiment and research conditions; to select necessary tools and equipment; to possess measurement skills; to work with manuals and instructions; to describe obtained results; to formulate conclusions and present the results of their research work in oral and written forms with the use of computer technologies and tools.

B. Communication Competencies

To develop communication competence, it is necessary to define specific and required communication objectives and methods to work with them in the learning process. Communication competencies assume that students possess the following skills: to make a written statement about the subject which may have a complex structure; to follow formatting text guidelines; to independently prepare a presentation plan which complies with the contextual norms of public speaking; to use verbal and non-verbal means of communication and illustrative materials; to be able to work in the group; to participate in discussion; to be prepared to help and cooperate, and to be able to observe contextual norms of behaviour.

C. Information Competencies

The World Wide Web, the globalization of information and educational space and the exponential growth in the usage of telecommunication and satellite technologies have together fundamentally changed the learning experience. Information competence is seems as an integral part of personal qualities and appears as a complex of motivational, theoretical and practical preparedness and ability to perform informational activity based on acquiring skills to derive knowledge from different sources of information. Such sources include communications and information tools (television, CD and DVD players, phones, faxes, smartphones, computers, tablets, printers, modems, copiers, etc.), and information technologies (audio and video recording, electronic mail, mass media, internet). Students with such competency will be able to search, analyze, select necessary information, and to be able to convert, save and transfer it.

Information technologies (ICT) have become, collectively, the universal learning tool which forms students' knowledge and skills, develop a child's personality, and stimulate and satisfy interest in knowledge. Psychological research suggests that ICT influence the forming of theoretical, creative and reflexive thinking in students.

III. STEM EDUCATION

Effective implementation of a competency-based approach in education can be made possible via STEM education. It is a new approach to students' education with the use of the project-based method. Problem-based learning (PBL) education is conducted via the integration of general science, technology, engineering and mathematics. By referencing this method as a pedagogical technology, we assume that such technology includes a complex of research, search and problem solving methodologies. These methodologies are creative in their essence and are focused on the application of acquired knowledge as well as on acquiring new knowledge, as distinct from the passive integration of factual knowledge [4]. They develop students' learning skills and ability to build their own knowledge independently; to feel confident in the informational space; to develop communication skills; to use critical and creative thinking, and to help the formation of learning motives, research skills, new knowledge, skills and activities.

Students are not satisfied with a solely remote perspective of education; i.e. study now to be prepared for your adult life. They want to receive immediate practical results from learning. The STEM approach is an education methodology which allows students to formulate and propose significant and meaningful problems in their life now- problems that need to be solved with concrete, practical and tangible results. STEM is an education method focused on addressing these problems, and from this perspective it is unique. It is effective because it generates a significant amount of skills and know-how. It uniquely, creates an activity experience. This approach helps precisely because it helps to develop the personality, creating a shift of emphasis from a passive approach of accumulating summary knowledge towards an active learning which can, by using access to information resources, respond to and utilize diverse resources in diverse contexts. It actively helps the generation of a creative personality which can solve non-traditional tasks in non-traditional situations [4].

Project stages, students' tasks, students' activity and teacher's activity on each stage are shown in Table I.

It can be seen in Table I that, it is notable that in all project stages there is a possibility to develop student competence in learning, communication and using information. Within the project's framework, students learning activity is focused on achieving an external result, which can be identified and applied in practical scenarios, as well as an internalized result, where the experienced activity becomes an invaluable

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achievement which connects knowledge and skills. Such an outcome is achieved while solving any given theoretical or practical problem. The students' practical activity during the creation of the project creation helps the development of a creative approach towards attaining ICT competencies. Students use learned knowledge, skills and know-how in ICT to access the information, process, integrate, evaluate and create it and so on. Within a collective project activity, students develop communication competencies via the following skills: interacting with others, listening to and understanding others opinions; being tolerant of other points of view; being able to present thoughts and ideas in oral and written forms, and to participate in discussions.

TABLE I
PROJECT STAGES

Stages	Tasks	Students' Activities	Teacher's Activity
Organizational	Project theme and goals definition Forming working groups	Discussing task Itemizing information Discussing project goals Assigning functional roles among group participants	Motivates students Moderates project goals discussion Assists in productive assignment of functional roles among participants Observes the students
Prognostic	Problem analysis Project plan execution	Defining problems Itemizing information Creating project staged tasks	Helps defining problems Helps planning tasks Observes students
Practical	Possible sources of information definition Search for necessary information	Defining sources of information Working with information	Provides consultation Suggests productive working methods with information sources Observes students
General	Process and project results compilation	Analyzing and evaluating the process Analyzing intermediary and final project results Finalizing project	Organizes students' activities as relates to analysis and generalization Observes students
Presentational	Project results presentation Final grading of project results	Preparing project presentation Presenting projects Participating in the group evaluation and grading process of project activities	Suggests presentation forms of project results Participate in group analysis and final evaluation of project results Observes students

IV. RESEARCH FINDING

Throughout the entire duration of the study, we observed serious students' interest in the creation of their own project. Learning activity was creative and, therefore, called for new knowledge and skills, and sparked interest in learning the subject. STEM education is a powerful tool for the development of class motivation.

Students deeply understand the nature of mathematics and general science and their connection to the surrounding environment and the significance of technology for solving real world problems. At the same time disconnected pieces of knowledge start to form a more holistic view of the surrounding world.

Our research was been conducted in the framework of STEM education, in three schools of Trinidad and Tobago during the period from September to December 2013.

128 students from forms II to IV took part in our research. The article authors participated as mentors. We made the hypothesis that after STEM education that scientific disciplines such as mathematics, general science, technology and engineering would become more significant in students' lives, and that they would value this experience in planning their future lives.

As a research methodology, we used a students' survey. The survey was conducted in two stages, before and after STEM learning process. To study the level of students' interest to the subjects and disciplines the survey developed by Knezek, Christencen & Tyler-Wood (2011) was used [4]. The response reflecting the level of students' interest towards learning one or another discipline was constructed on a scale from 1 to 7. Based on such criteria we categorized students between two levels of interest towards scientific disciplines (high, middle and low). Students who scored 26-35 points were placed in high category; students scored 5-25 points were placed in the middle and low category.

The results are shown in Table II.

TABLE II
LEVEL OF INTEREST

Levels of interest	Number of students (128)			
	Beginning	%	Completion	%
Low and Middle (1)	70	54.6	49	38.28
High (2)	58	45.4	79	61.72

The significance of difference between selected levels before the STEM was checked with multifunctional criteria in Pearson's chi-squared test. The following hypotheses were formulated:

H0. Distribution among levels of interest towards scientific disciplines statistically does not differ from each other.

H1. Distribution among levels of interest towards scientific disciplines statistically differs from each other.

We have identified criterion critical value and compared it with empirical value. Empirical value is $\varphi^*=1.12$ [5]. The obtained empirical value of Pearson's criteria is in the not significance zone (Fig. 1), i.e. the statistical distribution between levels of interest towards scientific disciplines do not

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differ from each other. Therefore H_0 is accepted is and H_1 is rejected.
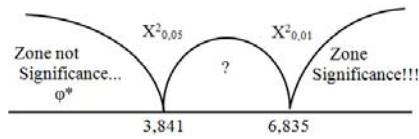

Fig. 1 Significance axis 1

After the STEM education project the same hypotheses were checked.

Empirical value is $\varphi^* = 7.03$. Therefore the obtained empirical value of Pearson's criteria is in the significance zone (Fig. 2). H_0 is rejected and H_1 is accepted. H_1 i.e. the statistical distribution between levels of interest towards scientific disciplines differing from each other. Based on this finding it can be concluded that STEM education can effectively influence students' level of interest in scientific disciplines.
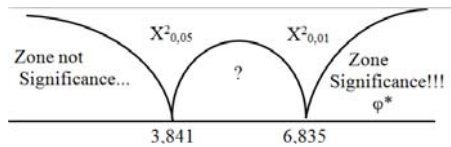

Fig. 2 Significance axis 2

V. CONCLUSION

The implementation of STEM education is more successful than traditional education in inculcating the development of students who have a wider and more rounded knowledge, who adopt a holistic view, and who are able independently categorize the knowledge they have obtained and can apply it in non- traditional ways to solve a range of tasks. STEM education goes beyond each student's usual boundaries and increases opportunities to develop creative abilities. Learning within a project helps to increase general learning motivation, to develop a wider interest towards education, to expand students' horizons and potential, and to generate the range of key competencies. This gives an opportunity to the student to have a more positive outlook on scientific disciplines, to more deeply understand their nature, to better see their connection to the real world and to more productively evaluate their significance in building a future career.

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