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DEVELOPING ENGINEERING STUDENT CREATIVITY IN MATHEMATICS CLASSES AT TECHNICAL UNIVERSITY

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ABSTRACT

The paper presents the teaching technique to develop university student creativity in mathematics classes. The technique lies in the resource-based classes when students gradually accumulate knowledge in several subjects, and then, in the resource-based interaction, in a group, they solve career-related assignments. We tested the approach by comparison testing of experimental and baseline groups of students. We had decided that assignments should meet the requirements including the following: a plot should be close to real phenomena from future careers of students, problem statements should very well to make students be not only able to solve the problem, but also make up their new problem, in the process of which they develop their creativity. In the experimental group, students started feeling better familiar with career-related assignments, desired to obtain as much useful information as possible from studies of the real process, unlike baseline group students. The introduction of resource-based classes in the learning process results in a visibly higher interest in career-related assignments and better communicability in the student community (small groups).

Disciplinary: Engineering Mathematic Education, Resource-based Learning, Teaching and Instruction (Method, Technique, and Strategy).

1. INTRODUCTION

We might explain the increasing public demand for engineers able to provide creative solutions to career challenges with the need to provide a proper response to rapidly changing conditions in modern society development. At the same time, at technical universities, professors with insufficient efficiency use the techniques, tools, and means that encourage the creativity of students, future engineers (Yudin *et al.*, 2017; Vlasov & Demin, 2017; Alcalde & Nagel, 2016). Gusev (1993) highlights the importance of the shared component of the activity, for instance, is an innovator and student, and concludes that they all search for “unknown connections between things.” He believes

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that the introduction to creativity implies teaching the student how to search for these unknown connections between objects in question.

Zagvyazinsky (1984) highlights the number of complex skills necessary for creativity. This includes the ability to analyze an initial situation, simulate the desired condition of an object, extrapolate approaches, etc. Altshuller (1979) believes that an inventive problem aims at conflict identification and solving. Therefore, the creativity promotion is associated with a choice of an approach to learning, while types of creativity manifestation depend on the aspect, in terms of which careers are considered.

The creativity is inherent in innovations as it generates new ideas. Innovations arise from a conscious and focused search for opportunities for the production of innovations based on a need in acquiring new knowledge (Laužikas & Dailydaite, 2013). Toomsalu *et al* (2019) conclude that higher competition, investments into technologies, and optimization tend to foster innovations. Hence, innovations represent an important factor for fostering the growth and development of SMEs and are likely to contribute to their overall success and economic profits (Goncharenko *et al.,* 2019).

The need for further research on specifics in the development of student creativity reasonably follows the statement of new educational targets. The growing knowledge content in production and engineer's responsibility for decision-making consequences impose new, heightened requirements to the quality of occupational training (Maklakova et al., 2019). The development of such personality traits of a future professional, as erudition, developed thinking abilities, and flexibility to changes are coming to the fore. Therefore, the research lies on *the hypothesis* that the creative development of engineering students at mathematics classes when they work with career-related assignments would be efficient if: a) learning come from real-life processes and phenomena that might occur in careers, b) set of principles to build and implement the procedural guidelines for mathematics teaching is updated, and c) algorithm is being introduced for the development of the student creativity.

Thus, this research aims at the elaboration of forms and means for the creative development of engineering students when they work with career-related assignments in mathematics classes.

2. LITERATURE REVIEW

The development of the creativity of an individual is one of the most important problems in the learning process. The meaning of creativity is an attitude towards various assignments. Therefore, the creativity characteristics are operating with the knowledge gained in the learning process, in emotional and ethic interaction in the society, intellectual and physical activities (Galasso & Kovářík, 2018). The process management is based on feedbacks: the higher the student creativity is, the more teaching experience professors need (Zubova, 2008a). Therefore, the development of student creativity depends on the methodology of discipline teaching to gain the most comprehensive knowledge of the world. Professors need ongoing targeted encouragement to ensure that students need learning (Ponomarev, 1976; Sam, 2018).

Identifying attributes in an act of creativity, almost all the researchers emphasize its unconsciousness, no control by the mind and will, spontaneity, and most importantly, the changed state of mind (Litau, 2018). The creative product actively generates unconsciousness and presents it to consciousness. Ponomarev (1976) believes that the creativity core comes down to the search for by-products of an author's work. A creatively thinking person understands by-products, which are the creation of something new, while a non-creatively thinking person only understands the results in terms of goal achievement (worthwhile results), passing by the novelty. The creative product assumes the intuition included, which is an unconscious process in this case. Poincare (1909) believes that the availability of intuition is the basis of creativity.

The creativity is mainly defined as "the highest form of human being's activities and independence" (Kairov & Petrov, 1965), "the activity that generates something qualitatively new and described with uniqueness, freshness" (Prokhorov, 1989), "the process in activities of the human being in which qualitatively new material and intellectual values are created" (Frolov, 1991).

Afanasyev (1996) refers the creativity to the targeted activity inherent in the human being, marked as unusual, unique, resulted from thinking, feeling, and acting outside the box, aimed at obtaining new, essential properties, attributes, and qualities in familiar procedures and processes, a final product of applied and intellectual efforts, as well as self-fulfillment in intellectual, emotional, and substantive-practical essential fields of the human being.

Platonov (1984) refers the creativity to thinking in its highest form, going beyond what is required to solve a problem with already known techniques.

When studying regularities in creativity, researchers by tradition distinguish the three following phases in creativity: problem statement, idea creation, and verification. In recent works on psychology and teaching (Krol, 2001), the phases have been supplemented and modified as follows: accumulating information, subconscious maturation of a solution (against the background when an individual forgets a problem), insight, and validation.

Many researchers looked for the boundary between creativity and non-creativity. Shalyutin (1985) provides an opinion and proves that in material and intellectual efforts of an individual, there are two intertwined components: algorithmic (it assumes a standard situation, certain elements of which are transformed with standard techniques in accordance with a standard target) and creative (when a technique has not been set in advance by an actor but depends on a situation).

Researches have various approaches to the creativity definition and transfer of these skills. Schukina (1979) refers to the manifested need for new knowledge. Shamova (1982) refers to the quality of the activity in which a student manifests his/her personality with his/her attitude towards content, nature of the activity, and desire to mobilize ethic and goal-focused efforts to achieve learning and cognitive goals. Afanasyev (1996) refers to the activity of an individual, that ensures involvement in the creation of something new, the transfer of knowledge and skills to new situations, and changed the mode of operation for learning assignments (Zubova, 2008b).

Having reviewed approaches to the development of the personality creativity, we conclude that in the creative process the main thing is not only its manifestations, characteristics, factors, and criteria (which are indeed basic milestones in the development), but inner creativity attributes (unconsciousness, spontaneity, no control by will and mind, mind variability.

Thus, creativity involves pro-activeness and is a characteristic of learning. The essence of learning is the ongoing discovery of new by students. The creativity in student studies is a process, in which students generate qualitatively new values. However, the practice points out to the fact that some students sometimes are not proactive in their creative learning. So, the task arises as follows: identify conditions to make learning more active, that is, conditions, forms, means, and success factors to develop the student creativity.

3. METHOD

The research hypothesized that the development of the engineering student creativity when they learn mathematics would be efficient in their work with career-related assignments if:

- university training is based upon updates and ongoing integration of mathematics knowledge in career-related assignments,
- there are updates to the principles following which professors develop and implement the mathematics tutorial system, which includes the following: availability, visualized simulation, variability, focus on career, subject-information content, introduced algorithms for the student creativity development.

The survey covered an entire course of mathematics and other STEM. Researchers assumed knowledge accumulation and integration during the period. When students had accumulated theoretical knowledge in certain fields, there were resource-based classes provided (the learning process included 8-9 sessions in two years of study, 2 sessions, 4 hours each, per term). At a resource-based class, students worked in small groups of 5-6 people. Students were proposed to solve a career-related assignment that needs to meet certain requirements. To develop student creativity, the considered methodology assumes that the assignment had three components: objects, relationships, and properties, making the field of students' research. Thus, having changed any component or some of them, students received another assignment to explore and solve it in small groups.

The resource-based classes (RCs) were built into the current schedule of mathematics classes following the pattern in Figure 1, cases of classes and assignments, **n** are from 1 to **m**. Their didactic target includes working with career-related assignments in small groups coming from reflection and communication, integration of mathematical knowledge, focused on the student creativity development.

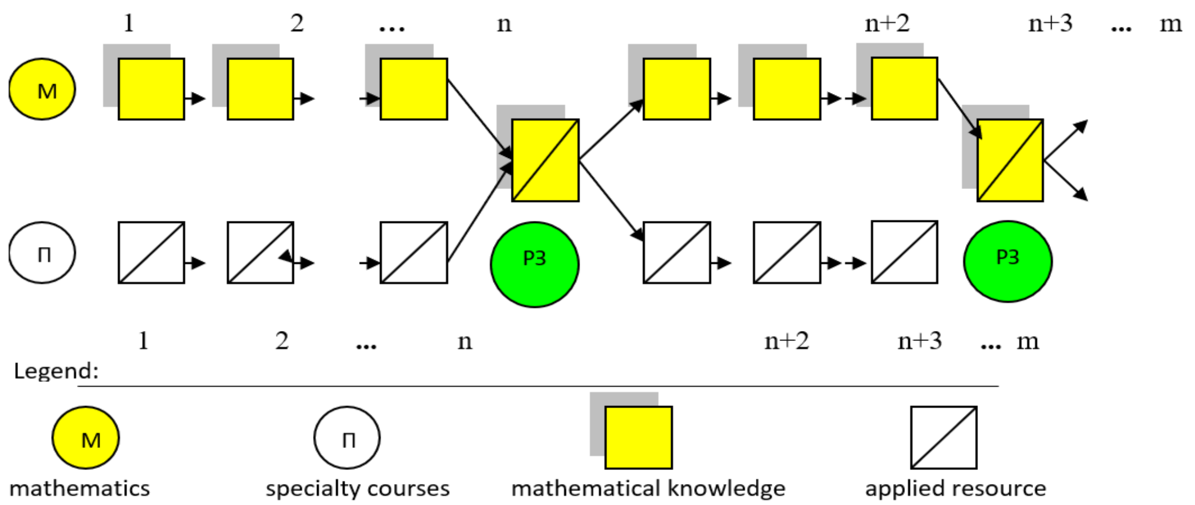

Figure 1: Schematic of introduction diagram of resource-based classes in the learning process.

At resource-based classes, there were ongoing adjustments of class content and procedure to respond to emerging challenges and suggestions made by the students who were working with assignments. Therefore, the late resource-based classes were without conflicts and any complaints from professors and students.

We experimented in the first and second years in two groups with the specialty of applied geology at the Tyumen Industrial University (Tyumen, Russia). The experiment covered the first and second years of study (2^{nd}-4^{th} terms) and included the introduced cycle of eight resource-based classes based on expanding of a teaching field to learn basic math concepts and procedures.

The entrance test of students in the experimental group (EG) and baseline group (BG) was at the end of the 1^{st} year (the 1^{st} term) under three directions (P3): 1) measurement of the motivation level, 2) indicators of the academic progress, 3) measurement of the level of the student creativity. The repeated exit tests in the same groups were at the end of the 2^{nd} year (end of the 4^{th} term) under the same three directions.

The experimental verification of the research included a psychological test for experimental and baseline groups of 30 and 29 persons, respectively. The test included the following methodology (Golovey & Rybalko, 2001), "Exploring the motivation to university studies" (test by Ilyina) used to track the university learning motivation: test "Acquiring knowledge", test "Learning of trade" (test by Rozhkov (2002)). We statistically verified the research following the test by Rozhkov for the diagnostics of the creativity using the Wilcoxon W-test on the homogeneity of two independent samples.

We measured the student creativity by 4 criteria: a sense of novelty, critical thinking, ability to transform an object structure, focus on creativity. The sense of novelty refers to the psychoemotional state of the student who, having completed a certain set of routine actions, comes to a new relationship, previously unknown to him/her, between objects in his/her mental activity. This quality underlies the measures taken to encourage search, creative, and heuristic learning. Critical thinking is an integrated trait, major components of which are abilities of the analysis, synthesis, and self-reflection. The ability to transform the object structure is an ability of deductive reasoning, ability to draw parallels and analogies, as well as make patterns. The focus on creativity refers to the pursuit of finding solutions to career-related assignments.

During the research, based on observations over students, we stated and analyzed the main difficulties encountered by students when they work with career-related assignments.

4. RESULT AND DISCUSSION

Let us evaluate student creativity at the beginning and end of the experiment. We will use the techniques described above. See the results of the entrance tests of future engineering students in Table 1.

Entrance tests of students shown that the mean gain of the student creativity in the first year at the end of the first term is within minimum values (0.92-0.94). Repeated diagnostics was at the end of the 2^{nd} year in the 4^{th} term, see results in Table 1.

Table 1: Student creativity levels of the experiment student group.

Parameter	Start		End	
	the 1st year	Baseline	the 2nd year	Baseline
Feeling of novelty	1.06	1.06	1.24	0.95
Criticality	0.81	0.82	0.94	0.68
Focus on creativity	0.87	0.88	0.90	0.83
Ability to transform the object structure	0.95	0.98	1.09	0.93
Mean gain	*0.92*	*0.94*	*1.04*	*0.84*

Exit tests showed changes in terms of the degree to which students' creative skills are developed. We received a mean gain of 1.04-0.84 as the creativity level in the second year at the end of the second term. Having analyzed the mean gain for the student creativity level at the beginning and end of the experiment, we saw that in the baseline group, the creativity level was distinctly lower. This suggests that in this group, students do not understand the importance of mathematics as both a single subject and a fundamental platform for future careers.

In the experimental group, students shown that they were much more familiar with career-related assignments, wanted to get as much useful information as possible from the real-life process they were exploring, unlike the students in the baseline group. This confirmed one of the first definitions of the creativity given by Batyushkov (Arsen'yev & Petrushevsky, 1901), where the creativity is the catalyst that encourages a person endowed with a creative potential to act unconventionally under each all direction, including both a process and product of external activity.

Resource-based classes shown that there were positive qualitative changes in terms of the mental approach, content, and structure of students' class activities:

Visible interest in career-related assignments and communication that make it possible to use the realistic mathematical apparatus based on variability and research.

Updated integration of the mathematical and engineering knowledge and skills contribute to the development of student creativity.

Students started working much more closely together. This points out to the fact that the group method of work makes it possible for students to be under ongoing self-control. However, each student, working in the group, wants to prove himself/herself and be the first to find solutions to the assignment. In real-life professional engagement, any future professional should have these traits.

The set of career-related assignments is close to real-life business problems. As a result, students become aware of the integration of all the subjects they learn. When they were solving problems, students had intensive discussions, they were independently trying to find real processes and phenomena from their future career. This points out that they have accumulated creativity. To solve an assignment, one need to move to another level, a creative one, otherwise a solution will fail.

This observation was the next confirmation of the available effect of collaboration in interaction with other students and knowledge integration (Aldieri *et al.,* 2017). Zubova (2011) refers to Afanasyev (1996) who believes that creativity is a process when somebody is making something new and it also refers to the combination of the personality traits that ensure its involvement in this process. The true student creativity starts where there is an independent search for new solutions, where there are outlines of new, advanced, and unique search directions, where there are more rational solutions to theoretical and practical problems. In the learning process, the academic progress manifests itself with the dynamics of the academic mobility that makes it possible to get advanced learning and practical experience (Sofoklis & Megalokonomou, 2016).

Having compared two-parent entities using the Wilcoxon W-test for small independent samples, we analyzed the results of statistical calculations for the creativity dynamics. See the findings in Table 3.

Table 2: Verification of sample groups by Wilcoxon criterion.

Group name	Experimental group (X_{1i}), the 1st term
Baseline group (Y_{1i}) 1st term	$W_{observ} = 985.4$; $n_{ЭX1} = 30$; $n_{ЭY1} = 29$ $790 < 985.4 < 1010$; $W_{min} < W_{observ} < W_{max}$ differences by Wilcoxon criterion have not been found
Group name	Experimental group (X_{2i}) the 4th term
Baseline group (Y_{2i}) The 4th term	$W_{observ} = 919$; $n_{ЭX2} = 28$; $n_{ЭY2} = 24$ $919 > 768.4$; $W_{observ} > W_{max}$ statistically clear differences have been found

Thus, we have a confirmed hypothesis that it is feasible to introduce the methodology of student creativity development based on the selection and study of career-related assignments at classes of further mathematics when students solve a wide range of engineering problems. During the experiment, we have also identified higher motivation for the discipline. It is not only advisable to use this integrative approach to teaching at mathematics classes but also for other subjects. When students were solving the set of problems, the professors, whose disciplines were beyond the presented methodology, also noticed the students' interest in the learning process. In the learning process in the resource-based interaction, students were persuaded that the actual practice is a basis for solutions to career-related assignments. They try to expand this belief to further education at university.

5. CONCLUSION

From this study result, it confirms our hypothesis that teaching mathematics using career-related assignments contributes to the development of students' motivation and creativity. The introduction of resource-based classes in the learning process results in a clearly higher interest in career-oriented assignments and better communicability in university student communities (small groups). The students who had been skeptical of the choice of their future careers, at resource-based classes became more confident in the correctness of their choice and shown heightened interests in their future specialty. The proposed methodological approach has produced positive results. Improved education quality in society is an indirect effect.

6. AVAILABILITY OF DATA AND MATERIAL

Data can be made available by contacting the corresponding author.

7. REFERENCES

Afanasyev, V.V. (1996). *Development of Students' Creativity when They Solve Mathematical Problems*. Yaroslavl: Publishing House of YSPU named after K.D. Ushinsky.

Alcalde, P., & Nagel, J. (2016). Does active learning improve student performance? A randomized experiment in a Chilean university. *Journal of Eurasian Social Dialogue, 1(2),* 1-11.

Altshuller, G.S. (1979). *Creativity as a STEM Discipline (Theory of Inventive Problem Solving)*. Moscow: Sovetskoye Radio.

Arsen'yev, K.K., & Petrushevsky, F.F. (Eds.). (1901). Encyclopedic Dictionary by Brokgauz and Efron. Vol. 32. Saint Petersburg: Akts. Obshch. "Izd. delo", Brokgauz–Efron.

Frolov, I.D. (Ed.). (1991). *Dictionary of Philosophy*. Moscow: Politizdat.

Golovey, L.A., & Rybalko, E.F. (Eds.). (2001). *Tutorial on Developmental Psychology*. Saint Petersburg: Rech'.

Goncharenko, O., Tohochynskyi, O., Sirenko, K., Chebonenko, S., & Tretiak, H. (2019). Innovative performance as a precondition of sustainable and secure development. *Journal of Security and Sustainability Issues, 8(3)*, 531-544. DOI: 10.9770/jssi.2019.8.3(19)

Gusev, V.A. (1993). Teaching mathematics and holistic development of student's personality (pp. 38-47). *Proceedings of MSPU. Series: Natural Sciences*. Moscow: Prometey.

Kairov, I.A., & Petrov, F.N. (Eds.). (1965). *Encyclopedia of Pedagogy*. Moscow: Sovetskaya Entsiklopediya.

Krol, M.V. (2001). *Psychology and Pedagogy*. Moscow: Vyssh. Shk.

Laužikas, M., & Dailydaite, S. (2013). Benefits of social capital for sustainable innovation capabilities. *Journal of Security and Sustainability Issues, 2(3)*, 85-97. DOI: 10.9770/jssi.2013.2.3(7)

Litau, E.Y. (2018). Cognitive science as a pivot of teaching financial disciplines. In *Proceedings of the 31st International Business Information Management Association Conference, IBIMA 2018: Innovation Management and Education Excellence through Vision 2020*, 72–80.

Maklakova, N.V., Khovanskaya, E.S., Senchenkova, E.A. (2019). Role and Place of Life-Long Learning in the University Education System. *International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies*, 10(16), 10A16D, 1-8.

Platonov, K.K. (1984). *Brief Dictionary of Concept System*. Moscow: Vyssh. Shk.

Poincare, J. H. (1909). *Mathematical Creativity*. Moscow: Tip. E. Bergmana.

Ponomarev, Ya.A. (1976). *Psychology of Creativity.* Moscow: Nauka.

Prokhorov, A.M. (Ed.). (1989). *Soviet Encyclopaedic Dictionary.* Moscow: Sovetskaya Entsiklopediya.

Rozhkov, M.I. (2002). Concept of existential pedagogy*. Yaroslavl Pedagogical Bulletin, 4,* 32-40.

Sam, V. (2018). Overeducation among graduates in developing countries: what impact on economic growth? *Journal of Eurasian Economic Dialogue, 3(6)*, 1-19.

Schukina, G.I. (1979). *The Problem of Cognitive Interest in Pedagogy*. Moscow: Prosveshcheniye.

Shalyutin, S.M. (1985). *Artificial Intelligence: Epistemological Aspect.* Moscow: Mysl'.

Shamova, T.I. (1982). *Promotion of School Students' Learning*. Moscow: Pedagogika.

Sofoklis, G., & Megalokonomou, R. (2016). Social interactions through space and time: evidence from university enrolment and academic mobility. *Journal of Eurasian Social Dialogue, 1(1)*, 6-25.

Toomsalu, L., Tolmacheva, S., Vlasov, A., & Chernova, V. (2019). Determinants of innovations in small and medium enterprises: a European and international experience. *Terra Economicus, 17(2),* 112–123. DOI: 10.23683/2073-6606-2019-17-2-112-123

Vlasov, A.I., & Demin, A.A. (2017). Visual Methods of Formalization of Knowledge in the Conditions of the Synchronous Technologies of System Engineering. *CEE-SECR'17: Proceedings of the 13th Central & Eastern European Software Engineering Conference in Russia*, 1-7. DOI: 10.1145/3166094.3166098

Yudin, A., Kolesnikov, M., Vlasov, A., & Salmina, M. (2017). Project-oriented approach in educational robotics: from robotic competition to the practical appliance. In: M. Merdan, W. Lepuschitz, G. Koppensteiner, & R. Balogh (Eds.), *Robotics in Education. Advances in Intelligent Systems and Computing*, Vol 457. Cham: Springer. DOI: 10.1007/978-3-319-42975-5_8

Zagvyazinsky, V.I. (1984). Development of students' creativity based on an independent problem analysis of learning materials. In *Problem of Abilities in Soviet Psychology* (129-134). Moscow: APN SSR.

Zubova, E.A. (2008a). Criteria for selection of career-oriented research problems. *Yaroslavl Pedagogical Bulletin, 4(57)*, 16-22.

Zubova, E.A. (2008b). Formation of creativity in future engineers. *Management of Education Quality*: *Proceedings of the Regional Research and Methodology Conference*, 101-108. Tyumen: Izd-vo TyumGNGU.

Zubova, E.A. (2011). Visual simulation in mathematics teaching to future engineers. *Yaroslavl Pedagogical Bulletin, 4(2),* 195-204.

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