MODESTUM EURASIA Journal of Mathematics, Science and Technology Education, 2022, 18(5), em2110
ISSN:1305-8223 (online)
OPEN ACCESS Research Paper https://doi.org/10.29333/ejmste/12033

STEM technology-based model helps create an educational environment for developing students' technical and creative thinking

Aleksey A. Oschepkov [1*], Alexey V. Kidinov [2], Nigina S. Babieva [3], Alexander S. Vrublevskiy [4], Eleonora V. Egorova [5], Sergei P. Zhdanov [6,7]

[1] Department of Humanities, Dimitrovgrad Engineering-Technological Institute, Dimitrovgrad, RUSSIA
[2] Department of Psychology and Human Capital Development, Financial University under the Government of the Russian Federation, Moscow, RUSSIA
[3] Department of Pedagogy and Medical Psychology, I. M. Sechenov First Moscow State Medical University (Sechenov University), Moscow, RUSSIA
[4] Department of Advertising, Public Relations, and Design, Plekhanov Russian University of Economics, Moscow, RUSSIA
[5] Department of the English Language for Professional Activities, Ulyanovsk State University, Ulyanovsk, RUSSIA
[6] Department of Customs Law and Organization of Customs Affairs, Russian University of Transport, Moscow, RUSSIA
[7] Department of Constitutional and Municipal Law, Moscow Region State University, Moscow, RUSSIA

Received 5 December 2021 ▪ Accepted 5 April 2022

Abstract

For successful technology adaptation today, individuals need not so much acquired experience and knowledge as certain personality traits in the form of skills, competencies, and abilities for collaborative problem solving, as well as achievement motivation and self-development. The purpose of this study was to develop and test a model for the formation of personality traits associated with the development of technical and creative thinking. The study was conducted using the modeling method and a psychodiagnostic approach based on the characteristics of creative thinking. An experimental study was conducted with a sample of 120 students from Plekhanov Russian College of Economics. The age range of the respondents was from 19 to 21 years. The results showed 1) the characteristics and dynamics of students' value systems and creative thinking, 2) a developed program for the development of intrinsic motivation, 3) a model for designing a pedagogical environment for students' engineering and creative thinking in education STEM; 4) testing the developed programs and models. The results also showed that there is a statistically significant relationship between the development of students' intrinsic motivation and the reorientation from normative-limited to creative-free thinking. Considering the results of this study, it was concluded that the model developed by the authors helped to shape and develop students' engineering and creative thinking. Implications for further research and teaching are drawn.

Keywords: STEM education, creative thinking, engineering education, educational environment, motivation

INTRODUCTION

The main feature of today's society is a high level of changes and a large amount of corresponding information, which changes the complexity of requirements for a person's personality. For successful adaptation today a person needs not so much acquired experience and knowledge, but certain personality traits expressed in the formation of skills, acquisition of competencies and development of the ability to solve problems together, as well as motivation for achievement and self-development (Gafurov et al., 2020).

✉ sladkod@yandex.ru **(*Correspondence)** ✉ a080ak@gmail.com ✉ n.s.babieva@mail.ru ✉ vrublevskiy.as@rea.ru ✉ eleanor_63@mail.ru ✉ zhdanov120009@yandex.ru

Contribution to the literature

- This study presents a model developed for shaping the educational environment for students' engineering and creative thinking based on STEM technology.
- This study provides 1) an investigation of the characteristics and dynamics of value systems and creative thinking in students; 2) the development of a program for the development of intrinsic motivation; 3) the confirmation of the developed programs and models for the formation of the educational environment for students' technical and creative thinking based on the STEM technology.
- This study proves that it is necessary to stimulate the development of social and pedagogical programs in education, as well as to develop comprehensive programs to adapt the STEM approach in the higher education system.
- The study of the results proves that through the practical implementation of STEM technologies in the system of higher vocational education, it is possible to develop technical and creative thinking in students.

Modern pedagogy uses practice-based learning to develop in students the professional skills that employers desperately need and to develop an understanding of where, how, and why the skills they acquire are applied in practice. Developing critical thinking skills is considered an important educational goal and has gained greater recognition in recent years (Tavukcu et al., 2020). Critical thinking is disciplined, self-directed, and self-regulated thinking that demonstrates the mental abilities appropriate to a particular mindset or domain. Within the STEM training, psychological and educational skills are developed to help freely choose ways to solve the problem being discussed. Practice-based learning influences both the activity and emotional intelligence of the individual and has a system of means, forms and methods that contribute to the educational activities of students by involving them in real professional conditions. Using critical thinking strategies can also prepare students for the rigors of college life and help them develop the skills they need for successful employment. Developing critical thinking skills helps students solve real-world problems and think with an open mind. To develop critical thinking in students, the future teacher must be able to recognize student responses, provide timely feedback, and apply an individualized approach as much as possible (Cortázar, et al., 2021; Kareem, Thomas, & Nandini, 2022).

Most importantly, however, is to develop one's own critical thinking skills. To achieve this goal, the STEAM and STEM curriculum encourages students to combine scientific, technical, engineering, artistic, and mathematical knowledge in the form of group instruction and experimental research, as well as to acquire the skills needed in today's society (Akiri et al., 2021; Alsmadi, 2020; Bahrum et al., 2017; Hashemi et al., 2015; Nourooz et al., 2015; Salakhova et al., 2021).

At the current stage of development of higher education in Russia, the authors consider the idea of using STEM in the educational process and the idea of extensive use of intelligent technologies in practice-oriented training of future teachers. In this context, education STEM is important for prospective teachers as they can use modern digital technologies and a practice-oriented approach to teaching students. Psychological orientation of professional training of future teachers includes formation of personal and professional views and humanistic ideas about educational process in general. Many empirical studies have examined the effects of various teaching strategies and interventions on the development of students' critical thinking skills (De Meester et al., 2021; Kelley & Knowles, 2016; Loyalka et al., 2021; Ma, 2021; Park & Nuntrakune, 2013; Sabirova & Deryagin, 2018; Parks et al., 2021). In this study, the teaching methods of STEAM are used as a tool to develop critical thinking in future teachers. This teaching method is an effective tool for developing thinking because it allows future teachers to use their own experiences and information, identify the strengths and weaknesses of their personality, and build a developmental path for their development as future teachers. The purpose of the study was to determine the degree of effectiveness of using STEAM in training and developing future teachers' critical thinking skills. To achieve this goal, the following objectives were established:

1. theoretical and methodological analysis of the research problem and development of a theoretical model for designing the pedagogical environment for students' technical and creative thinking;
2. development and testing of a model for the formation of personality traits in students related to the development of technical and creative thinking;
3. examining the characteristics and dynamics of value systems and creative thinking in college students;
4. developing and testing an additional course "STEAM -Education" for students.

THEORETICAL ANALYSIS

An effective means of intellectual development, formation of motivation for learning activities and development of creativity is scientific and technical creativity, as well as the introduction of innovative subprograms aimed at the development of a child's personality (Murodkhodzhaeva et al., 2021). There is a need to implement STEM education by integrating knowledge into solving applied urgent problems in project groups, and there is a shortage of trained STEM professionals in education to organize a new approach to learning, as well as a detailed description of how to implement the approach in an educational organization (Panyushkin, 2021). This confirms the need to develop new methods of work and include them in the program of psychological and educational support for student self-determination. However, if competent and comprehensive work on career guidance is carried out, paying due attention to the formation of motivational factors for high school students in career choice, it is possible to achieve positive development in career choice (Andreeva et al., 2021).

For example, a study by researchers in Italy found that children's preference for spatial toys and spatial sports promotes spatial thinking skills, which contributes to the successful inclusion of engineering thinking in STEM programs based on a project-based and interdisciplinary approach (Moè, Jansen & Pietsch, 2018). Learning spatial reasoning contributes to a successful STEM career in a person's life (Jeng & Liu, 2016). Moreover, in the context of STEM technology, the conditions for independent learning, on the one hand, and a friendly and supportive environment, on the other hand, are created, which increases the motivation for independent problem solving (León et al., 2015).

An analysis of the results of a study by researchers from China showed that children develop mathematical skills, especially spatial reasoning, which is necessary for future engineers, especially at the age of 5-6, through the approach of STEM (He et al., 2021). It was found that boys' choice of STEM subjects was based on their interest in the field, while for girls this choice was determined by their confidence in their mathematical abilities (Sakellariou & Fang, 2021). Along the same lines, the results of a study conducted by a group of researchers from Switzerland have shown that by fostering students' interest in mathematics and science, the inherent value of mathematics and science and the likelihood of choosing a STEM career in the future increase (Aeschlimann et al., 2016).

STEM forms high motivation in students, and independence in decision making contributes to the formation of appropriate conditions for creativity (Vanykina & Sundukova, 2020). Through STEM education, students can delve deeper into the logic of ongoing phenomena, understand their interrelationships, study the world systematically, and thereby develop curiosity, an engineering style of thinking, the ability to get out of critical situations, develop teamwork skills, and master the basics of management and self-presentation (Lazareva & Marchuk, 2019). Critical thinking is one of the driving forces of science in general, and in modern science there are many perspectives to take a new look at the existing reality and approach to discoveries in the field of science (Chaika, 2017). Learners from the basics of professional activity, the skills of a scientific, systemic approach to solving specific educational problems related to the design of educational programs. Students are able to delve into the logic of the phenomena studied and understand their interrelationships and consistency. Thus, they develop an engineering style of thinking, the ability to get out of critical situations, teamwork skills, management and self-presentation skills (Zubenko & Sukhova, 2018).

For example, in a study conducted in the United States, it was found that the relationship between personal characteristics such as cognitive ability and independence was a very important factor for success in the field STEM, and that the personal characteristic of sociality provided the opportunity to successfully adapt in the organizational environment (Fagan et al., 2019). Emotional intelligence was found to have a significant impact on the effectiveness of STEM training (Ferguson & Austin, 2011). A similar study has shown the cognitive impact of interests and current intentions on the success of STEM education (McIntyre, Gundlach & Graziano, 2021). In a large sample, intrinsic motivation was found to positively impact high student achievement in STEM courses, warranting a problem-based approach to student learning (Botnaru et al., 2021). And based on the analysis of differential equation solving results of students who participated in STEM courses, it was found that there were certain thinking patterns that negatively affected the mastery of new equation solving methods that were influenced by previous experiences (Stratton, 2021).

According to STEM, when creating a robot, a student can deal with concepts such as the coordinate axis, angles, curves, and even the basics of neural networks (mathematics), algorithms for finding the shortest path in the shortest possible time (computer science, energy and time saving), different sensors based on basic mechanical, optical, electromagnetic laws (physics). Such a topic is also a technical, design and sometimes artistic task (Kostina & Gladkikh, 2019). With regard to STEM education, we can conclude that the expediency of its use to maintain the effectiveness of teaching and processes, to adapt the current electronic information and educational environments to new conditions, to ensure the productive compatibility of educational and educational work in the digital educational environment of educational institutions of all levels (Aniskin et al., 2019).

An analysis of the professional and academic careers of students in England showed the growing interest in subjects related to mathematics and science and their further preference for STEM careers (Banerjee, 2016). In this context, the results of a theoretical analysis of students' expectations allowed us to theoretically support and empirically confirm the influence of biological, sociocultural, and psychological factors on the motivational basis for choosing a STEM career from the perspective of individual and gender differences (Wang & Degol, 2013). Moreover, the analysis of personality profiles showed the influence of motivation on high achievement in mathematics and science (Fong et al., 2021). The results of a similar study of scientists from the United States showed the possibility that students develop an identity associated with science during their studies, which determines their trajectory in terms of pursuing deeper study of science and choosing STEM in the professional field (Robinson et al., 2019).

It should be noted that only teachers who have received special education or additional professional training are able to work in a unified system of scientific disciplines and technologies (STEM education) (Chemenkov & Krylov, 2015). Training future teachers using the latest developments in the field of STEM education can improve the quality of education for the younger generation and solve the problem of shortage of qualified teachers who are ready to organize the educational process by using modern equipment and educational technologies for engineering skills of students (Marinyuk & Serebrennikova, 2018).

In this regard, certain beliefs of teachers who want to integrate the STEM approach into their courses form the normative component of STEM education (Pryor et al., 2016). In a recent study, it was found that a teacher who cannot distinguish between the racial or ethical background of his or her students is more objective in his or her assessment in STEM (Good et al., 2020). Therefore, students who take STEM courses are convinced of the social usefulness of their activity (Steinberg & Diekman, 2018). However, the gender factor plays some role in the selection of tasks in STEM, as boys are more likely to choose technological tasks and girls are more likely to choose tasks related to art and design (Farrell & McHugh, 2020). In general, it is possible to develop interactive courses available on the Internet that have a long-term impact on skill development STEM (Dreessen & Schepers, 2019).

Recently, there have been many projects aimed at introducing STEM education in schools at different levels. This situation shows that the modern education system has responded in practice to the needs of society in the context of Industry 4.0 (Bogdanova, 2018). In a STEM module, students have the opportunity to identify the problem, determine the importance of the topic, the objectives and hypotheses of the study, conduct an experiment, analyze and evaluate the results or conduct an engineering (IT -project) aimed at solving applied technical cases of specific companies (Konyushenko et al., 2017). In this regard, it is possible to train teachers who can give high-quality STEM education to the young generation (Grigoriev et al., 2018).

METHODS

The Methodological Basis of this Study was the Modeling Method and the Psychodiagnostic Approach

The study included 5 phases:

Phase 1: the theoretical and methodological analysis of the research problem and the development of a theoretical model for designing the educational environment for students' technical and creative thinking.

Phase 2: The survey experiment - studying the characteristics and dynamics of students' value systems and creative thinking before the introduction of the intrinsic motivation value development program.

Phase 3: The formative experiment - the introduction of value development programs of intrinsic motivation into the educational process.

Phase 4: The control phase - confirmation of the changes in the value systems and the level of creative thinking of students.

Phase 5: The analysis, synthesis and generalization of the obtained results: the formulation of conclusions.

The experimental study was conducted at the Dimitrovgrad Institute of Engineering and Technology, a subsidiary of MEPhI, the Financial College of the Government of the Russian Federation, and the Plekhanov Russian College of Economics. The study involved 120 students between the ages of 19 and 21. The control and experimental groups consisted of a homogeneous gender and age composition with 60 boys and 60 girls in each group. The S. Schwartz Value Questionnaire was used as a diagnostic instrument, which allows identifying the main value-motivating areas of young people's personalities (Schwartz, 2012). The F. Williams Test was used to measure the cognitive component associated with creativity (Tunick, 2003). The t-test was used to analyze the empirical data.

RESULTS AND DISCUSSION

Based on the results of the study obtained after the theoretical and methodological analysis, we applied the modeling method, which made it possible to develop a model for the design of the educational environment for engineering and creative thinking of students. In the model, five structural and functional blocks and their interrelationships were identified. In the goal block, the goal is specified in the tasks, which divide the subsequent blocks into cognitive, motivational, and active components. The identified components made it possible to reveal the basic concepts in the content block, systematically distribute the principles and approaches in the methodological block, determine congruent methods and means in the technological block, and identify the criteria for training students' technical and creative thinking in the evaluative and effective block.

Modeling the pedagogical process of forming engineering and creative thinking in students through the STEM technology allows the development of a structural and functional model that includes the following sections: Main goals, objectives, principles, approaches, methods, connections and structural components in the modeled process. Taking into account the specifics of children's innovative education and technological activities, as well as the age characteristics of students, the following 5 blocks were included in the structural-functional model: the goal, the content, the methodology, the technology, and the evaluative-effective part (see Table 1).

Considering the developed structural and functional model of technical and creative thinking, it should be added that the social institution of higher education in contemporary Russia is increasingly characterized by the need to introduce such a pedagogical process, the goal of which is to form a harmoniously developed personality of a young person. This trend explains the desire to integrate a humanistic approach into the pedagogical technologies of higher professional education, which, in addition to the acquisition of knowledge by students, means the integration of value-based education into the educational process (Mackay et al., 2021). All this is determined by the fact that, as a result, a college graduate is a person who can adapt to the requirements of contemporary society and, accordingly, to the value system in force in this society.

At the same time, internalization of social values by an individual is a long, multi-stage process, in which adolescence occupies the last stage, which determines its importance for the formation of a harmonious

Table 1. Structural and functional model of the formation of engineering and creative thinking of students through STEM technology

TARGET BLOCK	**Purpose**		
	the formation of engineering and creative thinking of students through STEM technology		
	Objectives		
	1. formation of a system of skills, knowledge and creative skills of students in the field of engineering activity using the STEM technology. 2. creating a special creative environment that takes into account the age characteristics of students and encourages them to take up engineering activities. 3. developing students' creative skills in creating and implementing engineering projects. 4. career guidance for teenagers.		
CONTENT BLOCK	**Motivation-Value Component**	**Activity Component**	**Cognitive Component**
	Willingness to introspect mental activity. Willingness to make new hypotheses and formulate the conditions of the problem, the implementation of appropriate transformations. Training of mental actions such as analysis, planning and introspection of mental activity within the framework of specially organized educational activities. Readiness for project activities. Willingness for self-realization and continuous self-improvement in the field of technology.	The ability to think creatively based on STEM education, finding different ways to solve a problem of a certain type using special methods of organizing mental activity, incorporating visual-figurative associative thinking in the process of teaching STEM technologies, solving scientific problems using heuristic methods of thinking, using intellectual collective creativity, the ability to apply the latest resources and technical means of engineering activity.	Knowledge of how to find solutions to engineering problems; knowledge of engineering; understanding of the engineering profession; understanding of technical and creative thinking; indicators of developing imagination, curiosity, intellectual ability, visual thinking, fluency of thought, flexibility, originality of thought, divergent thinking.
METHODOLOGICAL BLOCK	**Principles**	**Approaches**	**Techniques**
	1. Individualization and taking account of age characteristics 2. Flexibility and originality of thinking, creativity 3. Meta-subject 4. Links between theory and practice 5. Creative initiative and consciousness 6. Illustration	1. Creative 2. Personal activity 3. Project-based 4. Competence-based 5. Environmental 6. Systemic	1. test of "general intelligence" by D. Wexler 2. methodology for studying the level of analysis and synthesis of intelligence 3. a modified version of the methodology for studying visual thinking (proposed by Torrens). 4. test of creative qualities of personality by F. Williams 5. test of divergent creative thinking by F. Williams.

Table 1 (continued). Structural and functional model of the formation of engineering and creative thinking of students through STEM technology

<table>
<tr><td rowspan="3">TECHNOLOGICAL BLOCK</td><td colspan="3">Technologies for training students' engineering and creative thinking through STEM in engineering programs as a set of interrelated forms, modern methods, and teaching tools.
Technologies: STEM technologies, metatheme, project and research, game and interactive learning.</td></tr>
<tr><td>Methods</td><td>Forms</td><td>Aids</td></tr>
<tr><td>1. Modern educational technologies
2. Technique for teaching robotics and intelligent systems
3. Meta-subject teaching methodology
4. Methods of design and research work.
5. Methods for solving mathematical problems.
6. Information and communication technologies</td><td>Group work, conversation, video lecture, workshop lesson, lecture lesson, seminar lesson, presentation lesson, project defense lesson, brainstorm, lesson-business game, lesson-competition, lesson with the didactic game, case, discussion, testing.</td><td>Multimedia tutorials (presentations, websites), tutorials, visual aids (video films, mind maps, infographics, designs, models) hardware (projector, tablet, computer equipment, mobile devices), robotic complex (Lego and others), game development, project activities based on the interpreted Python language, Tkinter GUI module, and other software tools.</td></tr>
<tr><td rowspan="3">EVALUATIVE AND EFFECTIVE BLOCK</td><td>Criteria for assessing the results achieved by schoolchildren:
1. optimum level
2. sufficient level
3. insufficient level</td><td colspan="2">Levels of the formation of engineering and creative thinking of schoolchildren:
1. high
2. medium
3. low</td></tr>
<tr><td colspan="3">Result</td></tr>
<tr><td colspan="3">a high level of the formation of engineering and creative thinking of students</td></tr>
</table>

personality (Luneva et al., 2020). The most important personal constructs of this age period are the formed self-concept, self-esteem, and a system of value orientations that harmonize a person's relationship with himself, with the people around him, and with society in general (Purvis et al., 2020). At the same time, as R. Cover (2021) notes from Australia, the transformation of value self-determination can lead to both an increase in self-esteem and an underestimation of self-esteem (Cover, 2021). And as for the educational process at the college, the formation of the value bases of the student's personality as a future specialist able to work effectively in the modern world is characterized precisely by the humanization of the educational process.

On the other hand, modern scientific and technological progress is characterized by constant innovation and reaches a level that requires a specialist to develop continuously and, accordingly, to grow professionally and personally. In turn, modern pedagogy provides young people with opportunities, thanks to which they are able to fully meet the demands that today's society places on them. However, the decreasing humanitarian component of higher education should be noted, which may negatively affect the innovative component of the educational process (Merzlyakova et al., 2020; Rikel, 2020; Shaidullina et al., 2018). Finally, as stated by a group of researchers from High Point College (USA), choosing the right pedagogy is the first step to a student's proper acquisition of knowledge (Sahagun et al., 2021).

In this context, it is necessary to apply a systematic approach to the formation of a system of value orientations in the personality of a young person. This is determined by the fact that in the value-normative system social, social-psychological and psychological-pedagogical relations of the individual are interconnected, the core of which is the understanding of one's purpose in life, the formation of a worldview and orientation in one's life. Thus, the implementation of a systematic approach makes it possible to uncover the spiritual and creative potential of a young person's personality, and the necessary pedagogical conditions for the implementation of this task can be a methodological basis aimed at the creative development of the personality and, consequently, the development of creative thinking (Shmeleva, 2020).

This basic approach, which combines the features of creative thinking in the high motivation to solve educational problems and value self-determination expressed in the high importance of cognition, was the basis of the developed program for value development of young people.

The value development program is based on the assumption that developing intrinsic motivation for activities increases the level of creative thinking. Within the framework of the program, an analysis of the life path of young people was carried out, through which the personal characteristics of significant people associated with important events of young people were revealed (G. Kelly's Theory of Personality Constructs, 1963). In the program, through a series of theoretical and practical lessons, young people are invited to take on the roles of internally motivated personalities, giving them a new experience of personal development and increasing their motivation for creative activities. In this regard, the program is a pedagogical technology aimed at developing motivation for creative activity, which allows studying the impact of motivation development

Table 2. Comparison of indicators of values and creative thinking in the control groups of boys and girls before and after the experiment using Student's statistical t-test

Variables	Boys			Girls		
	before	after	$t_{emp.}$	before	after	$t_{emp.}$
Values						
Pleasure	4,3667	4,3667	0,0000	3,6333	3,8000	0,4348
Achievements	5,1867	5,1867	0,0000	2,2400	2,2800	0,1284
Social power	4,9000	4,9000	0,0000	2,1000	2,2667	0,5010
Self-determination	5,0333	5,0333	0,0000	2,7889	2,8444	0,1425
Stimulation	4,8889	4,8889	0,0000	1,9333	1,9778	0,1808
Conformism	4,2500	4,2500	0,0000	3,5667	3,8167	0,6444
Support of traditions	3,0667	3,0667	0,0000	3,4833	3,7000	0,5683
Sociality	4,4583	4,4667	0,0330	4,1667	4,2833	0,3536
Security	4,8111	4,8111	0,0000	4,8000	4,8667	0,2175
Maturity	4,9714	4,9714	0,0000	4,6667	4,7524	0,2762
Social culture	3,3429	3,3429	0,0000	2,6381	2,6571	0,0798
Spirituality	3,9200	3,9200	0,0000	3,3333	3,3333	0,0000
Creative thinking						
Fluency	1,0778	1,1667	0,5640	0,9667	0,9778	0,1147
Flexibility	0,5333	0,5500	0,1698	0,7111	0,8500	0,9679
Originality	1,7722	1,7778	0,0332	2,4611	2,5222	0,4321
Elaboration	1,1167	1,1222	0,0383	2,0722	2,0722	0,0000
Verbal creativity	2,0500	2,0500	0,0000	1,7278	1,8944	0,7627
Level of creative thinking	3,2639	3,3278	0,4137	3,9778	4,0179	0,2430

* - significant differences at $\rho \leq 0.05$
** - significant differences at $\rho \leq 0.01$

on value self-determination and the relationship with creative thinking (Vershinina & Ilyushkina, 2020). All this is in line with the sociocultural theory of creative self-determination developed by Danish scholars V. P. Glaveanu and L. Tanggaard (2014), who point to the relationship between creative thinking and personal self-determination expressed in attitudes toward oneself, others, and society. To test this thesis, it was proposed to conduct an experimental implementation of the values development program in groups of students as part of the educational process.

In order to analyze the dynamics of changes in the indicators of values and the indicators of creative thinking, a comparative analysis was conducted using Student's statistical t-test. The result of this analysis was that there were no statistical differences in the indicators before and after the experiment in the control group of boys and girls (Table 2).

The absence of changes in the dynamics of the importance of value systems and indicators of creative thinking in the control group of boys and girls is explained by the absence of socio-psychological factors influencing these groups; the activities of these groups took place in the conditions of a normal educational process.

A comparative analysis of the indicators of values and creative thinking in the experimental group before and after the experiment revealed statistically significant differences in the values and creative thinking scores of boys and girls.

In the sample of young men, the significance level of the value pleasure (temp=2.9704 at $\rho \leq 0.01$) increased statistically significantly, and the significance levels of the values conformism (temp=4.0757 at $\rho \leq 0.01$), support of traditions (temp=3.8405 at $\rho \leq 0.01$), sociality (temp=3.7262 at $\rho \leq 0.01$), safety (temp=2.5940 at $\rho \leq 0.05$), maturity (temp=2.6916 at $\rho \leq$ 0.05), social culture (temp=3.2455 at $\rho \leq 0.01$). In the sample of girls, the significance level of the value of pleasure (temp=2.8180 at $\rho \leq 0.05$) increased statistically significantly, and the significance levels of the values of conformism (temp=2.7431 at $\rho \leq 0.05$), sociality (temp=2, 5683 at $\rho \leq 0.05$), security (temp=2.3857 at $\rho \leq 0.05$). As for the indicators of creative thinking in the sample of young men, there was a general increase in the scores for fluency (temp=2.6015 at $\rho \leq 0.05$), flexibility (temp=2.6073 at $\rho \leq 0.05$), originality (temp=2.9047 at $\rho \leq 0.05$), elaboration (temp=3.3830 at $\rho \leq 0.01$), verbal creativity (temp=2.8731 at $\rho \leq 0.05$), integral level of creative thinking (temp=6.3289 at $\rho \leq$ 0.01). In girls, the level of flexibility (temp=2.8678 at $\rho \leq 0.05$), elaboration (temp=2.9059 at $\rho \leq 0.01$), verbal creativity (temp=3.0056 at $\rho \leq 0.01$) and integral level of creative thinking (temp=5.9489 at $\rho \leq 0.01$) increased (Table 3).

The obtained data show that the ongoing social pedagogical program had an impact on the observed dynamics of the importance of values and indicators of creative thinking. At the same time, the increase in the importance of the value pleasure can be explained by the release of intrinsic motivation, which is accompanied by a decrease in the restrictions in one's life, which is also

Table 3. Comparison of indicators of values and creative thinking in the experimental groups of boys and girls before and after the experiment using Student's statistical t-test

Variables	Boys			Girls		
	before	after	$t_{emp.}$	before	after	$t_{emp.}$
Values						
Pleasure	4,0000	4,6667	**2,9704****	2,8667	3,6667	**2,8180***
Achievements	3,8267	4,0267	0,9629	4,0667	3,8133	1,1044
Social power	3,9667	4,1167	0,5185	3,4333	3,5000	0,3417
Self-determination	4,9000	4,7889	0,5385	4,5111	4,3444	0,7012
Stimulation	4,1333	3,9333	1,0882	4,6222	4,4667	0,6904
Conformism	4,2167	3,1667	**4,0757****	3,5167	2,8667	**2,7431***
Support of traditions	4,0333	3,2667	**3,8405****	3,5833	3,5500	0,1872
Sociality	4,9417	4,1667	**3,7262****	4,3917	3,7333	**2,5683***
Security	5,5444	5,0111	**2,5940***	4,6778	4,1444	**2,3857***
Maturity	4,6381	4,0381	**2,6916***	4,4190	4,1905	1,1088
Social culture	3,7524	3,0476	**3,2455****	2,8190	2,6667	0,6096
Spirituality	4,0667	3,8571	0,8601	3,5067	3,4400	0,3246
Creative thinking						
Fluency	0,5333	0,8778	**2,6015***	0,8167	0,9111	0,7093
Flexibility	0,2444	0,4889	**2,6073***	0,6111	1,0667	**2,8678***
Originality	1,1389	1,6389	**2,9047****	1,8333	1,9833	0,8988
Elaboration	0,4111	0,7944	**3,3830****	0,8722	1,3944	**2,9059****
Verbal creativity	0,5278	0,8444	**2,8731***	0,7333	1,3389	**3,0056****
Level of creative thinking	1,4417	2,3222	**6,3289****	2,4500	3,3611	**5,9489****

* - significant differences at $\rho \leq 0.05$
** - significant differences at $\rho \leq 0.01$

manifested in a decrease in the importance of normatively oriented values, such as the values conformity, support of traditions, sociality and social culture. At the same time, it is worth noting that both boys and girls in the experimental group decrease the importance of the value of security, which is also associated with a reorientation towards a creative approach to life. In this regard, the analysis of one's values and their reorientation towards an internally motivated activity also has a significant effect on the cognitive component of the activity, which is reflected in an increase in the level of the main indicators of creative thinking. The indicators of flexibility, elaboration and verbal creativity also increased in the girls, but it is worth mentioning. The indicators of fluency and originality were initially at a high level in the girls.

CONCLUSION

The results of the study show that the socio-educational program has an impact on the observed dynamics of the importance of values and indicators of creative thinking. At the same time, there is a shift away from norm-oriented values towards a transgression of the limiting framework, which is consistent with general theoretical ideas about the creative approach and creative personality. A creative approach to one's life activities increases both enjoyment of life and more productive solution of creative problems.

Our study proves that value structures and cognitive structures are not significantly related (correlations were not significant). It should be noted that the relationship found has a non-linear structure, which conditions the absence of statistically significant differences in the control group sample at all stages of the experimental study. However, our results indicate the relationship between mental structures and value-motivational structures. The discovered relationship is expressed in the dependence of the development of the level of creative thinking on the values of the individual, which can be explained by the orientation of students towards creativity, the desire for self-development and self-actualization. The main activity of college students is educational and vocational (Vygotsky, 1978), which determines the dominance of motives oriented to cognition, creativity, and personal development.

Thus, the results show that there is a statistically significant relationship between the development of the individual's internal motivation and the reorientation from normative-limited to creative-free type of thinking in students. It has been shown that the model developed by the authors, based on the technology of STEM, shapes and develops the engineering and creative thinking of students. The obtained results can be used in the development of educational programs both in the system of higher and secondary schools.

In addition, it is worth noting that the problem of the relationship between value-motivation structures and students' creative thinking should be further pursued to uncover the factors that contribute to a creative approach in the educational process. At the same time, the observed relationship between the value of spirituality and the level of creative thinking can be recommended for the use of practical work in higher education.

Author contributions: All authors have sufficiently contributed to the study, and agreed with the results and conclusions.

Funding: No funding source is reported for this study.

Declaration of interest: No conflict of interest is declared by authors.

REFERENCES

Aeschlimann, B., Herzog, W., & Makarova, E. (2016). How to foster students' motivation in mathematics and science classes and promote students' STEM career choice. A study in Swiss high schools. *International Journal of Educational Research, 79*, 31-41. https://doi.org/10.1016/j.ijer.2016.06.004

Akiri, E., Tor, H. M., & Dori, Y. J. (2021). Teaching and assessment methods: STEM teachers' perceptions and implementation. *Eurasia Journal of Mathematics, Science and Technology Education, 17*(6), em1969. https://doi.org/10.29333/ejmste/10882

Alsmadi, M. A. (2020). Requirements for application of the STEM approach as perceived by science, math and computer teachers and their attitudes towards it. *Eurasia Journal of Mathematics, Science and Technology Education, 16*(9), em1879. https://doi.org/10.29333/ejmste/8391

Andreeva, I. V., Mikhailik, E. V., Dobrynina, M. A. (2021). STEM education as a key factor in the development of engineering and technical competencies of students in educational institutions. *The World of Science. Pedagogy and Psychology, 9*(1), 1-9.

Aniskin, V. N., Aniskin, S. V., Zamara, E. V., & Yankevich, O. A. (2019). Using the didactic potential of STEM and STEAM technologies in solving the problems of digitalization of education. In the collection: Higher Humanitarian Education of the 21st Century: Problems and Prospects. *Proceedings of the Fourteenth International Scientific and Practical Conference* (pp. 19-24).

Bahrum, S. & Wahid, N. & Ibrahim, N. (2017). Integration of STEM Education in Malaysia and Why to STEAM. *International Journal of Academic Research in Business and Social Sciences, 7*, 646-654. https://doi.org/10.6007/IJARBSS/v7-i6/3027.

Banerjee, P. A. (2016). A longitudinal evaluation of the impact of STEM enrichment and enhancement activities in improving educational outcomes: Research protocol. *International Journal of Educational Research, 76*, 1-11. https://doi.org/10.1016/j.ijer.2015.12.003

Bogdanova, A. N. (2018). STEM education at school in the context of industry 4.0. *Science and education: problems, ideas, innovations, 6*(9), 14-16.

Botnaru, D., Orvis, J., Langdon, J., Niemiec, Ch. P. & Landge Sh. M. (2021). Predicting final grades in STEM courses: A path analysis of academic motivation and course-related behavior using self-determination theory. *Learning and Motivation, 74*, 101723. https://doi.org/10.1016/j.lmot.2021.101723

Chaika, S. A. (2017). Possibilities of the STEM approach in teaching natural sciences. *Problems of modern science and education, 22*(104), 74-77.

Chemenkov, V. N., & Krylov, D. A. (2015). STEM - a new approach to engineering education. *Bulletin of the Mari State University, 5*(20), 59-64.

Cortázar, C., Nussbaum, M., Harcha, J., Alvares, D., López, F., Goñi, J., & Cabezas, V. (2021). Promoting critical thinking in an online, project-based course. *Computers in Human Behavior*, *119*, 106705.

Cover, R. (2021). Identity in the disrupted time of COVID-19: Performativity, crisis, mobility and ethics. *Social Sciences and Humanities Open, 4*, 1-8. https://doi.org/10.1016/j.ssaho.2021.100175

De Meester, J., De Cock, M., Langie, G., & Dehaene, W. (2021). The process of designing integrated STEM learning materials: Case study towards an evidence-based model. *European Journal of STEM Education, 6*(1), 10. https://doi.org/10.20897/ejsteme/11341

Dreessen, K., & Schepers, S. (2019). Foregrounding backstage activities for engaging children in a FabLab for STEM education. *International Journal of Child-Computer Interaction, 20*, 35-42. https://doi.org/10.1016/j.ijcci.2019.02.001

Fagan, M. A., Hul, D. M., Gray, R. & Bolen, J. A. (2019). Predicting STEM performance in a Hispanic serving institution. *Personality and Individual Differences, 141*, 18-24. https://doi.org/10.1016/j.paid.2018.12.017

Farrell, L., & McHugh, L. (2020). Exploring the relationship between implicit and explicit gender-STEM bias and behavior among STEM students using the Implicit Relational Assessment Procedure. *Journal of Contextual Behavioral Science, 15*, 142-152. https://doi.org/10.1016/j.jcbs.2019.12.008

Ferguson, F. J., & Austin, E. J. (2011). The factor structures of the STEM and the STEU. *Personality and Individual Differences, 51*(6), 791-794. https://doi.org/10.1016/j.paid.2011.07.002

Fong, C. J., Kremer, K. P., Cox, Ch.H.-T., & Lawson, Ch. A. (2021). Expectancy-value profiles in math and science: A person-centered approach to cross-domain motivation with academic and STEM-related outcomes. *Contemporary Educational Psychology, 65*, 101962.

Gafurov, I. R., Ibragimov, H. I., Kalimullin, A. M., & Alishev, T. B. (2020). Transformation of higher education during the pandemic: pain points. *Vysshee obrazovanie v Rossii= Higher Education in Russia*, *29*(10), 101-112. https://doi.org/10.31992/0869-3617-2020-29-10-101-112

Glaveanu, V. P., & Tanggaard, L. (2014). Creativity, identity, and representation: Towards a socio-cultural theory of creative identity. *New Ideas in Psychology, 34*, 12-21. https://doi.org/10/1016/j.newideapsych.2014.02.002

Good, J. J., Bourne, K. A., & Drake, R. G. (2020). The impact of classroom diversity philosophies on the STEM performance of undergraduate students of color. *Journal of Experimental Social Psychology, 91*, 104026. https://doi.org/10.1016/j.jesp.2020.104026

Grigoriev, S. G., Sadykova, A. R., & Kurnosenko, M. V. (2018). STEM-technologies in the preparation of masters of pedagogical direction. *Bulletin of the Moscow City Pedagogical University. Series: Informatics and informatization of education, 3*(45), 8-13.

Hashemi, N., Abu, M., Kashefi, H., Mokhtar, M., & Rahimi, K. (2015). Designing Learning Strategy to Improve Undergraduate Students' Problem Solving in Derivatives and Integrals: A Conceptual Framework. *Eurasia Journal of Mathematics, Science and Technology Education, 11*, 227-238. https://doi.org/10.12973/eurasia.2015.1318a

He, X., Li, T., Turel, O., Kuang, Y., Zhao, H., & Hea, Q. (2021). The impact of STEM education on mathematical development in children aged 5-6 years. *International Journal of Educational Research, 109*, 101795. https://doi.org/10.1016/j.ijer.2021.101795

Jeng, Hi-L., & Liu, G.-F. (2016). Test interactivity is promising in promoting gender equity in females' pursuit of STEM careers. *Learning and Individual Differences, 49*, 201-208. https://doi.org/10.1016/j.lindif.2016.06.018

Kareem, J., Thomas, R. S., & Nandini, V. S. (2022). A conceptual model of teaching efficacy and beliefs, teaching outcome expectancy, student technology use, student engagement, and 21st-century learning attitudes: A STEM education study. *Interdisciplinary Journal of Environmental and Science Education, 18*(4), e2282. https://doi.org/10.21601/ijese/12025

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *IJ STEM Ed, 3*, 11. https://doi.org/10.1186/s40594-016-0046-z

Kelly, G. A. (1963). *A Theory of Personality: The Psychology of Personal Constructs*. W.W. Norton and Company. p. 190.

Konyushenko, S. M., Petrushenkov, A. V., & Zhukova, M. S. (2017). STEM approach in education: Russian and foreign educational practices. *Proceedings of the Baltic State Academy of the Fishing Fleet: Psychological and Pedagogical Sciences, 4*(42), 96-101.

Kostina, I. B., & Gladkikh, Yu. P. (2019). The degree of effectiveness of the use of STEM technologies in the framework of the educational environment. *Proceedings of the Baltic State Academy of the Fishing Fleet: Psychological and Pedagogical Sciences, 3*(49), 126-131.

Lazareva, S. A., & Marchuk, T. L. (2019). STEM-technology as a means of forming the engineering thinking of schoolchildren. *Perm Pedagogical Journal, 10*, 76-79.

León, J., Núñez, J. L., & Liew, J. (2015). Self-determination and STEM education: Effects of autonomy, motivation, and self-regulated learning on high school math achievement. *Learning and Individual Differences, 43*, 156-163. https://doi.org/10.1016/j.lindif.2015.08.017

Loyalka, P., Liu, O. L., Li, G., Kardanova, E., Chirikov, I., Hu, S., Yu, N., Ma, L., Guo, F., Beteille, T., Tognatta, N., Gu, L., Ling, G., Federiakin, D., Wang, H., Khanna, S., Bhuradia, A., Shi, Z., & Li, Y. (2021). Skill levels and gains in university STEM education in China, India, Russia and the United States. *Nat Hum Behav, 5*(7), 892-904. https://doi.org/10.1038/s41562-021-01062-3

Luneva, E. V., Bobkova, N. D., Bryzgalova, O. N., Khripunova, O. G. (2020). Formation of professional value orientations of students. *Alma mater (High School Bulletin), 8*, 38-42.

Ma, Y. (2021). Reconceptualizing STEM Education in China as *Praxis*: A Curriculum Turn. *Sustainability, 13*(9), 4961. https://doi.org/10.3390/su13094961

Mackay, C. M. I., Cristoffanini, F., Wright, J. D., & Neufeld, S. D. (2021). Connection to nature and environmental activism: Politicized environmental identity mediates a relationship between identification with nature and observed environmental activist behavior. *Current Research in Ecological and Social Psychology, 2*, 1-10. https://doi.org/10.1016/j.cresp.2021.100009

Marinyuk, A. A., & Serebrennikova, Yu. A. (2018). Preparing Future Primary School Teachers to Use STEM Education Resources. *Proceedings of the Institute of Pedagogy and Psychology of Education, 3*. 37-41.

McIntyre, M. M., Gundlach, J. L., & Graziano, W. G. (2021). Liking guides learning: The role of interest in memory for STEM topics. *Learning and Individual*

Differences, 85, 101960. https://doi.org/10.1016/j.lindif.2020.101960

Merzlyakova, S. V., Golubeva, M. G., & Bibarsova, N. V. (2020). Dynamics of value orientations of boys and girls in the process of studying at a university. *Society: sociology, psychology, pedagogy, 6*(74), 103-110.

Moè, A., Jansen, P., & Pietsch, S. (2018). Childhood preference for spatial toys. Gender differences and relationships with mental rotation in STEM and non-STEM students. *Learning and Individual Differences, 68,* 108-115. https://doi.org/10.1016/j.lindif.2018.10.003

Murodkhodzhaeva, N. S., Averin, S. A., Romanova, M. A., & Serebrennikova, Yu. A. (2021). Continuity of preschool and primary school education by means of STEM education. *Hominum, 2,* 84-99.

Nourooz, H., Mohd, A., Hamidreza, K., Mahani, M., & Khadijeh, R. (2015). Designing Learning Strategy to Improve Undergraduate Students' Problem Solving in Derivatives and Integrals: A Conceptual Framework. *Eurasia Journal of Mathematics, Science and Technology Education, 11*, 227-238. https://doi.org/10.12973/eurasia.2015.1318a

Panyushkin, D. A. (2021). Review of practices and approaches in STEM education in Russia and abroad. Artemovsky readings. Materials of the XIII International Scientific Conference (pp. 157-164). Samara.

Park, J.-Y. & Nuntrakune, T. (2013). A conceptual framework for the cultural integration of cooperative learning: A Thai primary mathematics education perspective. *Eurasia Journal of Mathematics, Science & Technology Education*, *9*(3), 247-258. https://doi.org/10.12973/eurasia.2013.933a

Parks, M. B., Hendryx, E. P., & Taylor, A. T. (2021). The study of stream litter accumulation as a model for cross-disciplinary, transformative, affordable, and scalable undergraduate research experiences in STEM. *Interdisciplinary Journal of Environmental and Science Education, 17*(3), e2245. https://doi.org/10.21601/ijese/10935

Pryor, B. W., Pryor, C. R., & Kang, R. (2016). Teachers' thoughts on integrating STEM into social studies instruction: Beliefs, attitudes, and behavioral decisions. The Journal of Social Studies Research, 40(2), 123-136. https://doi.org/10.1016/j.jssr.2015.06.005

Purvis, A. J., Rodgers, H. M., & Beckingham, S. (2020). Experiences and perspectives of social media in learning and teaching in higher education. *International Journal of Educational Research Open, 2,* 1-9. https://doi.org/10.1016/j.ijedro.2020.100018

Rikel, A. M. (2020). Perception of social maturity criteria, self-perception and value orientations among Russian millennials. *RUDN Journal of Psychology and Pedagogics, 17*(3), 491-503. https://10.22363/2313-1683-2020-17-3-491-503

Robinson, K. A., Perez, T., Carmel, J. H., & Linnenbrink-Garcia, L. (2019). Science identity development trajectories in a gateway college chemistry course: Predictors and relations to achievement and STEM pursuit. *Contemporary Educational Psychology, 56,* 180-192. https://doi.org/10.1016/j.cedpsych.2019.01.004

Sabirova, F. M., & Deryagin A. V. (2018). The creation of junior schoolchildren's interest in the experimental study of physical phenomena using the elements of the technology of problem-based. *International Journal of Engineering & Technology, 7*(2.13), 150-154.

Sahagun, M. A., Moser, R., Shomaker, J., & Fortier, J. (2021). Developing a growth-mindset pedagogy for higher education and testing its efficacy. *Social Sciences and Humanities Open, 4,* 1-9. https://doi.org/10.1016/j.ssaho.2021.100168

Sakellariou, Ch., & Fang, Zh. (2021). Self-efficacy and interest in STEM subjects as predictors of the STEM gender gap in the US: The role of unobserved heterogeneity. *International Journal of Educational Research, 109,* 101821. https://doi.org/10.1016/j.ijer.2021.101821

Salakhova, V. B., Masalimova, A. R., Belyakova, N. V., Morozova, N. S., Osipova, N. V., & Prokopyev, A. I. (2021). Competitive teacher for higher education: Risk-based models of its development. *Eurasia Journal of Mathematics, Science and Technology Education,* *17*(10), em2021. https://doi.org/10.29333/ejmste/11187

Schwartz, S. H. (2012). Refining the theory of basic individual values. *Journal of Personality and social psychology, 103,* 663-688. https://doi.org/10.1037/a0029393

Shaidullina, A. R., Zakirova, V. G., Kashurnikov, S. N., Arestova, E. N., Shmidt, A. N., & Kovaleva, N. I. (2018). Students training for innovative entrepreneurial activity: social responsibility competences. *Espacios, 39*(02), 15-26.

Shmeleva, Zh. N. (2020). The use of heuristic teaching methods in the study of the discipline "marketing" to increase the creative thinking level in students of secondary professional education. *Baltic Humanitarian Journal, 9*(3), 208-212.

Steinberg, M., & Diekman, A. B. (2018). Considering "why" to engage in STEM activities elevates communal content of STEM affordances. *Journal of Experimental Social Psychology, 75,* 107-114. https://doi.org/10.1016/j.jesp.2017.10.010

Stratton, D. H. (2021). Negative transfer in implicit differentiation. *International Journal of Educational Research Open, 2*(2), 100051. https://doi.org/10.1016/j.ijedro.2021.100051

Tavukcu, T., Kalimullin, A., Litvinov, A., Shindryaeva, N., Abraukhova, V., & Abdikeev, N. (2020). Analysis of articles on education and instructional technologies (Scopus). *International Journal of Emerging Technologies in Learning (iJET)*, *15*(23), 108-120. https://doi.org/10.3991/ijet.v15i23.18803

Tunick, E. E. (2003). Modified Williams creative tests. St. Petersburg: Rech, 96 p. http://mrc.kpk1.ru/images/stories/news/2014/vilyams.pdf

Vanykina, G. V., & Sundukova, T. O. (2020). Educational robotics in educational institutions: an empirical study of motivation and STEM skills. *Pedagogika Informatiki, 3,* 1-10.

Vershinina, T. S., & Ilyushkina, M. Y. (2020). Social practices of advertising disclosure: influence of stylistic expressive means of forming value orientations. *Russian Linguistic Bulletin, 3*(23), 94-101.

Vygotsky, L. S. (1978). *Mind in society: the development of higher psychological processes*. Cambridge, p. 159.

Wang, M.-T., & Degol, J. (2013). Motivational pathways to STEM career choices: Using expectancy–value perspective to understand individual and gender differences in STEM fields. *Developmental Review, 33*(4), 304-340. https://doi.org/10.1016/j.dr.2013.08.001

Zubenko, N. Yu., & Sukhova, E. I. (2018). Features of building a STEM module "Designing educational programs for preschool education" for bachelors in the direction of training "Pedagogical education". *Society: Sociology, Psychology, Pedagogy, 11*(55), 76-80.