O‘RTA MAKTAB O‘QUVCHILARINING IJODIY KOMPETENSIYALARINI RIVOJLANTIRISHDA STEAM YONDASHUVINING DIDAKTIK IMKONIYATI

ДИДАКТИЧЕСКИЕ ВОЗМОЖНОСТИ STEAM - ПОДХОДА В РАЗВИТИИ ТВОРЧЕСКИХ КОМПЕТЕНЦИЙ СРЕДНИХ ШКОЛЬНИКОВ.

DIDACTIC POTENTIAL OF THE STEAM APPROACH FOR DEVELOPING SECONDARY SCHOOL STUDENTS' CREATIVE COMPETENCIES.

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Annotatsiya. Мақолада STEAM ёндашувининг қайси хусусиятлари ўқувчиларнинг креатив компетенцияларини ривожлантиришга хизмат қилиши ва бу қандай шароитда амалга ошиши таҳлил қилинган. Илмий манбалар, халқаро ҳисоботлар ва Ўзбекистон меъёрий ҳужжатлари интегратив таҳлили асосида STEAMнинг еттита дидактик имконияти аниқланган: очиқ муаммоли мазмун, фанлараро интеграция, муҳандислик-лойиҳалаш цикли, санъат компоненти, жамоавий ғоялар генерацияси, рақамли ижод ва жараёнга йўналтирилган баҳолаш. Ҳар бир имконият учун механизм, у ривожлантирадиган креативлик кўрсаткичи ва амалга ошиш шарти кўрсатилган.

Аннотация. В статье анализируется, какие особенности STEAM-подхода способствуют развитию креативных компетенций учащихся и при каких условиях. На основе интегративного обзора исследований, международных докладов и нормативных документов Узбекистана выделены семь дидактических возможностей STEAM: открытое проблемное содержание, межпредметная интеграция, инженерно-проектировочный цикл, художественный компонент, коллективная генерация идей, цифровое творчество и оценивание процесса. Для каждой возможности описаны механизм, развиваемый показатель креативности и условие реализации.

Abstract. This article asks which features of the STEAM approach actually support the development of creative competencies and under which conditions. Using an integrative review of research, international reports and Uzbek regulatory documents, the study identifies seven didactic opportunities of STEAM: open-ended problem content, interdisciplinary integration, the engineering design cycle, the arts component, collaborative idea generation, digital making and process-oriented assessment. For each, the mechanism, the targeted creativity indicator and the condition for its realisation are described. The main limiting factors are insufficient

guidance for novice learners, tokenistic use of the arts, time and resource constraints and uncritical use of generative AI.

Kalit so‘zlar: STEAM ta’limi, kreativ kompetensiya, didaktik imkoniyat, fanlararo integratsiya, dizayn-fikrlash, loyihaviy ta’lim, o‘rta maktab.

Ключевые слова: STEAM-образование, креативная компетенция, дидактические возможности, межпредметная интеграция, дизайн-мышление, проектное обучение, средняя школа.

Keywords: STEAM education, creative competence, didactic potential, interdisciplinary integration, design thinking, project-based learning, secondary school.

Introduction.

Employers surveyed by the World Economic Forum expect 39% of workers' core skills to change by 2030, and creative thinking is among the five core skills they value most [1]. Schools are expected to respond, but the starting point in many systems is weak. In the first PISA assessment of creative thinking (2022), the OECD average was 33 points out of 60; students in Uzbekistan scored 14 [2]. Uzbekistan took part in PISA for the first time in 2022, and its results in the core domains were 108 to 140 points below the OECD average (Figure 1) [3].

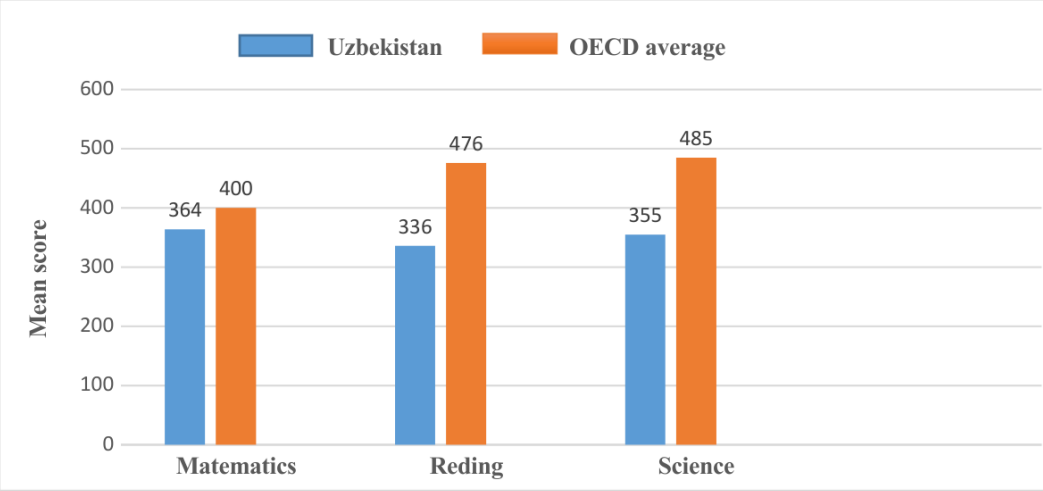

Figure 1. PISA 2022 mean scores: Uzbekistan and the OECD average (data: OECD [3])

STEAM, which adds the arts to science, technology, engineering and mathematics, is one of the most common answers. G. Yakman described it in 2008 as a framework of integrative education in which the arts connect technical knowledge with human purposes [4]. South Korea made STEAM national policy in 2011 [5], and in Uzbekistan the STEAM programme was introduced into Presidential schools by Presidential Resolution PQ-4199 of 20 February 2019 [6], with STEAM foundations later extended to pre-school education [7].

The research evidence is less uniform than the policy enthusiasm. Kwon and Lee's meta-analysis of eight studies (702 participants, secondary and university level) found a positive effect of STEM project-based learning on creativity [8]. Cao and colleagues,

analysing 66 experimental and quasi-experimental studies from 2000–2024, reported a moderate overall effect of STEM education on learning outcomes (d = 0.46) but no significant effect on primary pupils' creativity [9]. A review by Perignat and Katz-Buonincontro adds that STEAM is defined in many different ways and that the arts are often used decoratively rather than as a way of thinking [10]. The more useful question is which features of STEAM develop creativity and under what conditions.

The aim of this article is to identify and systematise the didactic potential of the STEAM approach for developing the creative competencies of lower-secondary students (grades 7–9) and to specify the conditions under which this potential is realised.

Methods. The study is an integrative literature review. The corpus included the foundational works on project-based and experiential learning, peer-reviewed reviews and meta-analyses on STEM/STEAM and creativity, OECD, UNESCO and World Economic Forum reports, and regulatory acts of the Republic of Uzbekistan; all sources are listed in the references. The analysis proceeded in three steps. First, claims about how STEAM affects creativity were extracted from each source. Second, these claims were grouped into didactic categories: content, methods, learning environment, tools and assessment. Third, for each group we specified the mechanism, the creativity indicator it targets (fluency, flexibility, originality, elaboration or usefulness) and the condition under which the effect was reported. Empirical verification is outside the scope of this article.

Results.

The analysis produced seven didactic opportunities. They are summarised in Table 1 and discussed below

Table 1. Didactic potential of STEAM for developing creative competencies

Opportunity	Mechanism	Creativity indicator	Condition
Open-ended problem content	An ill-structured real-life problem admits several solutions	Fluency, flexibility	The problem is relevant to students and has no single answer
Interdisciplinary integration	Knowledge from several subjects is combined around one problem	Flexibility, originality	Subjects are linked by the problem, not merely placed side by side
Engineering design cycle	Ask, imagine, plan, create, improve; repeat	Elaboration, usefulness	Time for iteration; error is not penalised

	after each failed test		
Arts component	Design, visualisation and aesthetics give form and purpose to a technical solution	Originality, elaboration	Art is a way of thinking, not decoration
Collaborative idea generation	Brainstorming, synectics and TRIZ techniques in small groups	Fluency, originality	Explicit rules for generating and evaluating ideas
Digital making	Coding, robotics, 3D modelling allow quick prototyping	Elaboration, usefulness	Access to equipment; tool use serves the idea
Process-oriented assessment	Rubrics, portfolio, self- and peer assessment	All indicators; reflection	Criteria known to students in advance

1. Open-ended problem content. STEAM tasks start from a problem rather than a topic. A task such as "design a low-cost way to keep drinking water cool in a classroom without a refrigerator" has no single correct answer, so students must produce and compare several ideas. This is the condition for divergent thinking that Guilford placed at the centre of creativity [11]. The problem has to be authentic for the students: a local water shortage or the cost of school lighting motivates more than an abstract exercise.

2. Interdisciplinary integration. Perignat and Katz-Buonincontro found that STEAM programmes range from loosely connected activities to projects in which the subjects are hard to separate [10]. Only the second kind changes how students think. Consider a project on reducing noise in the school canteen. Students measure sound levels in decibels and compare them with health norms (mathematics, physics), build sound-absorbing panels from cheap materials (engineering) and decide how the panels should look on the wall (arts). No single subject could have produced the solution. Creativity benefits because ideas are transferred between domains; Root-Bernstein and Root-Bernstein describe such transfer through analogy and pattern recognition as a common tool of creative people [12].

3. The engineering design cycle. Dewey's idea of learning through experience [13] and Kilpatrick's project method [14] are the didactic foundation of the STEAM project. What STEAM adds is iteration. The engineering design process taught in many school programmes runs through asking, imagining, planning, creating and improving, and it

returns to earlier steps whenever a prototype fails (Figure 2). Students soon see that the first version rarely works. Kapur's research on "productive failure" shows that students who first struggle with a problem and then receive instruction understand concepts more deeply than those taught first [15]. For creativity, the cycle develops elaboration and usefulness: an idea is not finished until it has been tested. The condition is time. A project squeezed into one lesson leaves no room for a second attempt.

Figure 2. The engineering design cycle and the creativity indicators developed at each step (compiled by the author)

4. The arts component. The "A" is what separates STEAM from STEM. Root-Bernstein and colleagues found that Nobel laureates in science were considerably more likely than other scientists to have serious arts avocations [16]. In the classroom, the arts bring design, visualisation, storytelling and attention to the user. Asking how a device looks, how comfortable it is to use and how it will be explained to others moves students from "it works" to "it is worth using" [17]. The risk, noted by Perignat and Katz-Buonincontro, is tokenism: drawing a poster after the engineering is done does not add a way of thinking [10].

5. Collaborative idea generation. STEAM projects are usually carried out in groups of three to five, which makes structured idea-generation techniques practical. Brainstorming separates generating ideas from judging them; synectics uses analogies to make the familiar strange [18]; TRIZ offers systematic ways to resolve technical contradictions [19]. These techniques increase fluency and originality, but only if their rules are taught explicitly. Unstructured group discussion is often dominated by one or two students.

6. Digital making. Coding, robotics, 3D modelling and digital design shorten the path from idea to prototype, so students can try several versions of a solution. Papert's constructionism explains why this matters: students learn most when they build a shareable object, because the object makes their thinking visible and open to revision [20]. The condition is that the tool serves the idea. Assembling a robot from step-by-step instructions is technical training, not creative work.

7. Process-oriented assessment. Traditional grading rewards the correct final answer. STEAM assessment can instead record the process: how many ideas were proposed, how the chosen one was justified, what changed after testing. Rubrics developed and piloted in an OECD project across 11 countries show that creativity can be assessed in ordinary classrooms when criteria are shared with students in advance [21]. Self- and peer assessment also develop reflection, which is especially important when students work independently.

Discussion.

The seven opportunities are potential, not guaranteed outcomes. The mixed meta-analytic results [8; 9] can be read through the conditions in Table 1. Four limiting factors stand out (Table 2).

Table 2. Factors limiting the creative effect of STEAM in independent learning.

Factor	Risk	Response in independent learning
Insufficient guidance	Cognitive overload; copying ready answers	Worked examples and checklists at the start; support withdrawn step by step
Tokenistic arts	STEAM reduced to STEM plus a poster	Design and user requirements written into the task brief from the start
Time and resources	No room for a second prototype; no laboratory	Projects spread over two to three weeks; low-cost and recycled materials
Generative AI	Text produced without the student's own thinking	Assessment of the prototype, test records and drafts as well as the report

The first is guidance. Hmelo-Silver, Duncan and Chinn argue that problem-based and inquiry learning succeed when they are heavily scaffolded, with the teacher modelling strategies and structuring the task [22]. Open STEAM projects without such support can overload students who lack basic knowledge, which may explain the weaker results in primary school [9]. The teacher's support should be strongest at the start and reduced gradually. The second is the arts component: if it is reduced to decoration, STEAM becomes STEM with a poster. The third is time and resources. Iteration needs several lessons, and many general schools have no laboratories; low-cost materials (cardboard, recycled plastic, simple electronics) allow the design cycle to work without expensive equipment. The fourth is generative AI. UNESCO warns that excessive reliance on such tools can weaken students' own thinking [23]. A STEAM task built around testing a physical prototype or a local problem is harder to outsource to a chatbot than a written report, which is an argument for making the product, not the text, the centre of assessment.

For Uzbekistan, the experience of Presidential schools [6] provides tested materials, but transferring it to general schools requires adapting projects to available resources and preparing teachers to manage open-ended work rather than deliver content.

Conclusion.

Calling a lesson STEAM does not make it develop creativity. What matters is whether the seven opportunities described here are actually used and whether their conditions are met: support that is reduced step by step, enough time to fail and try

again, a real role for the arts and assessment that records the process. These conditions explain much of the variation in the effects reported in the literature.

Independent learning is where these conditions are hardest to secure, since the teacher is not present during most of the work.

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