# DEVELOPING STUDENTS' RESEARCH COMPETENCIES IN SCIENCE CLASSES THROUGH THE STEAM APPROACH (ON THE EXAMPLE OF GRADE 6)

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**ANNOTATION:** This article presents methodological approaches aimed at developing research competencies in sixth-grade students through the implementation of the STEAM approach in science classes. As a core component of STEAM, the integration of biology, physics, geography, mathematics, and technology subjects is emphasized. The study analyzes how project-based learning, hands-on experiments, modeling, and differentiated assessment contribute to the formation of students' skills in scientific inquiry, observation, analysis, and drawing conclusions. Furthermore, the effectiveness of this approach is evaluated based on experimental trials conducted in real classroom settings.

**KEY WORDS:** STEAM approach, research competency, science education, grade 6, project-based learning, modeling, hands-on activities.

## INTRODUCTION

In the 21st century, the rapid advancement of technology, the surge of scientific discoveries, and the exponential growth of information flows on a global scale have created an urgent need for the development of new types of competencies in learners. Today's students are expected not merely to memorize traditional knowledge, but to critically analyze it, apply it to real-life situations, solve problems based on scientific reasoning, and demonstrate innovative thinking. These global shifts naturally demand profound reforms within educational systems.

International experience demonstrates that countries which have achieved notable success in modern education-such as Finland, South Korea, Japan, Singapore, and Canada-are placing an emphasis on nurturing students' analytical thinking, creative problem-solving, interdisciplinary integration, collaboration, and evidence-based reasoning. For example, in Finland, instead of delivering subject-specific knowledge in isolation, an integrated project-based learning system grounded in real-world challenges has been introduced. Through this approach, students are given the opportunity to test and apply their knowledge in practical contexts.

In South Korea, the education system has prioritized the development of students' research and inventive capacities through the STEM (Science, Technology, Engineering, Mathematics) approach, which has later evolved into STEAM with the inclusion of the Arts. Beginning at the school level, students are actively engaged not only in basic laboratory activities but also in designing real-life projects, engaging in robotics, and proposing solutions to ecological problems-all within the context of science classes.

In Uzbekistan's education system, these global trends have also been taken into consideration. In recent years, new-generation textbooks based on a competency-based approach have been gradually introduced. Notably, the Grade 6 "Science" textbook is designed with an emphasis on interdisciplinary integration, inquiry-based tasks, modeling, and project-based teaching methods. This approach not only helps students develop subject-specific knowledge in biology, geography, and physics, but also enables them to apply this knowledge to real-world problems through a holistic and integrated learning process.

Such an educational model aims to transform students from passive recipients of information into active creators of knowledge. For instance, the "Science" textbook includes tasks such as "Model the structure of a cell," "Investigate the states of water through experimentation," and "Create a model of the atmospheric layers." Through these activities, students engage in key stages of scientific inquiry: making observations,

asking questions, formulating hypotheses, conducting experiments, analyzing results, and drawing conclusions. This hands-on approach not only increases interest in science, but also fosters 21st-century skills such as critical thinking, problem-solving, collaboration, and creativity. Moreover, it contributes to the formation of a competitive, innovation-oriented personality aligned with the demands of the modern labor market.

Thus, in contemporary education, the student should no longer be seen merely as a recipient of knowledge, but as a generator of knowledge, a practitioner who applies learning in real-life contexts, and a socially beneficial actor. In this process, STEAM-based instructional methods and interdisciplinary textbooks like "Science" play a pivotal role.

The primary objective of our research is to develop a methodological framework for fostering research competencies in Grade 6 students through the application of the STEAM approach (Science, Technology, Engineering, Arts, Mathematics) in science lessons. This involves deepening students' subject knowledge through interdisciplinary connections, stimulating their interest in scientific inquiry, and reinforcing their ability to apply knowledge in practice through experimentation and modeling. Recent international studies (e.g., PISA and TIMSS) indicate that students' logical thinking, scientific literacy, and problem-solving abilities are not solely dependent on theoretical knowledge but are directly linked to their level of engagement in hands-on, practical activities. This further underscores the significance of lesson methodologies rooted in STEAM principles, particularly those that utilize project work, experimentation, and modeling.

Our research is guided by the following key objectives:

*1. To define the content and significance of research competence.*

Research competence is one of the core priorities in modern education. It encompasses a student's interest in scientific problems, the ability to work independently, carry out systematic observations, ask meaningful questions, propose hypotheses, conduct experiments, and draw analytical conclusions. This competency serves as a fundamental pillar not only in science education but across all subject areas. Educational reforms in Finland, the implementation of a national STEM-based curriculum in Singapore, and the widespread adoption of Inquiry-Based Learning in Canada provide concrete evidence of the growing importance of research competencies in global education systems.

*2. To analyze the components of the STEAM approach.*

Each component of STEAM serves a distinct didactic function: *Science* develops observation and scientific analysis; *Technology* fosters the use of modern tools and digital literacy; *Engineering* teaches systematic thinking and problem-solving through design; *Arts* promotes creativity, design thinking, and visual communication; *Mathematics* supports logical reasoning and quantitative analysis.

In many international educational systems, these components are harmoniously integrated into a single learning process. Students are tasked with solving real-world problems through interdisciplinary projects. This integrated approach not only strengthens cross-curricular connections but also fosters independent decision-making in authentic contexts. For instance, in the U.S., the Next Generation Science Standards (NGSS) incorporate STEAM-based learning from early grades, where each lab or project is designed to address a specific real-world challenge.

*3. To guide students toward scientific inquiry through project-based learning, experimentation, and modeling.*

*Project-Based Learning (PBL)* is an innovative methodology that cultivates independent inquiry, collaborative thinking, problem-solving, and the ability to present results effectively. Experimentation and modeling, in turn, enable students to apply theoretical knowledge in practical scenarios. For example, through a project such as *"Modeling the structure of Earth's atmosphere,"* students not only memorize information about the geosphere layers, but also draw, calculate physical parameters, and build models. This process integrates knowledge from biology, geography, physics, and the arts into a single, cohesive learning experience.

International studies, particularly in *Canada and Australia*, have shown that using modeling in science

lessons significantly improves students' comprehension of complex concepts. These methods do not merely increase student engagement but also ensure long-term retention and application of knowledge.

*4. Evaluating the Effectiveness of the Proposed Methodology Through Experimental Testing.*

Any methodology attains its true value only when its effectiveness is demonstrated in practice. Therefore, within the framework of this study, the STEAM-based instructional methodology was tested experimentally, focusing on evaluating students' performance indicators such as knowledge level, inquiry activity, independent thinking, and readiness for practical application.

Changes observed in the control and experimental groups were assessed using both quantitative and qualitative indicators. For example, students in the experimental group demonstrated a higher level of creativity during lab activities and project-based tasks, showed increased engagement in asking questions, and provided well-structured justifications for their hypotheses-serving as evidence of the methodology's practical effectiveness.

In international practice, especially in the *United States* and *United Kingdom*, any new instructional methodology is first introduced in the form of a *pilot project* before being widely implemented. Therefore, this stage is considered one of the most critical components of educational research.

This scientific study analyzed the development of research competencies in 6th-grade students through STEAM-based instruction in Natural Sciences. The research design was based on international educational models, particularly the *quasi-experimental design*, which allows comparison between groups while controlling for certain variables.

- *Research Object*: 6th-grade students studying Natural Sciences.
- *Target Age Group*: 11–12 years old - a crucial stage in cognitive development when learners begin forming logical reasoning, understanding cause-and-effect relationships, and developing readiness for scientific inquiry.

This developmental stage provides an optimal *psychopedagogical foundation* for cultivating research competence.

- ○ *Research Subject*: Methodological tools aimed at developing students' research competence through the STEAM approach. These included: *Project-Based Learning (PBL); Scientific modeling; Experimentation; Tasks focused on solving real-world problems.*

The overarching goal of these methods is to transform the student from a *passive recipient* of information into an *active investigator and creator of knowledge*. This principle is central to international educational frameworks such as the *Next Generation Science Standards (NGSS)* in the U.S. and *Inquiry-Based Science Education (IBSE)* in Canada and Singapore.

*Methods Applied During the Study:*

- *Practical Observation*: Continuous monitoring of students' participation, engagement, questioning, and attitude towards experiments during lessons.
- *Experimental Teaching*: The experimental group was taught using the proposed methodology for one academic term. Their results were compared to those of a control group taught using traditional methods.
- *Testing*: Special assessments were designed to evaluate students' level of knowledge and their research competencies (observation, hypothesis formation, analysis, and conclusion).
- *Project Work*: Each student completed an individual or group scientific mini-project (e.g., *"Water Cycle Model"*, *"Factors Influencing Plant Growth"*).
- *Semi-structured Interviews*: Conducted to assess students' motivation, interest, and ability to articulate their thoughts.
- *Modeling*: Students created visual models (e.g., 3D representations, system diagrams) to deepen their understanding of biological and ecological concepts.

These methods were selected based on the *blended evaluation approach* commonly used in international practice, wherein students are assessed not only by their final outcomes but also based on their

engagement and reasoning throughout the learning process.

The experimental testing was conducted at *School No. 114 in Chilonzor district, Tashkent city.* The school was selected due to its availability of modern-generation textbooks, laboratory equipment, and sufficient material-technical resources suitable for project-based and STEAM-integrated instruction. The research was carried out during the *2024–2025 academic year*.

Before implementation, detailed coordination was carried out with the participating teacher. STEAM-aligned practical and project-based tasks were incorporated into the lesson plans. Two groups participated in the research:

- *experimental group*: In this group, lessons were conducted using the STEAM approach, incorporating project-based assignments, modeling, hands-on experiments, and problem-solving activities. Instruction was designed to promote active inquiry, creativity, and interdisciplinary thinking.
- *control group*: This group was taught using traditional methods such as lectures, teacher-led discussions, and standard Q&A sessions. Students in this group participated more passively in the learning process, with minimal use of experimental or project-based learning techniques.

At the end of the experimental cycle, both groups were administered identical tools for assessment, including standardized tests, project tasks, and structured interviews. The collected data was analyzed both *quantitatively* (using statistical methods) and *qualitatively* (through content analysis of students' responses and projects).

This research design-*quasi-experimental* in nature-is widely used in international pedagogical research, as recommended by institutions like the ***Harvard Graduate School of Education*** and organizations such as the ***OECD***. Such a design allows for reliable comparison of instructional outcomes under real-world classroom conditions without the need for full randomization.

In our case, this methodological approach not only tested the theoretical framework but also generated ***practical evidence*** of its effectiveness. Measurable changes in students' skills, engagement, and development of research competencies were documented. These outcomes provide a strong foundation for arguing in favor of the ***practical value*** of the proposed STEAM-based methodology and its ***potential for wider integration*** into the national education system.

**Main section (analysis and results).** The modern education paradigm demands investment in human capital. Nowadays, the primary expected outcome of education is to transform students from traditional knowledge recipients into innovative and complex thinkers capable of analyzing real-world problems. One of the widely recognized approaches worldwide to achieve this goal is the STEAM model. The core idea of the STEAM concept is to teach the aforementioned subjects not separately but in an integrated and interconnected way, solving related problems collectively. This approach educates students through a multi-level system of interconnected knowledge that is close to real life. At the center of the learning process is a problem, question, or project through which the student unites all their knowledge and strives to achieve results.

Internationally, the STEAM approach has been successfully implemented in countries such as the United States, Finland, South Korea, Australia, and Singapore. For example, in the United States, STEAM became a priority in educational policy starting in the 2000s. In collaboration with major scientific centers such as NASA and MIT, STEM and STEAM laboratories were established in schools, where students participate in real projects ranging from building satellite models to finding solutions to environmental problems. In Finland, interdisciplinary integration is reflected in lessons conducted through phenomenon-based learning. For instance, the topic "Climate Change" is covered by linking biology, geography, mathematics, and technology through project work. In South Korea, the STEAM approach plays a key role in enhancing students' design thinking and technological literacy. Every school is equipped with STEAM laboratories for engineering basics and experiments, which fosters early interest in engineering and IT fields.

In classes taught through the STEAM approach:

- students learn critical thinking and systematic analysis;
- creative approaches and aesthetic thinking develop (through the arts component);
- skills in teamwork, sharing ideas, and reaching compromises improve;
- the ability to draw conclusions based on experiments and to strive to prove one's hypothesis strengthens.

STEAM ensures that students acquire knowledge through personal experience, fostering a truly constructive educational approach.

In Uzbekistan's education system, the early stages of this approach are visible in the new-generation 6th-grade "Natural Sciences" textbook. For example:

- modeling assignments (such as creating a "Model of the Earth's Atmosphere");
- experiment-based analysis (like measuring the evaporation of water);
- problem-based learning (e.g., "What causes global warming?");
- interactive group work (projects on "Ways to preserve ecosystems").

Through this, biology, geography, physics, technology, and even computer science complement each other. This way, the student understands the real-life significance of each studied topic and is motivated to test their knowledge in practice.

In our opinion, STEAM is not just integrated teaching but a conceptual method that actively engages the student in exploration, promotes deep knowledge acquisition, and prepares them for real life. International experience and practical trials show that students educated on a STEAM basis, compared to their peers in traditional education, are more interested in scientific research, have higher potential for innovation, and are more active in teamwork and expressing opinions. Systematic and well-founded implementation of this approach in the local education system serves as an important tool in developing students' research competencies.

Research competence is one of the crucial competencies of a modern student, reflecting their scientific thinking, active knowledge acquisition, and ability to conduct independent scientific inquiry. This competence comprehensively includes the student's ability to apply knowledge, solve problems, create new knowledge through observation, and draw conclusions based on projects and experiments. Below are the main components of research competence, enriched and explained with examples from international practice:

*1.Scientific Observation and Questioning.* Scientific thinking begins with the ability to observe and ask questions. A student's ability to observe real-life phenomena and formulate questions like "Why is this happening?" or "What would happen under different conditions?" is the first stage of scientific inquiry. In Canadian schools, a "Wonder Wall" is set up for grades 5-7, where students write down questions daily based on their observations, which then serve as a basis for project or experimental activities. In Singapore, students keep a "Science Journal" -each student observes a natural phenomenon or process weekly and records their questions and observations.

*2. Formulating Hypotheses.* After observation, the student proposes their personal assumption - a hypothesis. This hypothesis forms the foundation for the experiment they plan to conduct. Importantly, the student understands the hypothesis not just as "right" or "wrong," but as a testable assumption. In Australia, the "What if?" strategy is used to develop students' hypothesis-formulating skills, encouraging them to ask questions like: "What if this factor changes? How would the result be affected?"

*3.Conducting Experiments and Recording Results.* The most effective way to test a scientific hypothesis is through experimentation. The student plans the experiment carefully, selects necessary tools, defines procedures, and carries it out. Keeping accurate and systematic records throughout the process is essential. In some U.S. states, 6th and 7th graders maintain a "lab logbook" where they document step-by-step actions, observations, changes, and results. In Germany, students learn to express experimental results numerically and represent them graphically, which helps them develop skills in data analysis.

*4. Analyzing and Drawing Conclusions.* The most crucial stage of research competence is analyzing the results and drawing conclusions based on the hypothesis. The student compares the results, identifies

expected and unexpected outcomes, investigates causes, and substantiates whether their hypothesis is correct or not. This process teaches logical thinking, critical analysis, and objective evaluation. In the UK's KS3 Science Curriculum, students are asked after each experiment: "How does your result support or refute your hypothesis?" This question helps students justify their conclusions. In Norway, post-experiment analysis is conducted as a group discussion, fostering collaborative thinking skills.

*5.Presenting Results.* At the end of the research, the student must share their results in written, oral, or visual form. This stage develops communication, presentation, design, and aesthetic expression skills, highlighting the integration between "science" and "art" (the "A" in STEAM). Students present their work clearly and engagingly through infographics, presentations, posters, models, or videos. In Estonia, students present their experimental projects at the "Young Scientist Expo," allowing them to showcase their scientific thinking publicly. In the U.S., "Science Fairs" provide a platform for students to defend their scientific projects before experts, helping them develop skills to justify their ideas, answer questions, and communicate results to a wider audience.

In our opinion, research competence is not merely memorizing textbook knowledge but involves creating, testing, analyzing, and presenting knowledge. This competence shapes scientific thinking, engages the student as an active participant, and develops independent thinking, analytical, and communication skills. Therefore, the STEAM approach is one of the most suitable, modern, and effective methods for developing this competence.

Practical assignments based on the STEAM approach bring students closer to scientific activity, reinforce their knowledge through experimentation, and encourage the application of theory in practice. Below, real examples of such assignments illustrate how scientific inquiry, independent thinking, analysis, and result-oriented learning are fostered in students.

**1."Rate of Water Evaporation" Experiment**

**Objective:** to determine the relationship between heat and evaporation by comparing the rate of water evaporation in environments with different temperatures.

**Process:** students pour equal volumes of water into containers and place them in three different conditions (room temperature, warm place, cold place). They measure the decrease in water volume over a set period; each group records their observations in tables and represents the data graphically. Then, based on their hypothesis (e.g., "Water evaporates faster in a warm environment"), they draw conclusions.

**Developed Competencies:** scientific observation and experimentation; drawing conclusions based on hypotheses; mathematical thinking (creating graphs and tables); communication (through presentations).

**Interdisciplinary Integration:** Physics (heat, evaporation), Biology (water cycle), Mathematics (measurement and graphs).

**2."Earth's Atmosphere" Project**

**Objective:** to study the layers of the Earth's atmosphere, identify their functions, and represent them through a model.

**Process:** students work in small groups conducting independent research on atmospheric layers (studying sources, gathering information); they identify main features of each layer (troposphere, stratosphere, mesosphere, thermosphere, exosphere): temperature, altitude, phenomena (e.g., weather in the troposphere, ozone layer in the stratosphere). Students creatively present this knowledge by creating a 3D model and present it in class.

**Developed Competencies:** information search and analysis; modeling and design skills; presentation and teamwork; integrated understanding of natural sciences.

**Interdisciplinary Integration:** Geography (layers, altitude), Biology (conditions for life), Art and Design (model), Technology (material selection, construction).

**3. "Cell Model" Modeling Task**

**Objective:** To study the structure of animal and plant cells and strengthen memory through practical modeling of their parts.

**Process:** Students learn the parts of a cell (nucleus, cytoplasm, cell wall, chloroplasts, vacuole,

mitochondria, etc.); then they create 3D models of animal and plant cells using plasticine, cardboard, gel, or other materials; they label each part and write explanations of their functions.

**Developed Competencies:** Anatomical and functional analysis; modeling through crafting; memory and aesthetic imagination; visual expression and explanation.

**Interdisciplinary Integration:** Biology (cell structure), Art (modeling), Technology (working with materials), Language (written explanations, oral presentation).

**4."Find the Elements!" Interactive Game**

**Objective:** To reinforce knowledge about chemical elements, practice locating them in the periodic table, and develop analytical skills.

**Process:** Students are given the symbol, atomic number, or physical property of an element; they identify the corresponding element on the periodic table through an interactive game; then they research and present additional information about the element (where it is found, its uses). The game can be digitized using QR-coded cards or digital test platforms.

**Developed Competencies:** Attention and quick thinking; analytical thinking; digital literacy (if played digitally); quick information retrieval and understanding.

**Interdisciplinary Integration:** Chemistry (elements, periodic table), Informatics (digital games), Physics (element properties), Language (information presentation).

**5.Differentiated Testing for Assessment**

**Objective:** To accurately identify each student's research competencies through assessment tailored to individual learning levels.

**Process:** Test tasks are structured at three levels: reproductive (basic knowledge), analytical (logical connections), creative-research (problem-solving, hypothesis formulation); each student receives a test appropriate to their preparation level; results are analyzed to identify well-developed and needing improvement competencies.

**Developed Competencies:** Independent thinking and analysis; critical and creative approaches; self-assessment and reflection.

**Interdisciplinary Integration:** Tests based on each subject (biology, chemistry, physics, technology), psychology (individual approach), methodology (assessment tools).

As part of the research, an experimental learning process based on the STEAM approach was organized with experimental and control groups to determine the effectiveness of the developed methodology. During the 6th grade "Natural Sciences" lessons, students in the experimental group were taught through project-based learning, practical assignments, modeling, and differentiated assessment methods. The control group received traditional education based on standard textbooks and oral explanations. At the end of the experiment, the performance of students in both groups was analyzed across several key competencies:

| [1] Indicator | [2] Control group (%) | [3] Experimental group (%) |
|---|---|---|
| [4] Independent Thinking | [5] 45% | [6] 78% |
| [7] Scientific Research Ability | [8] 40% | [9] 82% |
| [10] Completion of Practical Tasks | [11] 50% | [12] 85% |

The above indicators demonstrate that the education process organized based on the STEAM approach has significantly increased students' levels of independent thinking (by 33%), nearly doubled their scientific research competencies (by 42%), and improved the effectiveness of completing practical tasks by 35%. These results reflect not only statistical differences but also qualitative changes. The activity level of students, their speed in asking questions, their ability to independently analyze problems, and their interest in finding solutions were clearly evident in the experimental group.

If this data were presented through graphs (bar charts, radar charts, or line graphs), it would be evident that the experimental group's indicators improved across all directions - meaning the STEAM approach deepened knowledge while also enhancing students' ability to work with it. The increase in independent thinking shows that students shifted from providing traditional answers to standard questions towards proposing solutions to problems. The improvement in scientific research skills confirms the mastery of

stages such as observation, hypothesis formulation, conducting experiments, and drawing conclusions.

The results of this study align with Vygotsky's "zone of proximal development" theory: new knowledge is learned faster and more effectively when delivered through interactive, practical, and collaborative activities. Likewise, according to Bruner's "constructivism" approach, children "construct" their knowledge through active engagement - exactly what we observed in the STEAM-model experimental group. Additionally, it can be seen that working at the higher levels of Bloom's taxonomy (analysis, synthesis, evaluation) has become routine for the students in the experimental group, which proves the real effectiveness of the competency-based approach.

**Conclusion and Recommendations:**

21st-century education demands students not only to passively acquire knowledge but also to search for knowledge independently, apply it in real life, and be capable of innovation. Based on the experimental work conducted within this research, it can confidently be stated that the education process organized on the basis of the STEAM approach is a highly effective methodology that meets these demands. The development of research competencies motivates students to ask scientific questions, observe problems, investigate their causes, and draw conclusions based on experiments. This was clearly demonstrated by the experimental group. The STEAM approach enables genuine integration between biology, physics, geography, technology, and mathematics. Students begin to understand the internal connections between subjects rather than artificial boundaries, leading to deeper and more meaningful learning and increased interest in science. Students not only learn but also discover, think critically, experiment, and draw conclusions - ensuring knowledge is solid and functional. Additionally, through project-based and practical tasks, students develop teamwork, communication, design thinking, critical, and creative thinking skills - essential competencies for the 21st century.

Taking into account the results of this research and international best practices, the following recommendations are proposed:

1. To include more STEAM-aligned tasks in textbooks and methodological manuals;
2. To organize specialized professional development courses for teachers on STEAM;
3. To widely implement laboratory and experimental equipment in schools.

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