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# THE PRACTICE OF USING STEM/STEAM TECHNOLOGIES IN THE INTELLECTUAL DEVELOPMENT OF PRESCHOOL CHILDREN

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**Abstract** The rapid transformation of education systems has increased the demand for pedagogical approaches that develop not only children's factual knowledge but also their ability to investigate, reason, create, communicate and solve problems. In this context, STEM and STEAM education have gained increasing significance in early childhood education. This article examines the pedagogical potential and practical application of STEM/STEAM technologies for promoting the intellectual development of preschool children. The study employs qualitative analysis, pedagogical observation, activity-based interpretation and comparative analysis of contemporary research on early childhood STEM/STEAM education. Particular attention is given to inquiry-based learning, problem-solving activities, engineering design, mathematical exploration, creative construction and technology-supported learning. The analysis indicates that developmentally appropriate STEM/STEAM activities can strengthen children's curiosity, logical reasoning, spatial thinking, creativity, collaboration and ability to formulate and test solutions. At the same time, successful implementation depends on teachers' methodological competence, appropriate learning materials, age-sensitive tasks and a balanced combination of digital and hands-on activities. The article concludes that STEM/STEAM should not be interpreted as the premature academic teaching of separate scientific disciplines. Rather, it should function as an integrated, play-based and inquiry-oriented pedagogical approach that enables young children to explore meaningful problems and construct knowledge through active experience.

**Keywords:** STEM education, STEAM education, preschool children, intellectual development, innovative teaching methods, inquiry-based learning, creativity, problem-solving, early childhood education.

## INTRODUCTION

Early childhood represents a particularly important period for cognitive development because children actively construct their understanding of the surrounding world through observation, experimentation, communication and play. Developmentally appropriate early education therefore requires learning environments in which children are encouraged to ask

questions, investigate phenomena, establish relationships and develop explanations rather than merely reproduce information. The National Association for the Education of Young Children (NAEYC) emphasizes that young children benefit from equitable learning opportunities that support development across multiple domains and that developmentally appropriate practice should be strengths-based, play-based and engaging.

Within this context, STEM—Science, Technology, Engineering and Mathematics—and its expanded form, STEAM, which incorporates Arts, provide a promising framework for integrating different areas of children's learning. The significance of such integration lies in its potential to connect scientific inquiry with mathematical reasoning, technological exploration, creative expression and engineering-oriented problem-solving.

The relevance of this approach is particularly evident in Uzbekistan. National policy has increasingly emphasized the introduction of innovative pedagogical technologies and the development of children's intellectual abilities. A 2022 governmental decision specifically provided for the gradual organisation of activities based on the STEAM approach in preschool educational organisations from the 2022–2023 academic year. More recent policy developments have continued to emphasise the professional development of preschool educators and the introduction of contemporary pedagogical methods and interactive learning resources.

International research also indicates growing scholarly interest in STEM integration during the preschool and early primary years. A systematic qualitative review of 60 studies identified a broad range of approaches to STEM integration among children aged 4–12, demonstrating that STEM learning can be organized through inquiry, problem-solving, engineering and other integrated pedagogical approaches. A 2025 systematic review and meta-analysis further examined STEM-related approaches to teaching problem-solving in early childhood education and care, screening more than 13,000 abstracts and including 19 studies in the systematic review.

Despite these developments, the implementation of STEM/STEAM in preschool settings requires methodological caution. Young children should not be exposed to abstract scientific instruction that is disconnected from their developmental characteristics. Instead, STEM/STEAM activities should emerge from children's natural curiosity and involve concrete objects, experimentation, construction, movement, visual representation and discussion.

The purpose of this article is therefore to examine how STEM/STEAM technologies can be used as pedagogical tools for strengthening the intellectual development of preschool children and to identify practical principles for their effective implementation.

The objectives are to:

1. clarify the pedagogical relationship between STEM/STEAM education and preschool intellectual development;
2. identify developmentally appropriate STEM/STEAM learning activities;
3. examine their potential contribution to problem-solving, creativity, reasoning and inquiry;
4. determine methodological conditions necessary for effective implementation in preschool settings.

**METHODS**

The study employed a qualitative pedagogical research design. The methodological framework combined theoretical analysis, comparative analysis, pedagogical observation and activity-based interpretation.

First, relevant scholarly literature on early childhood STEM/STEAM education was examined to identify major theoretical and methodological trends. Particular attention was paid to research addressing problem-solving, integrated STEM teaching, outdoor learning environments and STEAM-based learning media. Recent systematic reviews indicate that STEM/STEAM activities in early childhood are associated with cognitive development, problem-solving and other learning outcomes, although implementation conditions remain important.

Second, STEM/STEAM activities were conceptually analyzed according to five interconnected dimensions:

- **scientific inquiry** — observing, questioning, predicting and testing;
- **technology** — using tools and age-appropriate digital resources;
- **engineering** — designing, constructing, testing and improving;
- **arts** — representing ideas through drawing, modeling, music and creative design;
- **mathematics** — counting, measuring, comparing, classifying and recognizing patterns.

Third, the pedagogical activities were analyzed according to their potential contribution to children's intellectual development. The principal indicators were:

1. curiosity and questioning;
2. logical reasoning;
3. problem-solving;
4. spatial thinking;
5. creativity;
6. communication and collaboration;
7. ability to predict and evaluate outcomes.

The study also adopted the principle of developmental appropriateness. This means that activities should correspond to children's age, previous experience, interests and individual learning characteristics. NAEYC's framework identifies children's individuality, developmental commonalities and learning contexts as important considerations when designing developmentally appropriate educational experiences.

Technology was consequently treated not as an end in itself but as one possible pedagogical tool. NAEYC guidance similarly stresses that technology and interactive media can support young children's learning when used intentionally and appropriately, while limitations on technology use remain necessary.

**RESULTS**

The analysis indicates that STEM/STEAM technologies can support preschool children's intellectual development most effectively when activities are organised around meaningful problems rather than isolated disciplinary exercises.

**3.1. Development of problem-solving abilities**

Problem-solving emerged as one of the most important outcomes of STEM/STEAM activities. For example, children can be asked to construct a bridge capable of supporting several toy figures. Instead of receiving a predetermined solution, children select materials, construct a model, test its stability and modify the design.

Such activities require children to identify a problem, generate possible solutions, evaluate consequences and revise unsuccessful attempts. The process therefore develops flexible thinking and encourages children to perceive mistakes as part of learning.

This finding is consistent with recent systematic evidence showing that STEM-related teaching approaches can be used to develop problem-solving skills in early childhood education.

**3.2. Development of logical and mathematical thinking**

STEM/STEAM activities create natural opportunities for mathematical reasoning. Children can count objects, compare quantities, classify materials, measure length, identify geometric shapes and recognize patterns while completing practical tasks.

For example, an activity entitled **“Build a Strong Tower”** can require children to compare the height and stability of structures. Children may initially construct a tower that collapses and subsequently discuss why it failed. They can then modify the number, position or shape of building blocks.

Mathematics consequently becomes embedded in meaningful activity rather than being presented as a series of abstract exercises.

**Development of creativity**

The integration of Arts distinguishes STEAM from a narrowly disciplinary STEM model. Creative activities enable children to represent scientific and mathematical ideas through drawing, modelling, storytelling, music and visual design.

For instance, after observing plants, children can design and draw an imaginary “smart garden”. They can decide where plants should be placed, create models from recycled materials and explain the function of each element.

Recent research similarly identifies STEAM learning as relevant to creativity, inquiry, collaboration and problem-solving in early childhood.

**Development of inquiry and scientific thinking**

Inquiry-based STEM/STEAM activities encourage children to move through a simple cycle:

**Question → Prediction → Experiment → Observation → Explanation → Revision**

A teacher might ask:

“Which objects will float and which will sink?”

Children can first predict the outcome, test different objects, observe what happens and then discuss possible explanations. The educational value of such an activity lies not in memorizing the concept of buoyancy but in experiencing the process of inquiry.

**Development of collaboration and communication**

Many STEM/STEAM activities naturally require children to work in pairs or small groups. During construction tasks, for example, children need to negotiate roles, exchange ideas, explain decisions and reach collective solutions.

Consequently, intellectual development is connected with social and communicative development. Children learn not only to formulate their own ideas but also to listen to alternative explanations and reconsider their initial assumptions.

**Practical model of a preschool STEAM activity**

A practical STEAM lesson can be organized around the following sequence:

| **Stage** | **Teacher’s role** | **Children’s activity** |
|---|---|---|
| Engagement | Presents a problem | Ask questions |
| Exploration | Provides materials | Observe and experiment |
| Design | Encourages alternatives | Construct a model |
| Testing | Asks guiding questions | Test the solution |
| Improvement | Provides feedback | Modify the model |
| Reflection | Encourages explanation | Describe what was learned |

This model demonstrates that the teacher functions primarily as a facilitator rather than as the sole source of knowledge.

**DISCUSSION**

The findings support the view that STEM/STEAM education can become an effective pedagogical mechanism for intellectual development when it is integrated with play, exploration and children's everyday experiences.

A central methodological issue is the distinction between **teaching STEM content** and **developing STEM-oriented thinking**. In preschool education, the second objective is generally more developmentally appropriate. Children do not need formal definitions of engineering or advanced mathematical formulas. Instead, they need opportunities to observe, compare, predict, construct, test and explain.

This approach corresponds closely with developmentally appropriate practice, which emphasizes joyful, engaged and play-based learning.

Another important issue concerns the role of technology. Digital tools can enrich STEM/STEAM learning through interactive simulations, digital storytelling, coding activities and visual representations. However, excessive screen-based learning may reduce opportunities for physical manipulation, social interaction and direct exploration. Therefore, technology should complement rather than replace hands-on experience. NAEYC specifically stresses intentional and appropriate use of technology in early childhood settings.

The Uzbek educational context provides favorable institutional conditions for the development of this approach. The 2022 policy framework explicitly established the gradual introduction of STEAM-based activities in preschool organizations. This creates a practical basis for developing locally relevant teaching materials, teacher-training programs and methodological guidelines.

However, several challenges should be acknowledged. First, successful STEAM implementation requires teachers who understand not only individual STEM disciplines but also principles of interdisciplinary integration. Second, access to appropriate materials and

equipment may vary between institutions. Third, assessment should focus on children's processes of thinking and problem-solving rather than simply on the final product.

A further consideration is educational equity. STEM/STEAM activities should be accessible to children with different abilities, linguistic backgrounds and levels of prior experience. Early childhood education should therefore avoid designing STEM programs that depend excessively on expensive technological equipment. Simple materials such as paper, blocks, water, sand, recycled objects, natural materials and measuring tools can support meaningful inquiry.

The broader implication is that STEAM should be understood as a pedagogical culture of exploration rather than merely a collection of technological devices. Its effectiveness depends primarily on the quality of children's questions, the opportunities they receive to experiment and the teacher's ability to scaffold their reasoning.

## CONCLUSION

STEM/STEAM technologies have substantial potential for supporting the intellectual development of preschool children. When appropriately adapted to children's developmental characteristics, they can foster curiosity, logical reasoning, mathematical thinking, creativity, problem-solving, communication and collaborative learning.

The most effective implementation model is based on play, inquiry, experimentation and practical problem-solving. Children should be encouraged to formulate questions, make predictions, construct solutions, test their ideas and improve their designs. Such a process transforms learning from passive reception into active intellectual engagement.

For preschool educators, the principal methodological recommendation is therefore to integrate STEM/STEAM activities into everyday learning rather than treat them as isolated special lessons. Building towers, designing bridges, measuring objects, investigating water, observing plants, creating patterns, constructing models and solving simple technological problems can all become meaningful STEAM experiences.

The evidence reviewed in this article also suggests that technology should be used intentionally and in combination with hands-on activities. Professional development for preschool teachers is particularly important because effective STEAM implementation depends on pedagogical knowledge, appropriate questioning techniques and the ability to create developmentally suitable learning challenges.

In the context of Uzbekistan, the institutional commitment to introducing STEAM in preschool education provides a strong foundation for further methodological development. Future research should examine the long-term effects of STEAM-based preschool programmes, develop culturally responsive learning models and investigate how teacher competence, learning environments and family involvement influence children's STEM-related development.

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