SPECIFIC CHARACTERISTICS OF THE STEM APPROACH IN PRIMARY EDUCATION

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Abstract. This article examines the specific characteristics of the STEM (Science, Technology, Engineering and Mathematics) approach as applied in primary education. It argues that STEM in the primary grades is not a simplified version of secondary STEM, but a distinct pedagogical model shaped by the cognitive, emotional and social features of children aged 6–11. The article outlines the theoretical foundations of the approach, identifies its key characteristics — integration, inquiry, play, hands-on activity, real-life context, collaboration and the engineering design cycle — and describes practical forms of implementation, including a sample integrated lesson. It concludes with the main challenges facing primary schools and recommendations for teachers and school leaders.

Keywords: STEM education, primary school, integrated learning, inquiry-based learning, engineering design, project-based learning, early mathematics and science.

1. Introduction

The rapid development of digital technologies, automation and the knowledge economy has changed the demands placed on school graduates. Modern society needs people who can think critically, solve unfamiliar problems, work in teams and apply knowledge from different fields at the same time. In response, education systems around the world have adopted the STEM approach, which brings science, technology, engineering and mathematics together into a single, practice-oriented learning model.

For many years, STEM was associated mainly with secondary and higher education. Today, researchers and policymakers increasingly agree that its foundations must be laid much earlier. The primary school years are the period when children's

curiosity is strongest, when their attitudes toward mathematics and science are formed, and when basic habits of observation, questioning and reasoning develop. A child who decides at the age of eight that "mathematics is not for me" is far less likely to choose a STEM pathway later. Early, positive and meaningful experience with STEM is therefore a strategic investment.

At the same time, STEM in primary school cannot simply copy the methods used with older students. Young learners think concretely, learn through play and movement, have a short attention span and depend heavily on emotional engagement. The purpose of this article is to identify the specific characteristics that distinguish the STEM approach in primary education and to show how these characteristics can be translated into everyday classroom practice.

2. Theoretical Foundations

The STEM approach in primary education rests on several well-established theories of learning. John Dewey's idea of "learning by doing" holds that knowledge is most durable when children acquire it through purposeful activity connected to real experience. Jean Piaget showed that children of primary age are at the stage of concrete operations: they reason logically, but mainly about objects and events they can see and manipulate. This explains why physical materials, models and experiments are central to primary STEM.

Lev Vygotsky's sociocultural theory adds that learning is a social process. Children move forward within their "zone of proximal development" when they work with a teacher or more capable peers. Constructivism and its later form, constructionism (Seymour Papert), stress that learners build understanding most effectively when they build something tangible — a model, a machine, a simple program.

In the STEM literature, scholars distinguish several levels of integration. In the *disciplinary* model, subjects are taught separately; in the *multidisciplinary* model, they

are linked by a common theme; in the *interdisciplinary* model, knowledge and skills from several subjects are combined to solve a single problem; and in the *transdisciplinary* model, learning is organised around real-world problems that students define and solve themselves (English, 2016; Kelley & Knowles, 2016). Because primary teachers usually teach most subjects to one class, primary school is especially well placed to move toward the interdisciplinary and transdisciplinary levels.

3. Specific Characteristics of the STEM Approach in Primary Education

Analysis of research and classroom practice allows us to identify the following characteristics that make primary STEM distinctive.

3.1. Integration around a single, understandable problem. In the primary grades, STEM content is not divided into four separate subjects. Instead, children meet science, mathematics, technology and engineering together while solving one clear problem, such as "How can we keep our classroom plants watered during the holidays?" Mathematics (measuring, counting, comparing), science (what plants need), technology (tools and materials) and engineering (designing a watering system) appear naturally, because the problem requires them.

3.2. Inquiry and children's questions as the starting point. Primary STEM begins with curiosity. The teacher creates a situation that provokes questions — "Why does ice melt faster in one cup than in another?" — and guides children through a simple inquiry cycle: ask, predict, test, observe, explain. The aim is not to deliver ready-made facts, but to teach children how knowledge is obtained.

3.3. Learning through play. For children aged 6–11, play is a leading form of activity. Games, role play, construction sets, puzzles and challenges ("Who can build the tallest tower from 20 sheets of paper?") turn STEM tasks into meaningful and enjoyable experiences. Play lowers the fear of mistakes and keeps motivation high.

3.4. Hands-on, concrete activity. Because primary pupils think concretely, abstract concepts must be grounded in physical experience. Children weigh, measure,

build, cut, mix and test. Manipulatives, everyday materials (cardboard, straws, cups, rubber bands) and simple educational robots allow children to "see" mathematical and scientific ideas before they formalise them.

3.5. The engineering design cycle in simplified form. A key feature of STEM is the engineering design process. For young learners it is adapted to a few clear steps: *Ask* → *Imagine* → *Plan* → *Create* → *Test* → *Improve*. This cycle teaches children that a first attempt rarely works perfectly and that improvement comes from testing and revising. It develops perseverance and a healthy attitude toward failure.

3.6. Connection with real life and the local environment. Tasks are drawn from children's immediate world: the home, the school yard, the neighbourhood, nature, local traditions and crafts. When pupils design a bird feeder for the school garden or calculate how much water their family uses, STEM becomes personally meaningful and its practical value is obvious.

3.7. Collaboration and communication. Most STEM activities are carried out in pairs or small groups with clear roles (builder, measurer, recorder, presenter). Children learn to listen, negotiate, share materials and explain their thinking orally, in drawings and in simple tables. These "soft skills" are as important an outcome as subject knowledge.

3.8. Age-appropriate use of technology. Technology in primary STEM includes not only computers but any tool that extends human ability — a ruler, a magnifying glass, scissors, a thermometer. Digital tools are introduced gradually: unplugged coding activities, floor robots and visual programming environments such as ScratchJr or Scratch develop algorithmic thinking without overloading young learners.

3.9. Development of 21st-century skills and positive attitudes. Beyond content, primary STEM purposefully develops the "4C" skills — critical thinking, creativity, collaboration and communication — as well as curiosity, independence and

confidence. A particularly important goal is to build positive attitudes toward mathematics and science for all children, including girls and pupils from disadvantaged backgrounds.

3.10. Formative, process-oriented assessment. In primary STEM, the process matters as much as the result. Teachers assess through observation, discussion, learning journals, photographs of models, peer feedback and simple rubrics. The question is not only "Did the bridge hold?" but also "How did the group plan, test and improve it, and what did they learn?"

3.11. The teacher as facilitator. Finally, the role of the teacher changes. Instead of being the only source of knowledge, the primary teacher becomes an organiser of the learning environment, a guide who asks open questions ("What do you notice?", "What could you change?") and a co-explorer who models curiosity and is not afraid to say "Let's find out together."

4. Forms and Methods of Implementation

The characteristics described above are realised through a range of forms that can be combined depending on the school's resources:

Integrated STEM lessons that link mathematics, natural science ("The World Around Us"), technology and art around one theme.

Mini-projects and project weeks, in which pupils spend several lessons solving a practical problem and present their product to classmates or parents.

STEM challenges — short, time-limited design tasks with simple materials (e.g., build a boat from foil that carries the most coins).

Experiments and observations in the classroom, school garden or nature corner.

Educational robotics and coding, from unplugged activities to floor robots and visual programming.

STEM clubs, maker spaces, science fairs and family STEM days, which extend learning beyond the timetable and involve parents.

Sample integrated lesson: "A Bridge for the Toy Car" (Grade 3, 2 × 45 minutes).

Ask (problem situation). The teacher tells a short story: a toy car must cross a "river" 30 cm wide. Pupils discuss what a bridge needs to do.

Imagine and plan. In groups of four, children look at pictures of real bridges, sketch their own design and choose materials (paper, straws, tape, ice-cream sticks) within a set "budget".

Create. Groups build their bridges, measuring the span with rulers (mathematics) and testing which shapes — flat, folded, triangular — are stronger (science and engineering).

Test. Each bridge is tested by adding coins to the car until the bridge bends. Pupils record results in a simple table and compare them as a bar chart (mathematics and data).

Improve and reflect. Groups explain why some bridges were stronger, improve their design and present it. The lesson ends with a reflection: "What did we learn? What would we change next time?"

In this one lesson, children practise measurement, data handling, knowledge of shapes and forces, the design cycle, teamwork and oral presentation — an illustration of how primary STEM integrates content naturally.

5. Challenges and Recommendations

Despite its clear advantages, implementing STEM in primary schools faces several difficulties. Many primary teachers feel less confident in science, technology and engineering than in literacy, and have had little training in integrated teaching. Curricula and timetables are often organised by separate subjects, leaving little room

for project work. Some schools lack materials, equipment and space. Finally, assessment systems that focus on test scores may not capture the skills STEM develops.

To address these challenges, the following recommendations can be made:

Invest in teacher professional development through practical workshops, lesson study and mentoring, so that teachers experience STEM activities as learners before teaching them.

Create flexible time in the curriculum for integrated lessons and project weeks, and encourage collaboration between teachers of different subjects.

Use low-cost and recycled materials. Effective primary STEM does not require expensive equipment; cardboard, bottles and everyday objects are often sufficient.

Develop methodological resources — lesson plans, task banks and rubrics adapted to the national curriculum and local context.

Adopt formative assessment tools that value process, reasoning, creativity and collaboration alongside correct answers.

Involve parents and the community through family STEM events, visits to local enterprises and partnerships with universities and technology centres.

Ensure equity, so that all children, regardless of gender, location or family background, have access to engaging STEM experiences.

6. Conclusion

The STEM approach in primary education has its own distinct identity. It is built on children's natural curiosity and is realised through integration around real problems, inquiry, play, hands-on activity, a simplified engineering design cycle, collaboration and age-appropriate technology. Its goals go beyond subject knowledge to include thinking skills, creativity, perseverance and positive attitudes toward science and mathematics.

The primary school is the most favourable stage for laying these foundations: one teacher works with the class across subjects, children are eager to explore, and attitudes are still being formed. With well-prepared teachers, flexible curricula, simple materials and supportive assessment, primary schools can turn STEM from a fashionable term into everyday practice — and prepare children not only for future careers, but for active and thoughtful participation in a changing world.

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