The Evolution and Global Significance of STEM Education in The 21st Century

21. Yüzyılda STEM Eğitiminin Gelişimi ve Küresel Önemi

Abstract

Developing and changing technology brings different job opportunities. This change in the workplace also affects the education models in schools. It is expected that students will have the mathematical and scientific infrastructure that they will need in the 21st-century workforce competition. This need has been influential in the emergence of the STEM educational approach arising from the combination of disciplines of science, technology, engineering, and mathematics. This model which supports creativity, curiosity, inquiry, and production is accepted in many countries of the world. This study will focus on the content, importance, the situation in other countries and in Turkey of STEM education.

Özet

Gelişen ve değişen teknoloji farklı iş olanaklarını da beraberinde getirmektedir. İşyerlerindeki bu değişim okullardaki eğitim modellerini de etkilemektedir. Öğrencilerin 21. yüzyıl işgücü rekabetinde ihtiyaç duyacakları matematiksel ve bilimsel altyapıya sahip olmaları beklenmektedir. Bu ihtiyaç bilim, teknoloji, mühendislik ve matematik disiplinlerinin birleşiminden doğan STEM eğitim yaklaşımının ortaya çıkmasında etkili olmuştur. Yaratıcılığı, merakı, sorgulamayı ve üretmeyi destekleyen bu model dünyanın birçok ülkesinde kabul görmektedir. Bu çalışmada STEM eğitiminin içeriği, önemi, diğer ülkelerdeki ve Türkiye'deki durumu üzerinde durulacaktır.

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Introduction

What is STEM? STEM is a training program developed to prepare primary and secondary students for the university in the fields of science, technology, engineering, and mathematics (STEM). In addition to learning, STEM aims to improve the skills of inquiry, reasoning, and cooperation (Rouse, 2013). STEM education is the ability to convert theoretical knowledge acquired from science and mathematics with the practical application of technology and engineering. The main priority of STEM education is to analyze and solve problems in daily life and think in different ways based on children's learning. In addition, it enables them to combine solution methods with engineering skills and use these skills holistically for their solutions. This process, as elucidated by Sakarya (2015), not only equips them with problem-solving abilities but also ensures a deeper, more lasting understanding of the subjects at hand.

The underlying philosophy of STEM goes beyond merely classifying related fields. It is a dynamic response to the needs of the 21st-century workforce, fostering mathematical and scientific competencies that are paramount in modern industries (Jolly, 2014).

To provide a holistic STEM education, educators have outlined seven critical standards:

1. Mastery of content through active learning and practice.
2. Seamless integration of disciplines.
3. Ability to interpret and transfer knowledge across contexts.
4. Cultivation of an inquiry-based mindset.
5. Development of logical reasoning capabilities.
6. Emphasis on teamwork and collaborative problem-solving.

Kavak Ş. (2023). The evolution and global significance of stem education in the 21st century. The Journal of International Scientific Researches, 8(3), 410-415.

ISR Journal

7. Proficient and responsible use of technology (Rouse, 2013).

Significantly, global examples like the USA, UK, and Japan have demonstrated the profound impact of STEM, showing not just domestic economic growth but also improvement in global academic assessments like PISA and TIMSS. Consequently, many nations are now incorporating the STEM paradigm into their educational strategies, targeting the cultivation of innovation and problem-solving skills from early childhood (Sakarya, 2015; Akgündüz & Ertepınar, 2015).

At its core, STEM education aims to bolster the number of students opting for these disciplines in higher education, while concurrently arming them with the creativity and knowledge to address everyday challenges in these sectors. In essence, STEM is a multidisciplinary pathway to career readiness, aiming to produce outcomes aligned with the demands and skills of the 21st century (Education in Technology, 2016).

1. The Imperative of STEM Education: A Deep Dive into Curiosity and Policy

STEM represents an educational paradigm that leverages the inherent curiosity of children, channeling it into problem-centric work that fosters creativity from an early age. The profound significance of early childhood development has been underscored by recent research (Shonkoff & Phillips, 2000), particularly in the realm of cognitive growth. Such research accentuates the indispensable role of premium early childhood education programs, with empirical studies substantiating their manifold advantages (Barnett, 1995).

A hallmark trait of young children is their insatiable curiosity—constantly probing the what, why, and how of the world around them (Chuderski, 2013). At the heart of scientific learning lies this penchant for questioning and exploration, pillars of active and immersive learning. By nourishing this natural curiosity, we can potentially kindle a lifelong passion for science and discovery. Scientific inquiry shouldn't be compartmentalized into specific "science periods". Instead, preschool educators ought to embed scientific principles across the curriculum (Eshach & Fried, 2005).

Skills of inquiry and research, indispensable to all scientific pursuits, can be nurtured in early childhood through well-prepared materials, structured routines, and hands-on experiences (Eshach & Fried, 2005). Simple endeavors like crafting sandcastles or building cities from blocks lay the groundwork for abstract thinking. It is within these playful contexts that children grasp the utility of tools and appreciate their transformative potential.

2. US STEM Policy and its Evolution in Schools

Globally, nations have embarked on educational reforms to ensure equitable quality education for all (OECD, 2018). The United States, a vanguard in numerous domains, has been particularly proactive. The ascendancy of China in economics, technology, and defense triggered a sense of urgency, prompting the US to intensify investments in science, engineering, and innovation (Freeman & Huang, 2015). This was reminiscent of the competitive spirit evoked by Japan's economic prowess in the 1980s. A watershed moment was the unveiling of the National Science Education Standards in 1996, delineating both curricular content and pedagogical methodologies (NRC, 1996).

Simultaneously, the US instituted an accountability framework 'No Child Left Behind' during George Bush's tenure, aimed at ensuring universal quality education and systematic assessment of educational outcomes (Dee & Jacob, 2011). These endeavors primarily targeted elevating educational standards and ensuring egalitarian principles.

Despite these efforts, the US's policies faltered in their economic face-off with formidable counterparts like China. This led to a renewed focus on educational reforms, culminating in the advocacy of engineering education at the primary and secondary levels (Honey, Pearson, & Schweingruber, 2014). In tandem with institutional efforts, museums, and non-formal educational centers commenced supplementary programs centered on engineering.

3. The Evolution of STEM (FeTeMM) Education in Turkey

In Turkey, STEM is recognized as FeTeMM Education. This framework emerged to delineate the effective interdisciplinary application of knowledge and skills in teaching. The pioneering group comprising Tufan Adıgüzel, Mehmet C. Ayar, M. Sencer Corlu, and Serkan Özel set the foundation for FeTeMM in 2012 (Sakarya, 2015).

Eskişehir Osman Gazi University spearheaded a research project focusing on STEM practices, aimed at enabling science educators to address real-world challenges using interdisciplinary techniques. The project emphasized the cultivation of 21st-century competencies, such as creativity and problem-solving, and accentuated the symbiotic relationship between STEM and everyday experiences (STEM Akademi, 2016).

Despite enthusiastic strides by private institutions, National Education Directorates, and Science Centers, STEM's footprint in Turkey remains limited. Often, the curriculum is confined to robotics, accessible only to a select group of proficient learners.

A notable endeavor in Turkey's STEM landscape is the "STEM Camps" initiative, championed by Nobel Prize laureate Dr. Aziz Sancar. Targeting the education of girls, this project aims to further STEM's impact in Turkey. The program, encompassing 700 sixth-grade students across seven cities, culminates in university-based events (Ülkar, 2016).

TUSIAD, a leading national entity, ardently advocates for STEM, envisioning Turkey as a technological trailblazer on the global stage (Sakarya, 2015). Further, a comprehensive STEM Education Report was unveiled by the General Directorate of Innovation and Education Technologies in 2016. As a testament to STEM's growing prominence, four pilot schools in Kayseri have integrated the STEM curriculum, with plans for its broader implementation across all educational tiers in the city (Sakarya, 2015).

4. The Interplay of STEM with 21st Century Skills

STEM education, as proposed by thinkers like Gardner, is pivotal in driving innovation. This innovation emerges when foundational knowledge from sciences such as physics, chemistry, biology, and mathematics is synthesized with the practical aspects of technology and engineering. Gardner's insights underline the crucial nature of 21st-century skills, especially as we transition from an industrial age that spanned two centuries to an era of "individualized industries." As we navigate this shift, skills historically reserved for a select few—like creativity, critical thinking, problem-solving, and cooperativeness—are now becoming universally imperative (Erdogdu, 2016).

This dynamic evolution in science and technology impacts societal institutions, prompting a reimagining of educational frameworks. Modern curricula aim to cultivate students who embody 21st-century proficiencies, demonstrating advanced communication aptitudes, collaborative work ethics, diverse perspective thinking, and creative problem-solving skills (STEM Akademi, 2016). Professor Ziya Selçuk poignantly encapsulates this sentiment, highlighting the challenge of educating contemporary students: "We educate 21st Century children with 20th Century teachers in 19th Century buildings." Indeed, as emphasized in several STEM reports, skills have surpassed mere knowledge in importance (Erdogdu, 2016).

The P21 Framework for 21st Century Learning (2007) categorizes these skills into: 1) Life and career skills, 2) Knowledge, media, and technology skills, and 3) Learning and innovation skills. Both the STEM pedagogical approach and the 21st-century skillsets are emerging paradigms in American education, underscoring the intertwined nature of their objectives and content areas.

5. Interrelation of STEM education and multilingual in a globalized World

In an era characterized by multifaceted global integration, multiculturalism has become an innate aspect of numerous nations. Therefore, educational goals should extend beyond preparing students for national integration to fostering adaptability in diverse cultural landscapes (Oktay, 2013). The exponential advancements in communication technologies and the emphasis on STEM disciplines have concurrently underscored the importance of linguistic proficiencies, particularly in global languages. Such interconnected developments, coupled with a rising wave of

multiculturalism, necessitate the early integration of multiple languages in the educational spectrum.

Engaging children in STEM-based dialogues augments their linguistic development. By actively involving them in STEM explorations, they not only adopt the roles of budding scientists and engineers but also naturally incorporate relevant vocabulary in their discourse (Resources for Early Learning, n.d.). Educators are encouraged to spotlight children's actions, thereby prompting them to utilize verbs such as "observing," "designing," and "researching." Moreover, assimilating STEM terminologies consistently throughout learning processes ensures comprehensive vocabulary acquisition.

6. STEM in Early Childhood Education: A Natural Fit

STEM education, inherently experiential, aligns remarkably with the intrinsic curiosity and explorative nature of young children. Conventional teaching methods can often lead to compartmentalized knowledge that lacks real-world context. In contrast, STEM offers an organic connection between formal learning and daily observations, ensuring an enhanced, motivational learning experience (Clayton, 2016).

Children's consistent queries, such as "Where do clouds come from?" or "Why does ice melt?", are a testament to their natural inquiry-driven mindset. This aligns with the foundational tenets of STEM, which emphasizes exploration and problem-solving (Boston Children's Museum, 2013). Nobel laureate Isidor I. Rabi's recollection of his mother's unique inquiry - "Did you ask a good question today?" - encapsulates this philosophy (Ülkar, 2016).

Neuroscientific studies highlight the significance of early childhood as a period of rapid brain development. Here, educators wield substantial influence by presenting innovative concepts and fostering environments conducive to child-led exploration (Boston Children's Museum, 2013). When methodical learning environments synergize with intentional pedagogical tactics, optimal educational outcomes are achieved (Katz, 2010). Thus, STEM not only catalyzes creativity and confidence in children but also equips them for future global challenges.

Crucially, the modular design of the STEM curriculum facilitates its integration into diverse educational systems. This adaptability enables educators to cater to distinct learning needs and preferences. Emphasizing the shift from "why" to "what" in questioning can ignite dialogues that foster co-learning experiences with young scholars (Boston Children's Museum, 2013).

7. STEM Practices in Preschool: The Boston Model
7.1. A Typical Day of STEM Activities for a Preschool Teacher

The integration of STEM into early childhood education can be both dynamic and engaging. A well-rounded preschool schedule integrates STEM concepts seamlessly throughout the day, fostering a hands-on, inquiry-based learning environment.

7.1.1. Sample Daily Schedule with STEM Activities:

8:00 - Free Play Time:
- Introduce books themed on fruits and vegetables.
- Incorporate a sequencing game using plastic fruits.
- Set up a dramatic play corner mimicking a fruit and vegetable market.
- Provide aprons for the "shopkeepers" and recyclable bags for the "customers".

8:30 - Circle Time:
- Discuss an upcoming apple-picking field trip or share apples from a bag.
- Read "Applesauce" by Shirley Kurtz, allowing children to engage with the tactile and olfactory experience of the apple.
- Introduce the idea of making apple sauce as the special activity for the day.

9:30 - Outdoor Exploration:
- Engage children in a nature walk to observe fruits or flowers on trees.
- Facilitate the children's experience of picking and observing the natural flora.

11:00 - Cooking Activity:

- Organize small groups to collaboratively make apple sauce.
- Involve individual children with volunteers to assist in the cooking process.
- For those not participating in the cooking, engage them with songs, music, or a thematic reading, such as a story about Johnny Appleseed.

17:00 - Closing Time:
- Provide parents with notes about the apple sauce activity.
- Encourage them to discuss with their children about the apple sauce creation process and incorporate it into their dinner.

7.2. STEM Focused Learning Areas

7.2.1. Mathematics:
- **Objective:** Explore and categorize objects based on their attributes.
- **Activity:** Sort daily objects (like toys, rocks, and leaves) by size, texture, color, etc. Encourage descriptive terminology.

7.2.2. Inquiry Skills:
- **Objective:** Document observations and convey ideas through rudimentary expressions.
- **Activity:** After a nature walk, have children sketch their findings, emphasizing details and observations.

7.2.3. Earth and Space Sciences:
- **Objective:** Recognize and discuss observable scientific phenomena in children's lives.
- **Activity:** Utilize literature, such as "Goodnight Moon", to discuss day-to-night transitions. Discuss lunar cycles and their observations.

7.2.4. Life Sciences:
- **Objective:** Recognize and discuss seasonal transitions in flora, fauna, and daily life.
- **Activity:** Observe a specific outdoor spot across seasons, noting changes and discussing them in context.

7.2.5. Physical Sciences:
- **Objective:** Investigate the diverse movement modalities of objects.
- **Activity:** Have children emulate the movements of objects or entities from stories, fostering kinesthetic learning.

7.2.6. Technology and Engineering:
- **Objective:** Illustrate and instruct on the appropriate use of tools and materials.
- **Activity:** Provide progressive scissor-cutting exercises, highlighting the evolution of tool mastery among young learners.

Conclusion

STEM, has emerged as an indispensable educational paradigm, vital for preparing the next generation for an ever-evolving, technology-driven global landscape. By combining the theoretical foundation of sciences with applications, STEM ensures the cultivation of problem-solving, creativity, and critical thinking. While nations like the USA, UK, and Japan have showcased the profound impacts of STEM, countries like Turkey have made commendable strides towards embedding this paradigm into their education systems. The inclusive nature of STEM makes it a flexible fit across different cultures and systems, offering universally beneficial outcomes. As the 21st century unfolds, it is evident that the integration of STEM education, from early childhood to higher levels, will be instrumental in shaping innovative, competent, and adaptable global citizens.

In conclusion, the integration of STEM into preschool curricula cultivates a holistic learning environment that's engaging, interactive, and relevant. With its emphasis on inquiry-based learning and real-world problem solving, STEM education in early childhood provides foundational skills and attitudes that can inspire lifelong passions and career paths. Teachers, armed with such a curriculum, will have the tools to ignite curiosity, foster creativity, and equip young learners for a rapidly evolving world.

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