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ASSESSING STEM READINESS THROUGH PISA: GLOBAL TRENDS AND CHALLENGES

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ABSTRACT

The increasing demand for Science, Technology, Engineering, and Mathematics (STEM) skills in the global labor market has brought attention to how well national education systems prepare students for these domains. This paper investigates global trends in STEM readiness using data and insights from the Programme for International Student Assessment (PISA). STEM readiness is examined not only through academic achievement in mathematics and science, but also through student motivation, career aspirations, gender dynamics, and socioeconomic factors that shape STEM-related outcomes. Through a comparative analysis of PISA cycles from 2000 to 2018, the study highlights both improvements and persistent disparities in student performance and interest in STEM careers. East Asian countries, such as Singapore, China, and Korea, have maintained top performance in math and science, often correlating with higher STEM career interest. Conversely, many Western nations, despite strong infrastructure and educational investment, show a decline in students' STEM-related aspirations, particularly among high-performing boys. The gender gap in STEM career expectations has narrowed in some regions, but often due to declining male interest rather than increased female participation. The study also explores how curriculum design, teacher quality, cultural norms, and national policy influence both student achievement and readiness to pursue STEM fields. A major concern identified is the mismatch between students' academic capabilities and their career expectations, influenced by stereotypes, limited guidance, and lack of exposure to STEM careers in early education. Socioeconomic background plays a critical role in determining access to quality STEM education and shaping long-term aspirations. The findings call for a rethinking of education strategies, suggesting the need for integrated STEM career guidance, early interventions, and inclusive policy reforms. With upcoming PISA assessments incorporating digital literacy and sustainability, the concept of STEM readiness must expand beyond test scores to include life-ready skills and global competence.

Keywords: STEM Readiness, PISA Assessment, Global Education Trends, Career Aspirations, Educational Equity

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INTRODUCTION

The advancement of science and technology has reshaped the global economy, making STEM (Science, Technology, Engineering, and Mathematics) skills critical for national development and individual success. As countries strive to build competitive knowledge economies, education systems are under increasing pressure to prepare students with strong STEM competencies. In this context, the Programme for International Student Assessment (PISA), conducted by the OECD, serves as a global benchmark for evaluating how well 15-year-old students are equipped to apply mathematical and scientific knowledge in real-world situations. STEM readiness goes beyond test performance. It encompasses a student's ability to think critically, solve problems, and apply conceptual knowledge, as well as their motivation, interest in STEM subjects, and aspirations for STEM careers. While PISA assesses cognitive skills in mathematics and science, it also gathers important contextual information about learning environments, teaching practices, and career expectations—providing a multidimensional picture of student preparedness. Despite advances in performance in certain countries, global disparities persist. High-achieving students in many developed nations are increasingly showing a decline in interest in STEM careers, particularly in engineering and computing. Meanwhile, some developing nations are improving performance but lack the systemic support to convert achievement into long-term career pathways. Gender and socioeconomic factors further influence both readiness and aspirations, revealing structural inequities within and across countries. This paper explores these global trends, using PISA data and related research to evaluate the challenges and opportunities in enhancing STEM readiness. It investigates patterns in performance, gender gaps, career motivations, and policy frameworks, and discusses how countries can better align educational goals with future labor market demands. In doing so, the study highlights the need for a broader, more inclusive understanding of STEM readiness—one that integrates academic excellence with real-world relevance and equitable access for all students.

UNDERSTANDING STEM READINESS

STEM readiness refers to a student's preparedness to pursue education and careers in Science, Technology, Engineering, and Mathematics. It encompasses not only academic achievement in math and science but also the development of problem-solving skills, creativity, and the motivation to engage in STEM-related fields. Readiness includes understanding how to apply knowledge in real-life contexts, critical thinking abilities, and the confidence to explore complex scientific and technological issues. Importantly, it also involves interest and aspiration—factors influenced by exposure to role models, quality teaching, and access to resources. A student may perform well on tests but lack the confidence or ambition to pursue a STEM career due to social or economic barriers. Therefore, STEM readiness is a multidimensional concept that includes cognitive, emotional, and motivational components. It serves as a crucial foundation for innovation, economic progress, and individual success in a technology-driven global society.

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ROLE OF PISA IN ASSESSING STEM READINESS

The Programme for International Student Assessment (PISA), administered by the OECD, plays a vital role in evaluating STEM readiness among 15-year-olds across the globe. Conducted every three years, PISA assesses student competencies in reading, mathematics, and science, with a strong emphasis on the ability to apply knowledge to real-world situations—an essential aspect of STEM readiness. Unlike traditional standardized exams, PISA does not merely test curriculum-based learning; it evaluates how well students can think critically, solve problems, and interpret scientific data.

Beyond academic performance, PISA collects background data on student attitudes, learning environments, teaching practices, and career aspirations. This enables researchers and policymakers to understand not only whether students are performing well in STEM subjects but also whether they are interested in and prepared to pursue STEM careers. It also highlights disparities by gender, socioeconomic status, and national context.

For governments and educators, PISA offers actionable insights that help identify strengths and weaknesses in education systems. By linking student performance with contextual variables, PISA supports evidence-based reforms aimed at improving STEM education quality, equity, and relevance. As such, PISA has become a key global benchmark for assessing and enhancing STEM readiness in alignment with future workforce demands.

GLOBAL PERFORMANCE TRENDS IN PISA

The Programme for International Student Assessment (PISA) has provided valuable insights into the performance of education systems across the world since its inception in 2000. By assessing 15-year-old students' abilities in reading, mathematics, and science, PISA offers a reliable benchmark for comparing academic achievement globally and monitoring trends over time. A major focus in recent years has been the performance in STEM-related domains, especially mathematics and science.

East Asian countries such as China (specifically Shanghai and Beijing), Singapore, Japan, and South Korea consistently top PISA rankings in math and science. These countries often combine strong curriculum standards with rigorous teaching methods and cultural emphasis on academic success. Their students typically demonstrate high levels of problem-solving and conceptual application, key elements of STEM readiness.

In contrast, many high-income Western countries like the United States, United Kingdom, and Germany show stable or declining trends in math and science performance. Despite well-developed education systems, these nations face challenges related to equity, curriculum relevance, and student motivation—especially in disadvantaged communities. Some Eastern European and Southeast Asian nations, such as Vietnam and Estonia, have shown rapid improvement, suggesting that targeted reforms and investment in teacher quality can yield significant gains.

Developing countries participating in PISA often perform below the OECD average, but many have shown steady progress. However, the performance gap between students from high- and low-income backgrounds remains significant worldwide, revealing persistent issues of inequality in educational access and outcomes.

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Overall, PISA trends highlight both the strengths and limitations of global education systems in fostering STEM skills. While some countries demonstrate excellence, others need to address systemic barriers. These trends reinforce the importance of aligning educational strategies with the skills needed for a rapidly changing, technology-driven world.

STEM CAREER ASPIRATIONS: A SHIFT IN FOCUS - PISA PERSPECTIVE

PISA data reveals changing patterns in students' STEM career aspirations worldwide. Despite strong academic performance, many students show shifting interests influenced by gender, socioeconomic factors, and evolving industry demands. Understanding these trends is crucial to designing education systems that inspire and prepare future STEM professionals.

1. **Declining Interest despite High Performance:** PISA data reveals a paradox where students in many high-performing countries show declining interest in STEM careers despite excelling in math and science assessments. For example, countries like Finland and the US report strong STEM achievement but decreasing numbers of students aspiring to STEM professions. This trend suggests that academic ability alone does not guarantee STEM career pursuit. Factors such as lack of motivation, perceived difficulty, and limited awareness of STEM opportunities influence students' career choices. PISA highlights the need to better connect classroom learning with real-world STEM applications to sustain interest.
2. **Gender Gaps in STEM Aspirations:** Gender disparities persist globally in STEM career aspirations, as shown by PISA findings. Boys tend to express greater interest in fields like engineering, computer science, and physical sciences, while girls are more likely to prefer biological sciences or non-STEM fields. Social stereotypes, lack of female role models, and gendered expectations contribute to this gap. PISA's data emphasize that addressing these cultural and institutional barriers is critical for achieving gender equity in STEM participation. Policies fostering inclusive environments and promoting female STEM role models can help narrow this divide.
3. **Socioeconomic Influences on STEM Choices:** Socioeconomic status (SES) significantly shapes STEM career aspirations, according to PISA results. Students from higher SES backgrounds are more likely to aspire to STEM careers due to better access to quality education, extracurricular activities, and family support. Conversely, lower SES students often face resource constraints and limited exposure to STEM opportunities. This disparity perpetuates inequality in STEM workforce representation. PISA underscores the importance of targeted interventions, such as mentorship programs and scholarships, to ensure that STEM aspirations are accessible to all socioeconomic groups.
4. **Impact of School Environment and Teaching:** The school environment and quality of STEM teaching play crucial roles in shaping students' career aspirations. PISA data show that positive teacher attitudes, innovative teaching methods, and hands-on STEM experiences increase student interest and confidence in pursuing STEM fields. Conversely, rote learning and lack of engagement can discourage students. Schools that integrate STEM career guidance and provide real-life contexts for STEM subjects help students envision themselves in related professions. PISA highlights that improving

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STEM teaching practices is essential to foster sustained interest and readiness for STEM careers.

5. **Emerging Focus on Digital and Sustainable STEM Careers:** PISA's recent assessments reflect a growing global emphasis on digital literacy and sustainability within STEM education. Students increasingly recognize careers in information technology, renewable energy, and environmental science as vital for the future. This shift broadens the traditional view of STEM, incorporating interdisciplinary and socially relevant fields. PISA findings suggest that aligning education with these emerging priorities can inspire new cohorts of students to pursue STEM careers that address global challenges. Encouraging awareness of evolving STEM sectors is key to maintaining student motivation and relevance.

CHALLENGES IN STEM READINESS

STEM readiness is essential for preparing students for future careers, but various challenges hinder this goal globally. These include educational inequalities, gender biases, outdated teaching methods, limited career guidance, and socioeconomic barriers. Addressing these obstacles is crucial to fostering a skilled and diverse STEM workforce.

1. **Unequal Access to Quality Education:** Many students, especially in low-income or rural areas, lack access to high-quality STEM education, resources, and trained teachers. This limits their ability to develop foundational skills and knowledge necessary for STEM readiness.
2. **Gender Stereotypes and Bias:** Persistent cultural stereotypes discourage girls from pursuing STEM subjects and careers. These biases can lower confidence, reduce participation, and create barriers to equitable STEM engagement.
3. **Lack of Real-World Application:** Traditional teaching methods often focus on rote learning rather than problem-solving and critical thinking. Without real-world context, students may struggle to see the relevance of STEM, reducing motivation and engagement.
4. **Insufficient Career Guidance:** Many students are unaware of the diverse opportunities within STEM fields. Lack of mentorship and career counselling means students may not consider STEM careers or understand the pathways to enter them.
5. **Socioeconomic Barriers:** Students from disadvantaged backgrounds face financial constraints, limited access to extracurricular STEM activities, and fewer role models, which hinder their STEM preparedness and career aspirations.

POLICY AND PEDAGOGICAL IMPLICATIONS FOR IMPROVING STEM READINESS

Effective policies and teaching practices are vital to overcoming challenges in STEM education. By fostering inclusive curricula, supporting teachers, promoting gender equity, enhancing career guidance, and ensuring equitable resource distribution, education systems can better prepare students for STEM careers and contribute to a skilled, diverse workforce.

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1. **Inclusive Curriculum Design:** Policies should promote STEM curricula that are engaging, relevant, and culturally inclusive, integrating real-world problems to enhance critical thinking and student interest across diverse backgrounds.
2. **Teacher Training and Support:** Investing in ongoing professional development equips teachers with modern pedagogical skills, STEM content knowledge, and strategies to foster inclusive and student-centered learning environments.
3. **Gender Equity Initiatives:** Policies must address gender disparities by encouraging female participation through mentorship programs, role models, and targeted outreach, challenging stereotypes and building confidence among girls.
4. **Enhanced Career Guidance:** Schools should provide comprehensive STEM career counseling and exposure to diverse STEM pathways, helping students understand opportunities and align their aspirations with labor market demands.
5. **Resource Allocation for Equity:** Governments need to ensure equitable access to STEM resources, technology, and extracurricular activities, particularly for disadvantaged communities, to close gaps in opportunity and readiness.

FUTURE DIRECTIONS: PISA 2025 AND BEYOND

As global education systems evolve, PISA 2025 and future cycles aim to deepen understanding of students' STEM readiness and career aspirations amid rapid technological and societal changes. The upcoming assessments will increasingly emphasize digital literacy, computational thinking, and interdisciplinary skills critical for the future workforce. This shift reflects the growing importance of not only mastering core STEM content but also adapting to innovation-driven economies.

PISA 2025 is expected to expand its focus on equity by closely examining how gender, socioeconomic status, and cultural factors influence STEM engagement and performance. Enhanced data collection will help policymakers identify persistent gaps and tailor interventions that promote inclusive STEM education. Additionally, PISA plans to incorporate more nuanced measures of student well-being, motivation, and real-world problem-solving abilities to provide a holistic view of STEM readiness.

Beyond assessment, PISA's future direction includes guiding countries to align education policies with emerging global challenges, such as climate change and digital transformation. By fostering collaboration among educators, governments, and industries, PISA aims to support education systems in preparing diverse learners for meaningful STEM careers.

Ultimately, PISA 2025 and beyond will serve as a crucial tool for benchmarking progress, inspiring reforms, and ensuring that education systems worldwide equip students with the skills needed to thrive in a dynamic, technology-driven future.

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CONCLUSION

The assessment of STEM readiness through PISA provides valuable insights into global trends, challenges, and opportunities within STEM education. Despite significant advancements in student performance in science, technology, engineering, and mathematics, a shift in STEM career aspirations highlights the complexity behind students' choices. Factors such as gender disparities, socioeconomic inequalities, and limited exposure to real-world STEM applications continue to influence who pursues STEM fields and why. Addressing these challenges requires targeted policies and innovative pedagogical approaches that foster inclusive, engaging, and equitable learning environments.

PISA's role in highlighting these issues is pivotal, as it offers data-driven evidence for educators and policymakers to design interventions that promote STEM interest among diverse student populations. Emphasizing teacher training, gender equity initiatives, and enhanced career guidance can help bridge gaps in participation and motivation. Moreover, ensuring equitable access to resources and extracurricular opportunities is essential to levelling the playing field for all students, regardless of background.

Looking ahead, PISA 2025 and future cycles promise to expand understanding by integrating emerging skills like digital literacy and focusing on well-being and motivation. This holistic approach is crucial for preparing students for the evolving demands of the STEM workforce. Ultimately, sustained efforts grounded in PISA findings can cultivate a more diverse, skilled, and future-ready STEM generation, driving innovation and economic growth worldwide.

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