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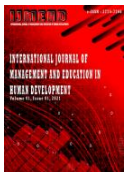

Transforming STEM Education to Prepare Future Generations to Face Global Challenges: A Narrative Literature Review

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ABSTRACT

The growing complexity of global challenges has intensified calls to transform education systems so that future generations can respond effectively to uncertainty, technological disruption, climate change, inequality, and changing labour-market demands. Within this wider agenda, STEM education has become increasingly important because it is now associated not only with scientific and technical knowledge, but also with problem-solving, innovation, digital competence, sustainability, and future readiness. This narrative literature review examines how recent scholarship and policy-oriented literature conceptualises the transformation of STEM education in response to global challenges. The review is guided by five questions: what global challenges are most frequently identified as drivers of educational transformation, how transforming education is conceptualised, what competencies, skills, and values are considered essential, what strategies are proposed for reform, and what barriers and gaps remain. The review draws primarily on the attached papers and supplements them with recent, verified scholarly and policy literature. The literature indicates that transforming STEM education is not limited to strengthening technical content or adding digital tools. Rather, it involves rethinking curriculum, pedagogy, teacher preparation, assessment, and partnerships so that STEM learning becomes interdisciplinary, problem-based, inclusive, ethically grounded, and connected to real-world issues. Across the literature, the most frequently emphasised competencies include critical thinking, creativity, collaboration, communication, problem-solving, digital literacy, adaptability, and social responsibility. The review also finds that teacher capacity, equitable access to resources, curriculum rigidity, exam-driven traditions, and weak implementation structures remain major barriers. Overall, the literature suggests that transformative STEM education is increasingly viewed as a strategic pathway for preparing learners not only for future employment, but also for responsible participation in building more sustainable, just, and resilient societies (Biseth et al., 2022; Čajková, 2021; Fan, 2025; Reimers, 2020; Teach For All, 2024).

Keywords: *Educational Transformation, Digital Transformation, Future Generations, Future-Ready Competencies, Global Challenges, Interdisciplinary Learning, Narrative Literature Review; Sustainability; STEM Education, Teacher Professional Development.*

I. INTRODUCTION

Education systems are under increasing pressure because the conditions shaping the lives of future generations have changed profoundly. UNESCO (2023) explains that contemporary education must now respond to global warming, conflict, protracted crises, and an accelerated digital revolution, which means that traditional models of schooling are no longer sufficient for present realities or future uncertainties. In a similar vein, Fan (2025) argues that the long-term effects of the pandemic, geopolitical instability, economic slowdown, and the rise of intelligent technologies have created an uncertain world that exposes the inadequacy of education systems still shaped by industrial-era assumptions. Likewise, Čajková (2021) links ecological disruption, technological change, fragmentation, and inequality to the urgent need for transformative education that can prepare learners to respond to complexity and uncertainty.

Within this broader transformation agenda, STEM education has become especially important because many current and future global challenges are scientific, technological, environmental, and systems-based. The Teach For All (2024) learning paper explicitly states that challenges such as poverty, climate crisis, global health threats, and inequitable access to resources require solutions grounded in science, technology, engineering, and mathematics. However, the same report also insists that effective STEM education should not be limited to disciplinary knowledge,

because students must also develop leadership, higher-order thinking, creative thinking, communication, collaboration, and socio-emotional competence if they are to thrive and contribute meaningfully in a technology-transformed world (Teach For All, 2024).

The literature also shows that STEM education is increasingly being reframed in relation to future-oriented competencies. Biseth et al. (2022) argue that education is meant to prepare pupils for occupations that cannot yet be foreseen and for challenges and technologies that are still unknown, which is why transformative and interdisciplinary approaches are becoming more important. Fan (2025) similarly argues that schools must move beyond knowledge-based education toward competency-based education, especially by promoting critical thinking, creativity, adaptability, self-regulation, and the transformative application of knowledge in changing social contexts. Reimers (2020) adds that education should prepare students not merely to understand change, but to invent the future.

At the same time, the literature is equally clear that current STEM education often falls short of these aspirations. Teach For All (2024) observes that STEM teaching frequently emphasizes rote memorization instead of critical and creative thinking, remains overly theoretical, and often fails to connect learning with students' lives and real-world challenges. The same report further highlights that women, low-income students, first-generation learners, and other underserved groups remain underrepresented in STEM, while digital inequality continues to restrict meaningful participation. Biseth et al. (2022) also show that even where policy ambitions are high, teacher education can remain conservative and insufficiently responsive to the competencies future generations need.

Accordingly, this review focuses on how the literature conceptualises the transformation of STEM education in response to global challenges. It specifically examines the drivers of transformation, the meaning of "transforming education," the competencies associated with future readiness, the strategies proposed for reform, and the barriers that continue to constrain implementation. These questions are consistent with the argument in Čajková (2021) that transformative education should be understood as education that prepares learners to engage critically with global issues, uncertainty, sustainability, and systemic change.

II. LITERATURE REVIEW

A central theme across the literature is that global challenges are acting as the main drivers of educational transformation. UNESCO (2023) frames education as a public good that must now respond to global warming, conflict, crises, and digital acceleration. Similarly, Čajková (2021) presents climate change, ecosystem degradation, social fragmentation, rapid technological change, and rising inequality as interconnected conditions that require new forms of learning. Fan (2025) extends this argument by showing that generative artificial intelligence, economic instability, and geopolitical uncertainty are not temporary disturbances but structural shifts that demand educational rethinking. Taken together, these sources suggest that educational transformation is being driven not by a single reform agenda, but by the convergence of ecological, technological, social, and economic pressures.

A second major theme concerns how the literature conceptualises "transforming education." Biseth et al. (2022) define transformative education broadly as an ideological nexus linking liberal education, progressive education, environmental education, and education for sustainable development, all of which aim to foster transformative learning for both teachers and learners. Čajková (2021) likewise states that education is transformative when it equips people with the knowledge and skills needed to promote sustainable development through critical thinking, global citizenship, human rights, gender equality, peace, and cultural appreciation. Fan (2025) complements these views by arguing that transformation requires a shift from imparting fixed knowledge toward cultivating creativity, critical thinking, adaptability, and the ability to reconcile multiple conflicting values in uncertain contexts. These authors collectively show that transforming education is not merely about updating content or adding technology, but about rethinking the purposes, structures, and outcomes of education itself.

When this transformation is considered specifically in relation to STEM, the literature shows a clear move from narrow technical preparation toward holistic and interdisciplinary development. Teach For All (2024) defines effective STEM education as a holistic approach that develops both disciplinary knowledge and a broader set of skills and mindsets, including leadership, higher-order thinking, creative thinking, problem-solving, communication, collaboration, and socio-emotional competence. This aligns with Biseth et al.'s (2022) emphasis on interdisciplinarity as a necessary response to current and future societal challenges, especially when educational systems seek to prepare learners for sustainable development, public health, democracy, and citizenship. It also aligns with Fan's (2025) call for curriculum systems that promote thinking, creativity, and the application of knowledge across different social scenarios rather than remaining locked within systematic knowledge transmission.

The literature also converges around a broad set of competencies needed for future generations. Reimers (2020) argues that students need cognitive, interpersonal, and intrapersonal skills if they are to invent the future rather than merely adapt to it. Teach For All (2024) similarly stresses leadership, decision-making, lifelong learning, and the ability to solve community and global challenges as key human competencies in an increasingly automated and artificial intelligence-driven world. Fan (2025) adds critical thinking, creativity, digital and data literacy, self-regulation, ethical responsibility, and the capacity to solve problems and create new value. Even adjacent literature on digital transformation and entrepreneurship education identifies creativity, problem-solving, critical thinking, collaboration, and digital literacy as central multidimensional competencies in digitally mediated educational environments (Park & Kim, 2025; Mu & Zhao, 2024). This repeated convergence across different bodies of literature strengthens the view that future-ready education, including STEM education, depends on a combination of disciplinary, digital, social, and ethical capacities.

A fourth theme concerns the strategies proposed for transforming STEM education. Reimers (2020) emphasizes learning by doing, problem-based education, and collaboration in diverse teams as central principles for future-oriented education. Teach For All (2024) similarly advocates locally contextualized STEM pedagogy, practical actions and strategies for teachers, and learning environments where students apply lifelong learning skills to issues relevant to their lives and to the wider world. Fan (2025) argues that schools should reconstruct curriculum systems around thinking, creativity, digital information processing, and hands-on, problem-based activities that stimulate participation and invention. Biseth et al. (2022) further show that interdisciplinary teaching and learning methods are increasingly understood as essential for linking school knowledge with societal needs, even though implementation remains uneven.

Finally, the literature consistently identifies barriers that hinder transformation. Teach For All (2024) points to rote memorization, theory-practice separation, underrepresentation in STEM, and the digital divide as major obstacles. Biseth et al. (2022) show that teacher education often lacks sufficient interdisciplinary exposure and that student teachers are not adequately provided with the tools or content needed to address interdisciplinary themes in practice. They also identify both structural and cultural obstacles, including weak collaboration across educational levels and insufficient institutional facilitation. Fan (2025) similarly criticizes the conservatism of knowledge-based schooling and argues that without conceptual reform, schools will remain poorly equipped to develop transformative competencies. Thus, the literature suggests that the barriers to transforming STEM education are systemic rather than incidental.

2.1 Research Objectives

The main objective of this paper is to review and synthesise the literature on how STEM education is being transformed to prepare future generations to face global challenges.

The specific objectives are to identify the global challenges most frequently described in the literature as drivers of STEM educational transformation, to examine how transforming education is conceptualised in recent scholarship and policy documents with particular attention to STEM education, to analyse the competencies, skills, and values considered essential for future generations, to review the strategies proposed for transforming STEM education systems, and to identify the major barriers and research gaps that remain in aligning STEM education with contemporary global challenges (Biseth et al., 2022; Čajková, 2021; Fan, 2025; Teach For All, 2024).

III. RESEARCH METHODS

This study employed a narrative literature review design. A narrative review was appropriate because the topic is conceptually broad and spans policy documents, conceptual papers, review articles, and empirical research. The purpose was not to calculate pooled effect sizes or statistically aggregate intervention findings, but rather to interpret and synthesise the principal themes, assumptions, conceptual trends, and recommendations that emerge across the literature on transforming STEM education in relation to global challenges. This choice is consistent with the nature of the topic itself, which concerns educational purposes, future readiness, sustainability, and institutional change rather than a narrow treatment effect or single instructional intervention (Čajková, 2021; Reimers, 2020).

The core corpus of the review was based on the attached papers, with particular emphasis on sources directly related to educational transformation, future challenges, and STEM education. These included the Teach For All (2024) learning paper on transforming STEM education, Čajková's (2021) foresight-based report on transformative education, Fan's (2025) article on the reconfiguration of human education in an uncertain world, Biseth et al.'s (2022) study on transformative teacher education, Reimers' (2020) conceptual paper on preparing students to invent the future, and Tanaka et al.'s (2019) policy paper on transforming education toward equitable quality education to achieve the Sustainable Development Goals. Additional attached sources on just transition, digital transformation, and entrepreneurship education were used selectively when they contributed conceptually to themes such as digital competence, creativity, innovation, interdisciplinarity, and future-oriented learning (Droubi et al., 2023; Mu & Zhao, 2024; Park & Kim, 2025).

To improve the recency and breadth of the review, the attached corpus was supplemented with recent and verifiable scholarly and policy literature, particularly where it strengthened discussion of sustainability in STEM education, artificial intelligence in learning, teacher professional development, and twenty-first-century skills. These supplementary sources were included only where they were relevant to one or more of the review questions and where they helped clarify emerging directions in the transformation of STEM education. Priority was given to peer-reviewed journal articles, international policy reports, and recognized institutional publications.

The literature was analysed thematically in relation to the five guiding questions of the study. First, the texts were examined for the global challenges identified as drivers of educational transformation. Second, the literature was compared to determine how "transforming education" was defined or conceptualised. Third, the review extracted the competencies, skills, and values most frequently associated with future readiness. Fourth, it identified the main strategies proposed for transforming STEM education. Fifth, it examined the barriers, implementation constraints, and unresolved gaps emphasised across the literature. The analysis was therefore interpretive and comparative rather than statistical, aiming to identify recurring patterns, areas of convergence, and important tensions across the reviewed sources (Biseth et al., 2022; Čajková, 2021; Fan, 2025; Teach For All, 2024).

IV. RESULTS AND DISCUSSION

A central theme across the literature is that global challenges are acting as the main drivers of educational transformation. UNESCO (2023) frames education as a public good that must now respond to global warming, conflict, crises, and digital acceleration. Similarly, Čajková (2021) presents climate change, ecosystem degradation, social

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V. CONCLUSION

This review shows that focusing the discussion on STEM education strengthens both the coherence and the contribution of the paper. Across the literature, STEM education is increasingly understood not as a narrow pipeline for technical employment, but as a transformative educational field that can help prepare future generations to confront climate crisis, digital disruption, inequality, uncertainty, and social change. This broader interpretation is evident in the work of Teach For All (2024), which frames STEM as a means of developing leadership and problem-solving for real-world challenges, in Čajková's (2021) emphasis on transformative learning for sustainability and global justice, and in Fan's (2025) call for a shift toward humanistic and competency-based education in an uncertain world.

The review also demonstrates that transforming STEM education requires far more than stronger disciplinary content or greater use of technology. It requires interdisciplinary curriculum, authentic problem-solving, ethical grounding, inclusive participation, and sustained teacher development. Reimers (2020) shows that future-oriented

education depends on problem-based learning, collaboration, and active creation of knowledge. Biseth et al. (2022) underline the importance of teacher preparation and interdisciplinarity, while Fan (2025) argues that conventional knowledge-based systems remain insufficient for the cultivation of creativity, adaptability, and critical reasoning. Together, these arguments indicate that where these conditions are absent, reform remains rhetorical; where they are present, STEM education can become a meaningful pathway for building more sustainable, just, and resilient societies.

Overall, the strongest message emerging from the literature is that STEM education should help learners not only understand the world, but also improve it. This is why STEM now occupies such an important place in efforts to rethink the purposes of education in the face of global challenges. The literature consistently suggests that future-ready STEM education must combine disciplinary competence with ethical awareness, digital capability, collaboration, adaptability, and responsibility. For this reason, the transformation of STEM education should be viewed not as an optional modernization project, but as a strategic educational response to the demands of an uncertain and rapidly changing world (Biseth et al., 2022; Čajková, 2021; Fan, 2025; Reimers, 2020; Teach For All, 2024).

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