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MULTIDISCIPLINARY AND PRACTICE-BASED PERSPECTIVES ON SCIENCE EDUCATION REFORMS

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Abstract

Science Education reforms worldwide are increasingly responding to the complexities of modern societies, technological advancements, and the need for scientific literacy. These reforms require a shift from traditional, discipline-bound approaches to more integrated, practice-oriented models. This thematic paper explores the role of multidisciplinary and practice-based perspectives in science education reforms, arguing that such approaches are essential for developing relevant, inclusive, and sustainable educational practices. Drawing on examples from various countries and educational levels, it highlights key themes such as collaboration across disciplines, contextualized learning, teacher professional development, and student-cantered pedagogies.

Key words: Science Education, Multidisciplinary**,** Scientific Literacy

Introduction

Contemporary Science Education is at a critical stage, faced with the dual challenge of remaining scientifically rigorous while becoming more inclusive and socially relevant. Traditional models rooted in discipline-specific instruction are being questioned for their lack of responsiveness to real-world problems and learners' needs. A multidisciplinary and practice-based approach offers a promising avenue for reform by bridging knowledge domains and integrating authentic scientific practices into classrooms. Bybee (2013) advocates for a multidisciplinary approach by blending science, technology, engineering, and mathematics, highlighting the importance of real-life applications and inquiry-based learning.

Science education must prepare learners to grapple with complex, real-world problems whose solutions lie at the intersection of scientific, technological, social, cultural, and ethical domains. Multidisciplinary thinking and practice-based approaches can be blended to create rich learning environments that foster conceptual understanding, scientific literacy, and civic action. Global challenges, climate change, pandemics, food insecurity and artificial intelligence underscore the need for a citizenry that can integrate diverse knowledge systems and translate theory into action. Traditional discipline-bounded science instruction, fenced off from everyday practice, often falls short of this goal. Science education should shift from traditional methods to more practice-based, model-driven inquiry in classrooms (Windschitl *et al.,* 2008).

Multidisciplinary and practice-based perspectives provide complementary pathways for re-imagining science teaching and learning. Lederman and Lederman (2013) explores how reforms like Next Generation Science Standards **(**NGSS) aim to integrate multiple disciplines while maintaining a strong practice-oriented pedagogy. Multidisciplinary perspectives weave together insights from biology, chemistry, physics, engineering, social sciences, and humanities to illuminate complex phenomena. Practice-based perspectives view learning as participation in purposeful activity, investigating authentic problems, designing products, and engaging with community stakeholders. Kelly and Licona (2018) highlights the importance of epistemic practices (argumentation, evidence evaluation) across disciplines, enriching the science curriculum through practical, real-world engagement.

Multidisciplinary Approaches in Science Education

Multidisciplinary education transcends the boundaries of individual scientific disciplines to address complex real-world issues such as climate change, public health, and energy sustainability. These issues cannot be fully understood or addressed from a single disciplinary perspective, necessitating the integration of biology, chemistry, physics, earth sciences, and increasingly, mathematics, engineering, and social sciences.

A significant body of research explores the benefits of breaking down the rigid barriers between biology, chemistry, and physics, often under the umbrella of integrated STEM (Science, Technology, Engineering, and Mathematics) education. A meta-analysis by Becker and Park (2011) found that integrated approaches in mathematics and science education had a positive and significant effect on student achievement. Similarly, a comprehensive review by Honey *et al*. (2014) for the National Academies of Press emphasized that integrated STEM education fosters a deeper understanding of content by situating it in real-world contexts, thus increasing student engagement and interest.

Curriculum Integration and Design

In reformed science curricula, thematic units such as "The Science of Water" or "Human Impact on Ecosystems" are designed to embed concepts from multiple disciplines. This encourages students to develop a holistic understanding of scientific phenomena and apply critical thinking across subject boundaries. Interdisciplinary and practice-based approaches in science education, encouraging integration of real-world problem solving and critical thinking (Beers, 2011).

<u>Case: High school STEM hydroponics</u>

A year-long professional development program in Indiana enabled teachers from biology, chemistry, physics, and engineering to co-design interdisciplinary hydroponics lessons. Teachers reported improved problem-solving skills in students and deeper engagement when addressing real-world issues like food security in agricultural systems

<u>Case: Coastal adaptation design</u>

In a project-based course, students from engineering, social science, ecology, and planning collaborated using the Adaptive Gradients Framework. Their interdisciplinary teamwork led to innovative, stakeholder-responsive coastal adaptation proposals

Practice-Based Perspectives in Science Education

- **Science as Practice**

A practice-based approach centers on how science is actually doneemphasizing inquiry, experimentation, argumentation and modelling. This aligns with the vision articulated in frameworks like the U.S. Next Generation Science Standards (NGSS) and similar international reforms.

- **Teacher Professional Learning and Collaboration**

Successful implementation of practice-based reforms depends on ongoing teacher professional development. Collaborative learning communities, action research, and partnerships with scientists help teachers engage in and reflect upon scientific practices in their own classrooms.

- **Student Engagement and Identity Formation**

Practice-based science education fosters deeper engagement by positioning students as scientists-in-training. It also helps students from diverse backgrounds see themselves as capable participants in science, thereby contributing to equity and inclusion.

Next Generation Science Standards (NGSS) aligned case studies

A multiple-case study investigating Next Generation Science Standards implementation revealed that engaging students in science and engineering practices such as argumentation from evidence and modelling in and out of school supports deeper content understanding.

Physics practicum experimentation

Guided inquiry practicum in electricity and magnetism significantly improved physics education students' science-process skills through iterative experimentation and reflection.

Clinical integration in medical education

At Izmir University, first-year medical students learned basic sciences through multidisciplinary case discussions led by instructors from physiology, anatomy, biochemistry, and internal medicine. This format enhanced retention and deepened contextual understanding

Parallel to the move towards integration is the powerful shift towards practice-based science learning. This perspective, championed by the NGSS, argues that students learn best by actively engaging in the practices of scientists and engineers.

A review of studies on the implementation of the NGSS, such as the work by Krajcik (2015), demonstrates that when students are engaged in practices like modelling, data analysis, and argumentation, they develop a more nuanced understanding of the nature of science and stronger critical-thinking skills. Research on specific practice-based pedagogies further supports this shift. A systematic review of Project-Based Learning (PBL) by Strobel and van Barneveld (2009) found that while traditional instruction may be more effective for short-term knowledge retention, PBL leads to greater long-term retention and the development of essential skills like problem-solving and collaboration. Similarly, a review of Argument Driven Inquiry (ADI) by Sampson and Gleim (2009) showed that this approach enhances students' ability to construct and critique scientific arguments, a core scientific practice.

The primary challenge identified in the literature on practice-based reforms is the need for a significant pedagogical shift from teacher-centered to student-centered instruction. This requires teachers to become facilitators of learning rather than dispensers of information, a transition that, as research by Windschitl *et al.* (2021) points out, demands sustained and intensive professional development focused on both content and pedagogy.

The Intersection: Multidisciplinary and Practice-Based Synergies

The most transformative reforms occur where multidisciplinary content meets practice-based pedagogy. For example, project-based learning environments that tackle real-world problems (e.g., designing a sustainable school) require students to apply knowledge from multiple disciplines through authentic practices like data collection, hypothesis testing, and peer review. This synergy supports the development of 21st century competencies such as collaboration, communication, critical thinking, and creativity, skills vital for future scientists and informed citizens alike. National Research Council (2012) Serves as a foundation for the NGSS (Next Generation Science Standards), promoting practice-based learning and interdisciplinary understanding in science teaching.

Structural Barriers Impede Integration and Effective Practice

Education systems must address structural barriers to integration and practice. This includes redesigning curriculum frameworks, investing in teacher training and rethinking assessment mechanisms to value process and understanding over rote memorization.

Science reforms must be guided by principles of equity, ensuring that multidisciplinary and practice-based opportunities are accessible to all learners, especially those in under-resourced or marginalized communities. Venville *et al*. (2002) analyses the impact and challenges of multidisciplinary integration in science education and its implications for teacher practice and curriculum structure.

Teacher Preparation & Collaboration

- Offer cross-disciplinary professional learning
- Facilitate partnerships with universities, industry, and community organizations

Assessment Systems

- Develop tools to evaluate both process skills (inquiry, argumentation) and interdisciplinary understanding.

Equity and Access

- Ensure inclusive design of makerspaces and embodied practices to welcome diverse learners

Resource Allocation

- Support for case-based teaching (as in medical and coastal adaptation studies) requires investment in collaboration time, materials, and expert facilitators

Conclusion

Science education reform rooted in multidisciplinary and practice-based perspectives is both timely and necessary. These diverse yet interconnected studies provide compelling evidence that Multidisciplinary perspective cultivates deeper learning and sustainability-minded inquiry. Practice-based pedagogies, such as guided inquiry labs, case discussions, and real-world project work, support conceptual understanding and student agency. The fusion of these approaches promises science education reform that not only equips learners with content knowledge but also with the skills, mindsets, and collaborative practices needed for 21^{st} century real-world challenges. It aligns education with the complexities of the modern world while making learning more meaningful and inclusive. While challenges remain in teacher readiness, assessment, and policy alignment and the potential benefits for students, educators, and society are profound.

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