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The transformative role of biological science education in students' everyday life

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Abstract
Biological science education has untapped potential to transform how students navigate their daily lives, yet traditional teaching methods often fail to link classroom content with real-world experience. This review article synthesises current research examining the connection between biology instruction and students' everyday lives, showing how contextualised learning approaches improve scientific literacy, decision-making, and civic participation. Using models like phenomenon-based learning, science-technology-society frameworks, and informal education paradigms, this review illustrates that when biological concepts are meaningfully connected to students' cultural backgrounds, community contexts, and personal interests, learners develop lasting scientific attitudes that extend beyond school. Analysis of empirical studies indicates that relevance-based biology education enhances higher-order thinking skills, encourages environmental responsibility, and supports equitable outcomes for historically marginalised students. Incorporating school-level biological knowledge, such as understanding the father's Y chromosome in sex determination, the importance of maternal health and legal marriage age, awareness of AIDS, and local medicinal plants, offers concrete paths for this transformation. The review highlights key implementation challenges, including gaps in teacher training, assessment mismatches, and infrastructure disparities that limit this potential. Comparing intervention studies, theoretical frameworks, student demographics, and learning outcomes provides broad insights into current research directions. The article ends with suggestions for curriculum designers, teachers, and policymakers aiming to develop biologically literate citizens who can apply scientific reasoning to everyday issues.

Keywords: Biological science education, everyday life, contextual learning, scientific literacy, phenomenon-based learning, student engagement, school-level biology

Introduction

The fundamental goal of science education goes beyond just teaching facts and lab skills. Biology classrooms act as entrances to understanding living systems, but the influence on students' thinking often stays within school walls. This ongoing gap between formal biology education and its use in daily life is a major challenge for modern science teachers. Hoogland *et al.* [1] note that science education has little effect on students' everyday experiences because teachers find it hard to create meaningful learning situations. When important contexts remain outside of students' lives, they have limited power to connect with scientific ideas.

Contemporary society faces biologically grounded challenges that require a scientifically literate citizenry. Climate change adaptation, vaccine decision-making, evaluation of genetically modified food, biodiversity conservation, and personal health management all demand biological reasoning applied to complex socio-scientific issues. In school-level education, topics such as the role of the father's Y chromosome in sex determination offer immediate relevance, challenge persistent myths about sex determination, and promote gender equity. Similarly, understanding the importance of maternal health during pregnancy- including nutrition, disease prevention, and access to care- directly impacts family outcomes. The significance of the legal age of marriage links biological concepts of reproductive maturity with social policy to protect adolescent health. Awareness about AIDS remains crucial for preventive health behaviours, while knowledge of local medicinal plants connects traditional ecological knowledge with modern pharmacology. These school topics exemplify how biology can serve as a tool for navigating everyday life. Gormally *et al.* [2] define scientific literacy as the capacity to take scientifically informed action and make evidence-based decisions in daily life. Conventional assessment approaches have traditionally emphasised the acquisition of content knowledge over the development of skills [3].

The demographic reality of undergraduate education increases the urgency of transformation. Cooper *et al.* [4] document that about eighty-five percent of college students graduate as non-science majors. These individuals become lawyers, business owners, teachers, policymakers, and parents who make scientifically complex decisions. Knight and Smith [5] found that non-science majors reported less interest in genetics and considered the subject less relevant to their future careers. These emotional differences persist despite evidence that non-majors have cognitive abilities similar to those of majors when engaging in scientific reasoning [6].

Expectancy-value theory explains why relevance matters for student learning. Eccles and Wigfield [7] suggest that achievement motivation depends on students' beliefs about their chances of success and how they perceive the value of a task. Utility value, students' perceptions of a learning task's usefulness, is a key factor in engagement. When students see connections between biological concepts and personal goals, cultural backgrounds, or community issues, task value increases, and motivational barriers decrease [8]. For example, teaching the role of the father's Y chromosome becomes more meaningful when students discuss real-world implications for family planning and gender dynamics. Harackiewicz and Priniski [9] show that utility-value interventions provide especially strong benefits for students from underrepresented groups.

Self-determination theory offers additional insights into what makes things relevant. Ryan and Deci [10] identify autonomy, competence, and relatedness as basic psychological needs that support intrinsic motivation. When students see biological content as connected to their identities, they internalise regulatory processes and stay engaged even with difficult material [11]. This internalisation is especially important for non-science majors who may not initially have discipline-specific interest [12].

Interest theory further clarifies the developmental path from situational to individual interest in biological science. Hidi and Renninger [13] describe a four-phase model where momentary situational interest can evolve into maintained situational interest and eventually into well-developed individual interest. Rowland *et al*. [14] analyse interest measures in biology education, highlighting that purposeful relevance moments within classroom activities help foster lasting disciplinary interest. For example, introducing awareness about AIDS through community health projects can turn abstract virology into personally meaningful prevention.

Phenomenon-based learning is a pedagogical approach that responds to these theoretical insights. Walker and Nouri [15] systematically reviewed PhBL implementations, identifying six interconnected themes: theoretical foundations, curriculum design, teacher development, student learning outcomes, contextual factors, and implementation challenges. PhBL focuses instruction on observable natural-world events, shifting the emphasis from traditional subject-based teaching to integrated, inquiry-driven learning [16].

Science-technology-society models connect scientific ideas with social issues to promote higher-order thinking skills [17]. Khoeriyah *et al*. [18] reviewed the use of STS in biology education, showing consistent gains in analytical, evaluative, and creative thinking, as well as improved science process skills. Topics like the importance of the legal age of marriage naturally fit within STS frameworks by linking reproductive biology, public health data, and societal norms.

Informal learning environments provide additional ways to connect biological education to everyday life. Chappell *et al*. [19] describe how learning in families, community gardens, and outdoor spaces offers opportunities for play-based exploration. Correa [20] demonstrates that kitchen-based experimentation with bioplastics helps students understand the impacts of materials while developing the skills to create regenerative community solutions. Knowledge of local medicinal plants flourishes in such informal settings, where students interview elders, document traditional uses, and link ethnobotany to scientific principles of phytochemistry.

Field courses are especially effective in linking biology to personal experience. Gya *et al*. [21] conduct a global scoping review of field course outcomes, documenting impacts on grades, motivation, sense of belonging, and retention rates. Immersive outdoor experiences connect theory with real-world applications, promoting environmental stewardship that is crucial during the biodiversity crisis.

Despite compelling theoretical foundations, significant barriers hinder widespread transformation. Teacher preparation is a critical challenge that requires deep interdisciplinary content knowledge and strong facilitation skills [22]. Assessment systems limit transformation, as traditional evaluations that emphasise factual recall fail to measure the skills most relevant to everyday biological reasoning [23]. The COVID-19 pandemic clearly demonstrated the consequences of insufficient biological literacy, with nearly one in four college graduates believing conspiracy theories about the virus [24].

Theoretical Frameworks

Understanding how biological science education changes students' daily lives requires exploring the theoretical foundations that explain why relevance is important for learning. Multiple motivational and learning theories agree that students' perceptions of the link between academic content and their lives influence their engagement, understanding, and application. The inclusion of school-level biological topics such as sex determination, maternal health, and medicinal plants shows how these frameworks work in practice.

Table 1: Comparative Analysis of Theoretical Frameworks

Theoretical Framework	Core Constructs	Key Proponents	Application to Biology Education	Primary Outcomes
Expectancy-Value Theory	Expectancy beliefs, task value, utility value	Eccles and Wigfield [7]	Connecting biological concepts to personal goals increases utility value	Motivation, persistence, achievement
Self-Determination Theory	Autonomy, competence, relatedness	Ryan and Deci [10]	Relevance supports autonomy and identified regulation	Engagement, well-being, retention
Interest Theory	Four-phase interest development	Hidi and Renninger [13]	Purposeful relevance triggers situational interest	Curiosity, continued engagement
Situated Learning Theory	Legitimate peripheral participation	Lave and Wenger [25]	Field courses embed learning in authentic contexts	Identity development, transfer

Expectancy-value theory is the most thoroughly tested framework for understanding relevance interventions. Eccles and Wigfield [7] explain that achievement-related motivation depends on students' beliefs about their chances of success and their perceptions of task value. Utility value has attracted particular attention because teachers can more easily influence students' perceptions of usefulness than other aspects. For example, when students learn about the role of the father's Y chromosome, linking this to family-planning decisions or discussions about gender bias directly enhances perceived utility. Hulleman and Harackiewicz [26] show that when students create their own links between course content and their lives, utility value increases and predicts interest and performance.

The mechanisms by which utility value functions have significant implications for biology education. Canning and Harackiewicz [27] show that instructor-provided examples are helpful only when students find them personally relevant, necessitating student-generated connections. Harackiewicz *et al*. [28] demonstrate that utility-value interventions produce particularly strong benefits for first-generation and underrepresented minority students.

Self-determination theory complements expectancy-value theory by specifying psychological needs that support internalised motivation. Ryan and Deci [10] identify autonomy, competence, and relatedness as universal psychological necessities. Learning environments that support these needs foster intrinsic motivation and promote the internalisation of extrinsic motivations. When students explore local medicinal plants, they experience autonomy by designing their own investigations, competence by mastering identification skills, and relatedness by connecting with community knowledge holders. Assor *et al.* [29] demonstrate that conditions emphasising personal relevance trigger identified regulation, wherein students engage because they personally value the importance of the content.

Interest theory explains how momentary engagement with relevant content develops into lasting disciplinary interest. Hidi and Renninger [13] suggest that interest development occurs in four phases, each requiring different assessment methods and instructional supports. Harackiewicz *et al.* [30] show that utility-value interventions trigger situational interest, which, with ongoing support, can grow into lasting individual interest in science. Awareness of AIDS, when introduced through compelling local stories, can evoke situational interest and lead to sustained public health engagement.

Situated learning theory emphasises the importance of authentic context for meaningful learning. Lave and Wenger [25] argue that learning is inherently embedded in the activities, contexts, and cultures in which it takes place. Legitimate peripheral participation allows newcomers to gradually acquire practices and identities through engagement in authentic tasks. Knowledge of local medicinal plants exemplifies situated learning when students participate in community-based documentation projects, progressing from peripheral observers to competent practitioners.

Pedagogical Approaches

Translating theoretical insights into classroom practice requires pedagogical approaches that systematically link biological content to students' lived experiences. Different instructional models share commitments to contextualization, inquiry, and authentic engagement, but they vary in scope and in the demands they place on implementation. The five school-level topics offer concrete examples for each approach.

Table 2: Comparative Analysis of Pedagogical Approaches

Approach	Characteristics	Implementation Scope	Teacher Demands	Evidence Base
Phenomenon-Based Learning	Anchored around observable phenomena	Broad interdisciplinary philosophy	High	Adipat [16] positive impacts
Storylines	Coherent sequences driven by student questions	Existing course frameworks	Moderate	Penuel *et al.* [31] feasibility
Science-Technology-Society	Links concepts with social issues	Unit or course level	Moderate	Khoeriyah *et al.* [18] HOTS improvement
Place-Based Education	Uses local environments as context	Curriculum integrated with the place	Moderate to high	Gya *et al.* [21] motivation impacts
Informal Learning	Learning outside formal settings	Flexible implementation	Variable	Deehan *et al.* [32] found large effects
Utility-Value Interventions	Student-generated connections	Brief writing assignments	Low	Harackiewicz *et al.* [28] achievement gains

Phenomenon-based learning is the most comprehensive way to connect biology to everyday life. Originating from Finnish educational reforms, PhBL focuses on observable natural events, shifting from subject-based teaching to integrated inquiry [15]. Students observe phenomena, ask questions, and develop explanations that combine multiple scientific disciplines. Silander [33] emphasises that PhBL requires flexible learning environments in which goals are not fixed. An example, such as "why do some families have children of only one sex?", can serve as a basis for teaching about the role of the father's Y chromosome, connecting genetics, social studies, and ethics.

Storylines developed within the Next Generation Science Standards framework to organise instruction into logical sequences driven by student questions about phenomena [31]. While sharing PhBL's goal of anchoring learning around real-world events, storylines offer more structured teaching sequences. Chen and Techawitthayachinda [34] describe storylines as connected learning experiences that help students develop coherent understanding over time. A storyline on maternal health might start with student questions about why pregnant women receive specific dietary advice, then move through nutritional biology, foetal development, and healthcare access.

Science-technology-society (STS) models offer alternative approaches supported by extensive empirical evidence. Khoeriyah *et al.* [18] conducted a systematic review of STS applications in biology education. The results show consistent improvements in students' analytical, evaluative, and creative thinking skills, as well as enhanced science process abilities. Most studies used quasi-experimental designs with learning contexts focused on local environmental, health, and technological issues. The legal age of marriage is particularly suitable for STS inquiry, as students can examine biological data on adolescent reproductive health, legal frameworks, and cultural practices.

Place-based education uses local environments as contexts for learning. Sobel [35] articulates principles such as starting with local settings, engaging students in authentic projects, and fostering community connections. Semken and Brandt [36] demonstrate that paying attention to the sense of place improves engagement and learning outcomes. Field courses exemplify place-based approaches by immersing students in authentic environments where biological concepts can be observed directly [21]. Knowledge of local medicinal plants is inherently place-based, as students learn to identify, harvest, and prepare plants from their immediate surroundings.

Informal learning environments go beyond organised field experiences to include everyday settings. Chappell *et al.* [19]

describe learning in families, community gardens, libraries, and outdoor spaces as opportunities for play-based exploration that are not restricted by formal curricular pressures. Correa [20] demonstrates that kitchen-based experimentation with bioplastics enables students to become aware of material impacts while developing the ability to create regenerative solutions. Awareness about AIDS often begins informally through family discussions, media campaigns, and peer networks, serving as a natural bridge between formal and informal learning.

Student Populations and Differential Responses

Understanding how biological science education transforms everyday lives requires attention to diverse student characteristics that influence responses to instructional approaches. Research consistently shows that relevance-focused interventions have different effects across student groups, with particularly strong benefits for historically marginalised populations. The five topics- Y chromosome, maternal health, legal marriage age, AIDS awareness, and medicinal plants- resonate differently among student populations, providing multiple points for engagement.

Table 3: Comparative Analysis of Student Population Characteristics

Population	Science Identity	Relevance Perceptions	Response to Interventions
Science Majors	Strong identification	Already perceive relevance	Moderate additional benefits
Non-Science Majors	Weak science identity	Fail to see relevance	Strong positive effects
First-Generation Students	Developing identity	May not see science as relevant	Particularly strong benefits
Underrepresented Minorities	Often underrepresented in images	Cultural relevance critical	Substantial gains
Rural Students	May connect to the environment	Local relevance resonates	Place-based approaches effective
Urban Students	Diverse connections	Justice issues matter	STS approaches resonate

The distinction between science majors and non-science majors is the most extensively documented population difference. Cooper *et al.* [4] report that about eighty-five percent of college students graduate as non-science majors but receive little research attention. Hebert and Cotner [6] directly compare non-biology and biology majors, finding significant differences that exist before college. Non-biology majors reported fewer advanced high school science courses and were less likely to describe themselves as science people, yet they showed equal ability to "do" science when assessed. For these students, topics such as the importance of maternal health provide accessible entry points because they connect to universal human experiences rather than to disciplinary expertise.

Knight and Smith [5] found that non-science majors showed less interest in genetics, perceived it as less relevant to future careers, and were less motivated than science majors. Glynn *et al.* [37] reported that biology majors scored higher on every motivation component than non-biology majors. Cotner *et al.* [38] documented that non-biology majors held more misconceptions about the nature of science while viewing science as important and relevant. Knowledge of local medicinal plants can serve as a culturally relevant bridge for these students, connecting scientific inquiry to traditional practices they may already value.

First-generation college students respond differently to relevance-focused instruction. Harackiewicz *et al.* [28] found that utility-value interventions yielded particularly strong benefits for first-generation students, narrowing achievement gaps in introductory biology courses. Stephens *et al.* [39] show that first-generation students benefit from interventions that frame college as aligned with interdependent motives common in their backgrounds. For these students, linking the importance of the legal age of marriage to family well-being and community health aligns with interdependent values.

Underrepresented minority students also benefit more from relevance-focused approaches. Vasquez and Atwood [40] show that integrating relevance into biology classrooms boosts motivation, engagement, and trust in science for students from traditionally marginalised backgrounds. These effects occur through multiple means, including increased utility value, decreased stereotype threat, and a stronger sense of belonging. Awareness about AIDS, when viewed through health equity and community impact, becomes especially meaningful for students from communities heavily affected by HIV.

Rural and urban student populations show different patterns of engagement with biological content. Rural students often have direct experience with agricultural systems, natural environments, and practical biological applications. Place-based education that leverages local environments proves especially effective. Knowledge of local medicinal plants may be directly accessible to rural students who grow up with traditional botanical knowledge. Urban students connect easily through perspectives of health, environmental justice, and technology, making STS approaches particularly meaningful. The role of the father's Y chromosome and the importance of maternal health relate to reproductive justice discussions that resonate in urban contexts.

Learning Outcomes and Assessment

The ultimate measure of the transformative role of biological science education lies in its impact on students' ability to apply biological knowledge in everyday situations. This section examines documented learning outcomes and assessment methods that can effectively measure everyday biological literacy, with a specific focus on how the five school-level topics can be meaningfully evaluated.

Table 4: Comparative Analysis of Learning Outcomes

Outcome Category	Assessment Methods	Evidence from Interventions	Key References
Content Knowledge	Multiple-choice tests	Large effects for student-centred approaches	Deehan *et al.* [32]
Higher-Order Thinking	Performance tasks	Consistent improvements with STS	Khoeriyah *et al.* [18]
Science Process Skills	Laboratory practicals	Significant gains with inquiry	Gormally *et al.* [2]
Scientific Literacy	TOSLS assessment	Improvements with innovation	Gormally *et al.* [2]
Motivation and Interest	Surveys, interviews	Strong positive effects	Harackiewicz *et al.* [30]

Identity and Belonging	Identity scales	Field courses show strong effects	Gya *et al.* [21]
Civic Engagement	Behavioral measures	Limited evidence, case studies	Correa [20]
Persistence	Enrollment data	Strong evidence for interventions	Gya *et al.* [21]

Content knowledge remains the most commonly assessed outcome, reflecting historical tradition and practical convenience. Deehan *et al.* [32] conducted a scoping review of primary science interventions and found that student-centred interventions were linked to significant improvements in science content knowledge. Effect size analyses showed that inquiry-based approaches produce knowledge gains greater than those of traditional instruction. For school-level topics, content knowledge about the role of the father's Y chromosome can be evaluated through student explanations of sex determination mechanisms, but a deeper understanding occurs when students apply this knowledge to correct misconceptions in their communities.

Higher-order thinking outcomes address content knowledge limitations by assessing students' ability to analyse, evaluate, and create. Khoeriyah *et al.* [18] systematic review demonstrates consistent improvements in analytical, evaluative, and creative thinking skills as defined in Bloom's taxonomy. Studies employing performance tasks and rubrics captured gains that are invisible to traditional assessments. The importance of the legal age of marriage provides rich opportunities for higher-order thinking as students analyse epidemiological data, evaluate competing policy arguments, and propose evidence-based recommendations.

Science process skills form a related outcome domain that emphasises practices over products. Gormally *et al.* [2] created the Test of Scientific Literacy Skills to directly assess students' ability for scientifically informed action. TOSLS evaluates skills such as identifying valid scientific arguments, assessing the quality of evidence, and making evidence-based decisions. Awareness about AIDS requires these skills as students critically evaluate health information sources, distinguish evidence-based prevention from misinformation, and make personal health decisions.

Scientific literacy skills go beyond laboratory practices to include competencies needed for everyday science engagement. Feinstein [41] argues that science must be useful for students, enabling them to connect scientific information to decisions that matter to them. Cooper *et al.* [4] support assessing science literacy in terms of skills rather than just content knowledge, with an emphasis on evaluating evidence. Knowledge of local medicinal plants can be assessed by students' ability to evaluate traditional claims using scientific evidence, demonstrating how different knowledge systems can be integrated.

Motivation and interest outcomes capture affective dimensions that are essential for sustained engagement beyond formal schooling. Rowland *et al.* [14] analyse interest measures in biology education, identifying instruments suitable for different interest development phases. These outcomes are important because students who find biology interesting are more likely to seek biological information throughout their lives. The importance of maternal health, which connects to family experiences, often generates sustained interest among students who might not otherwise engage with biology.

Implementation Challenges

Despite strong evidence of transformative potential, widespread adoption of relevance-focused biology education faces significant obstacles. Recognising these challenges is essential for developing effective improvement strategies. Implementing school-level topics such as the five discussed requires overcoming systemic barriers well-documented in educational literature over many decades.

Teacher preparation is the biggest challenge, a concern that has been repeatedly highlighted in science education research since the 1990s. Darling-Hammond [42] documented that teacher quality is the most crucial school-level factor affecting student achievement, yet science teachers often lack the pedagogical content knowledge necessary for contextualised instruction. Anderson [43] emphasised that effective science teaching requires teachers to have not only content knowledge but also an understanding of how students learn and how to connect abstract concepts to lived experience. Walker and Nouri [15] reaffirm these findings, noting that educators need deep interdisciplinary content knowledge and comfort with less structured learning environments. Without proper training, teachers may implement innovative approaches superficially or revert to traditional methods. Teaching knowledge of local medicinal plants effectively requires not only botanical expertise but also cultural competency to respectfully engage with traditional knowledge systems and community elders- competencies that are rarely addressed in conventional teacher preparation programmes [44].

Curriculum design challenges deepen gaps in teacher preparation. Developing coherent instructional sequences and maintaining student engagement while building disciplinary understanding requires expertise and resources that are often unavailable in under-resourced settings. Van Driel *et al.* [45] noted that even well-designed curricula need teachers to adapt to local contexts and student populations, a process that demands significant professional autonomy and support. Topics like the role of the father's Y chromosome must be approached with sensitivity to cultural beliefs about sex determination, requiring careful adaptation that is difficult to achieve with prescriptive, one-size-fits-all curriculum materials. The National Research Council [46] has long emphasised that curriculum reform fails when it does not consider the realities of classroom implementation.

Assessment systems pose another significant barrier with deep historical roots. Black and Wiliam [47] demonstrated that traditional summative assessments often undermine formative instructional practices, creating tensions that limit pedagogical innovation. Shepard [48] argued that the disconnect between assessment purposes and instructional goals has continued despite decades of reform efforts. Traditional standardised tests that focus on factual recall fail to measure the skills most relevant to everyday biological reasoning, such as evaluating health information or making evidence-based decisions. Nevertheless, teachers and schools remain responsible for student performance on these assessments, which discourages instructional innovation. Awareness about AIDS is often reduced to memorised facts about transmission modes rather than demonstrated through health literacy skills, reflecting a broader pattern identified by Hurd [49] over two decades ago. Time constraints permeate all educational levels, posing a structural challenge, as documented by Marx *et al.* [50] in their analysis of the implementation of inquiry-based science. Developing students' higher-order thinking skills requires extended engagement that crowded curricula may not allow. The interdisciplinary nature of Phbl necessitates collaboration time that is rarely scheduled for teachers. The importance of the legal age of marriage links biology with social studies, economics, and ethics, yet curriculum structures often compartmentalise these disciplines, a problem Klein [51] identified as a persistent barrier to integrated curriculum approaches.

Institutional structures create systemic barriers that have long been recognised as obstacles to reform in science education research. Lattuca [52] found that departmental boundaries hinder interdisciplinary collaboration, while course scheduling often fails to support extended investigations. These structural issues operate beyond individual teachers' control. Maternal health education ideally integrates biology, nutrition, public health, and sociology, but schools rarely facilitate such coordination. Cuban [53] explained how the "grammar of schooling," the ingrained structures of classrooms, periods, and subject divisions, resists fundamental change even when individual teachers embrace innovation.

Equity concerns permeate all implementation challenges, representing what Lee and Luykx [54] termed "the equity paradox" in science education. Under-resourced schools serving marginalised populations face the greatest barriers to innovation while educating students who would benefit most from relevance-focused approaches. Oakes [55] documented how tracking and resource disparities systematically disadvantage students of colour and low-income students in science education. Addressing this paradox requires systemic attention to resource distribution. Knowledge of local medicinal plants may be undervalued in standardised curricula that prioritise Western biomedical frameworks, despite its relevance to many communities. Barton and Osborne [56] argued that equity in science education requires centring the knowledge and experiences that students bring from their communities, rather than treating them as deficits to be overcome. This perspective remains critically relevant for integrating the five school-level topics examined in this review.

Conclusion

The transformative potential of biological science education lies in its ability to equip students with dispositions, skills, and understandings that help them navigate everyday life as scientifically literate citizens. This review synthesises the current literature on how biology instruction can meaningfully connect to students lived experiences, using multiple theoretical frameworks and pedagogical approaches to highlight both the promises and challenges. The integration of concrete school-level topics, such as the role of the father’s Y chromosome, the importance of maternal health, the legal age for marriage, awareness about AIDS, and knowledge of local medicinal plants, shows how theoretical insights are applied in practice. The evidence indicates that when students see biological content as relevant to their personal goals, cultural backgrounds, and community contexts, they engage more deeply, learn more effectively, and develop dispositions that last beyond formal schooling.

The theoretical foundations for relevance-focused biology education are strong and diverse. Expectancy-value theory explains how utility value boosts motivation and persistence. Self-determination theory shows how autonomy-supportive conditions help internalise initially uninteresting content. Interest theory maps the development from triggered situational interest to lasting individual interest. Situated learning theory stresses the importance of authentic contexts for meaningful learning. Together, these frameworks offer complementary perspectives to understand how biology education influences students' daily lives.

Pedagogical approaches that translate these insights into practice have proliferated across educational levels and contexts. Phenomenon-based learning anchors instruction around observable, real-world events, fostering integrated inquiry across disciplines. Storylines provide structured sequences driven by student questions while maintaining alignment with standards. Science-technology-society models connect biological concepts with social issues, enhancing higher-order thinking. Place-based education leverages local environments as contexts for learning and stewardship. Informal learning reclaims everyday spaces as sites of biological inquiry. Each approach offers distinctive benefits while sharing a commitment to connecting biology to students' lives. The five topics examined in this review exemplify how these approaches can be operationalised in classrooms worldwide.

The different ways students respond to relevance-focused instruction have important implications for fairness. Non-science majors, who make up most college graduates, particularly need and benefit from making relevant connections. First-generation and underrepresented minority students see especially strong gains from utility-value interventions and culturally responsive approaches. Rural and urban students relate to biological content in different ways, reflecting their unique experiences. These results suggest that effective biology education should provide multiple relevance pathways, allowing diverse learners to find personally meaningful connections.

Documented outcomes encompass cognitive, affective, and behavioural domains. Content knowledge gains from student-centred interventions match or surpass those from traditional approaches. Higher-order thinking and science process skills develop through inquiry-based methods. Motivation and interest increase when students see relevance. Identity and belonging grow through immersive experiences and inclusive environments. Civic engagement and environmental stewardship arise from community-connected projects. Persistence and retention improve when students find meaningful connections to biological science. The five school-level topics demonstrate how these outcomes can be achieved through a curriculum that prioritises everyday relevance.

Implementation challenges, as documented in both recent and foundational literature, temper enthusiasm for transformative approaches. Gaps in teacher preparation, curriculum design constraints, assessment misalignment, time limitations, institutional structures, and equity concerns each pose significant obstacles. These barriers disproportionately impact under-resourced schools serving students who would benefit most, risking to further widen educational inequities. Overcoming these challenges requires systemic efforts to integrate locally relevant topics such as medicinal plants, reproductive health, and infectious disease awareness, while leveraging established knowledge about sustainable educational reform.

The path forward requires coordinated effort across multiple areas. Teacher education programs must prepare educators for facilitation roles that demand interdisciplinary knowledge and inquiry skills, drawing on the extensive literature on effective science teacher preparation. Curriculum developers must create materials that support coherent phenomenon-based sequences adaptable to local contexts. Assessment designers need to develop practical tools that measure everyday biological literacy, going beyond the limits of traditional standardised tests. Policymakers should align accountability systems with reform goals and distribute resources fairly. Researchers need to produce evidence about sustained impacts and the conditions necessary for scaling. Educators must stay committed to connecting biology to students' lives while managing systemic constraints. The topics discussed in this review, from Y chromosome genetics to traditional plant knowledge, serve as tangible starting points for this transformation.

The ultimate goal of biological science education is to nurture citizens who can engage with the living world as informed decision-makers, responsible stewards, and curious lifelong learners. When students leave formal education, they face biological questions daily: whether to vaccinate, what to eat, how to interpret health news, and how to respond to climate change. They will also encounter questions about sex determination, maternal health, marriage age, disease prevention, and traditional medicine. The quality of their responses depends on whether their biological education connected meaningfully to these everyday concerns or remained abstract information to be memorised and forgotten. Transformative biological education makes science applicable to living, thereby fulfilling its deepest purpose.

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