

Learning and Teaching Package 3

iSTEM for active and responsible citizenship

Foundations for Primary Education.

Teacher Academy Project

DEMOCRATIC CITIZENSHIP EDUCATION

Co-funded by the European Union

LTP 3 aims to foster critical thinking and ethical decision-making by engaging young people with real-world challenges in science, technology, engineering, and mathematics (STEM). It encourages to critically examine the ecological, social, and economic impacts of technological innovation. Through inquiry-based and project-oriented learning, students are supported in analysing complex problems, reflecting on questions of responsibility, fairness, and sustainability, and envisioning more sustainable alternatives. The LTP also promotes interdisciplinary perspectives, enabling young people to connect knowledge with ethical reasoning and democratic values.

Democratic Citizenship Education Goals of LTP 3:



Authors:

POLITÉCNICO DE SANTARÉM

Elisabete Linhares | Isabel Piscalho | Marta Uva | Neusa Branco | Susana Colaço

PH Wien Pädagogische Hochschule Wien

Lara Leik | Elena Revyakina

Disclaimer

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the EACEA. Neither the European Union nor the granting authority can be held responsible for these.

CC BY NC

This license enables reusers to distribute, remix, adapt, and build upon the material in any medium or format for noncommercial purposes only, and only so long as attribution is given to the creator.

Cover image and a number of icons were created with AI such as ChatGPT and NotebookLM prompted by the content of LTP 3

Contents

1. Why iSTEM for active and responsible citizenship?....4

2. LTP 3 Themes and Methodologies: What to Expect?....7

Theme 1. Biodiversity and Climate Action....10

Theme 2. Energy Literacy....12

Theme 3: Circular Economy....14

Theme 4. Health and Wellbeing....17

3. What Pedagogical Approaches Support iSTEM for Democratic Citizenship Education....20

Project based learning....20

Collaborative learning....21

Socio-Scientific Issue Engagement....22

Design Thinking and Engineering Design....23

Inquiry Based Learning....23

Outdoor and Place-Based Education....24

Education for Environmental Citizenship....25

Global citizenship education....26

3.1. Implementing iSTEM for DCE in Primary Settings....27

4. Challenges and Prerequisites for implementing iSTEM for active and responsible citizenship....29

Glossary....33

References....37

1. Why iSTEM for active and responsible citizenship?

In a world shaped by increasing complexity and global challenges, such as climate change, biodiversity loss, health issues, increasing energy demands and changing patterns of consumption, education needs to help children understand these challenges, think critically about them and feel **empowered to contribute to possible solutions.**

Integrated STEM (iSTEM) offers valuable opportunities by connecting science, technology, engineering and mathematics in meaningful ways to explore and address real world challenges (Chen et al., 2025; Zhou et al., 2024). The Framework provides a powerful pathway for Democratic Citizenship Education by enabling learners to connect scientific and technological knowledge with critical thinking, ethical reasoning and responsible action on real-world challenges such as climate change, biodiversity loss, health issues, rising energy demands and changing consumption patterns.

By exploring meaningful questions, investigating problems, designing solutions and working collaboratively, learners develop knowledge and skills while making sense of the world around them. Rather than learning science, technology, engineering and mathematics as separate subjects, children are encouraged to use them together to explore issues that matter to them and their communities.

Socio-scientific issues (SSI) provide particularly meaningful contexts for this work, as they engage learners with complex and often controversial real-world challenges that require consideration of evidence, values and different perspectives. Through these contexts, learners are encouraged not only to understand scientific and technological developments, but also to reflect on their social, ethical and environmental implications (Zeidler & Nichols, 2009; Zeidler, 2014a, 2014b).

In TAP-DCE, iSTEM education is closely linked to Democratic Citizenship Education (Council of Europe, 2010, 2023). Learning is not only about acquiring knowledge; it is also about **learning how to participate, listen to different perspectives, make informed decisions, and take responsible action.** This connection is increasingly recognised in international and European policy frameworks, which highlight STEM competences as essential for sustainable development, active citizenship and participation in democratic societies (UNESCO, 2017, 2019; European Commission, 2025). Through engaging with authentic challenges, children can begin to understand that their ideas, choices and actions **can make a difference** (Hilton & Hilton, 2024; Roehrig et al., 2021).

LTP3 explores this connection **through four thematic areas:**

 Biodiversity and Climate Action

 Energy Literacy

 Circular Economy

 Health and Well-being

These themes were selected because they are relevant to children's everyday experiences and provide meaningful contexts for connecting sustainability, citizenship and iSTEM learning.

Together, these themes encourage learners **to ask questions, investigate evidence, discuss alternative perspectives and reflect on how individual and collective decisions** can contribute to a more sustainable future.

Through engagement with *authentic socio-scientific issues*, learners are supported in developing *responsibility, critical thinking, collaboration and agency*, understood as the capacity to participate and act on issues that matter to them and their communities (Council of Europe, 2023). In this way, iSTEM becomes not only a way of learning about the world, but also *a way of participating in it and helping to shape it.*

Thus, the key objective of LTP 3 is to develop the following central competences for democratic citizenship:

- **Critical thinking and problem-solving** as foundational competences developed through integrated STEM, inquiry-based, and citizenship education approaches. *Critical thinking* involves analyzing information, evaluating evidence and arguments, identifying assumptions and biases, and developing reasoned judgments. *Problem-solving* involves defining problems, generating and evaluating solutions, implementing strategies, and reflecting on outcomes

- **Collaboration and communication** as essential citizenship competences developed through project-based, inquiry-based, and outdoor learning approaches. *Collaboration* involves working effectively with others, including listening to diverse perspectives, negotiating shared goals and strategies, and contributing to collective efforts. *Communication* involves expressing ideas clearly, adapting communication to different audiences and purposes, and using multiple modes of representation.

- **Ethical reasoning and values formation** developed through engagement with socio-scientific issues, environmental education, and global citizenship education. *Ethical reasoning* involves identifying ethical dimensions of issues, considering multiple ethical perspectives and principles, and developing reasoned ethical positions. *Values formation* involves developing commitments to democratic values such as justice, equality, and human rights, as well as environmental values.

- **Active citizenship and democratic participation** involve understanding democratic processes, engaging in deliberation and decision-making, and taking informed action on matters of public concern.

- **Environmental citizenship** involve understanding environmental systems and challenges, developing commitment to environmental responsibility, and taking informed action for environmental sustainability.

- **Global awareness and intercultural competence** involve understanding global interdependence and transnational issues, appreciating cultural diversity and multiple perspectives, and developing capacity for intercultural communication and cooperation

2. LTP 3 Themes and Methodologies: What to Expect?

The four thematic areas - Biodiversity and Climate Action, Energy Literacy, Circular Economy, and Health and Well-being - were selected because they connect with challenges that children already encounter in their daily lives and will continue to face as future citizens. Through these themes, learners can explore questions that matter to them, make connections between school learning and real-life situations, and better understand how their choices and actions can contribute to a more sustainable future.

Criteria for developing the Examples within each Theme

To ensure coherence across the four thematic areas, the examples developed within each theme follow a set of criteria grounded in international frameworks such as the RFCDC (Council of Europe), GreenComp[1] (European Commission), iSTEM research, Socio-Scientific Issues (SSI) literature and the Whole-School Approach. These criteria guide the design of learning scenarios that iSTEM learning with democratic citizenship.

The examples will be designed to:

1. **address real and socially relevant issues** that connect with children's everyday experiences and community contexts;
2. **integrate STEM disciplines** with ethical, social and environmental dimensions;
3. **promote student participation and agency**, enabling children to investigate, make decisions and take action;
4. **encourage deliberation and multiple perspectives**, including values, dilemmas and competing interests;
5. **support sustainability and responsibility**, helping learners reflect on environmental and social impacts;
6. **remain feasible in primary settings**, using accessible materials and age-appropriate approaches;
7. **offer opportunities for whole-school or community involvement**, in line with open-schooling principles;
8. **allow for formative assessment**, capturing both cognitive learning and citizenship competences such as collaboration, critical thinking and communication.

[1] https://publications.jrc.ec.europa.eu/repository/handle/JRC128040

These criteria ensure that the examples developed within each theme support integrated STEM learning while fostering democratic competences and responsible participation.

With the aim of promoting active and responsible citizenship, two reference frameworks will be central to the proposals of the LTP3. The RFCDC reference framework (Council of Europe, 2021) guides the focus on developing competences for a democratic culture by integrating values, attitudes, skills, knowledge and critical understanding, centered on each of the themes.

The GreenComp framework (Bianchi et al., 2022) guides the development of sustainability competence across the themes, enabling students to understand the complexity of systems and to act as agents of active, responsible and informed citizenship in pursuit of a more sustainable future. The four competence areas are highlighted in the themes of LTP 3: 1. Embodying sustainability values, 2. Embracing complexity in sustainability, 3. Envisioning sustainable futures and 4. Acting for sustainability.



Figure 1GreenComp conceptual reference model - Joint Research Centre

Each theme offers a different lens:

Biodiversity and Climate Action help understand environmental challenges and human interactions with natural systems;

Energy Literacy focuses on how energy is produced, used and managed;

Circular Economy encourages reflection on consumption, waste and resource use;

Health and Well-being highlight the importance of making informed choices that support both individual and collective quality of life.

Although each theme has its own focus (Figure 2), they are closely interconnected and encourage learners to recognise how environmental, social and technological issues influence one another. Through iSTEM learning, children are **encouraged to ask questions, investigate problems, work collaboratively, consider different perspectives, evaluate alternative solutions and take part in informed decision-making.** In this way, learning becomes a meaningful opportunity to develop the knowledge, skills and attitudes needed for active and responsible citizenship.

.



Figure 2. Interconnections between the four thematic areas explored through iSTEM for active and responsible citizenship. Source: Authors, generated with NotebookLM.

Theme 1. Biodiversity and Climate Action

Driving question

How can our daily actions help protect biodiversity and reduce the impacts of climate change?
Possible SSI Questions
Should part of the school playground be turned into a nature area?
Should schools take action to reduce food waste to help protect the environment?

Climate change and biodiversity loss are among the major challenges facing today's world. Through an iSTEM approach, learners investigate these issues using evidence, collaboration and problem-solving to better understand their causes, consequences and possible responses.
By exploring the connections between human activities, ecosystems and climate systems, children develop **a deeper understanding of how environmental changes affect both nature and people's lives.**
By connecting scientific understanding with real-life situations, this theme encourages children **to reflect on how individual and collective actions can contribute to more sustainable futures**, **while developing responsibility, participation and active citizenship**. Learners may also engage in activities inspired by citizen science, collecting and analysing data about their local environment and contributing to a better understanding of biodiversity and climate-related challenges (Heigl et al., 2020).

Why is this theme important?

Children are growing up in a world increasingly affected by climate change and biodiversity loss. Exploring these issues helps them understand the connections between human activities and environmental challenges, while developing the knowledge, skills and attitudes needed to make informed and responsible decisions. By engaging with these topics from an early age, learners can begin to see themselves as active contributors to more sustainable communities.

Related Frameworks

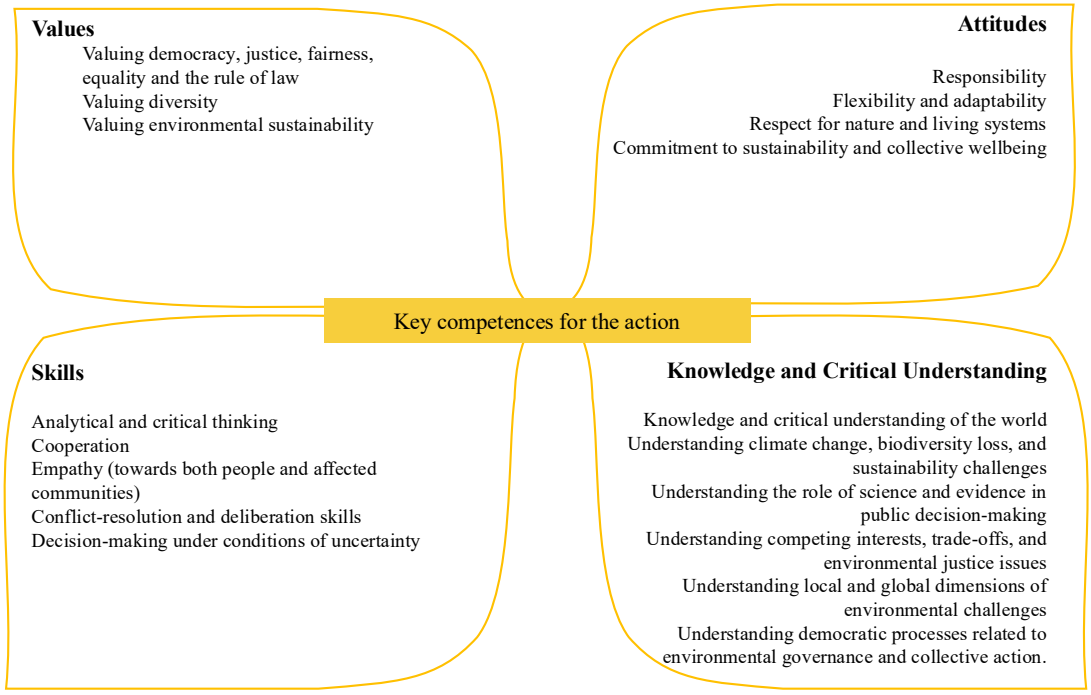
GreenComp (Bianchi et al., 2022)
Embracing complexity in sustainability
- ✓ Systems thinking
- ✓ Problem framing

Envisioning sustainable futures
- ✓ Adaptability
- ✓ Exploratory thinking

Acting for sustainability
- ✓ Collective action

RFCDC (Council of Europe, 2021)
Promotes competences such as critical thinking, responsibility, civic-mindedness and participation in collective decision-making processes.

Key competences in relation to RFCDC



Methodological Steps

Title	Socio-scientific Issues (SSI)
Description	exploring climate and biodiversity challenges through evidence, dialogue and informed decision-making.
Title	Inquiry-Based Learning
Description	investigating environmental phenomena, collecting evidence and analysing data.
Title	Outdoor Learning
Description	exploring biodiversity and environmental challenges through direct engagement with local ecosystems and communities.
Title	Action-Oriented Learning
Description	developing and implementing individual and collective actions that promote sustainability.

Theme 2. Energy Literacy

Driving question

How can we make better energy choices in our school and community?
Possible SSI Questions

- Should children be encouraged to walk or cycle to school, when possible, to reduce energy use?
- Should our school use air conditioning less often to save energy, even on very cold/hot days?

Energy literacy is about understanding **how energy is produced, used and managed, and how energy-related decisions affect people, communities, and the environment.** It also involves helping learners **understand their role** in shaping more sustainable energy futures through informed choices and responsible action (Gladwin & Ellis, 2023).
Energy is part of children's everyday lives, whether at home, at school or in their local community. They use electricity, travel by different means of transport and depend on technologies that require energy, often without thinking about where that energy comes from or how it is produced.
This theme invites learners to explore these questions and to understand the role that energy plays in contemporary society. Through an iSTEM approach, children investigate how energy is used, examine patterns of consumption, explore renewable energy sources and consider the consequences of different energy choices for people and the environment.
By connecting learning with situations that are familiar to them, learners are encouraged to reflect on how energy can be used more responsibly and how small individual and collective actions can make a difference in their school and community.

Why is this theme important?

Energy plays a central role in our daily lives and in many of the challenges facing contemporary societies. Developing energy literacy helps learners understand how energy is produced, used and managed, and how energy-related decisions affect people, communities and the environment. By exploring these issues from an early age, children can develop the knowledge, skills and attitudes needed to make informed and responsible choices.
Helping children understand where energy comes from, how it is used and how everyday choices influence energy consumption can encourage more sustainable behaviours and greater awareness of their role in building more sustainable communities (DeWaters & Powers, 2011). Research also highlights the importance of linking knowledge with attitudes and everyday practices, as these dimensions influence how individuals engage with energy-saving behaviours and sustainability-related actions (Cotton et al., 2016).

Related Frameworks

GreenComp (Bianchi et al., 2022)

Embracing complexity in sustainability

- ✓ Systems thinking
- ✓ Critical reflection

Acting for sustainability

- ✓ Collective action

European Green Deal (Tomassi, et al. (2024)

Provides a policy framework that connects energy transition, sustainability and active citizenship.

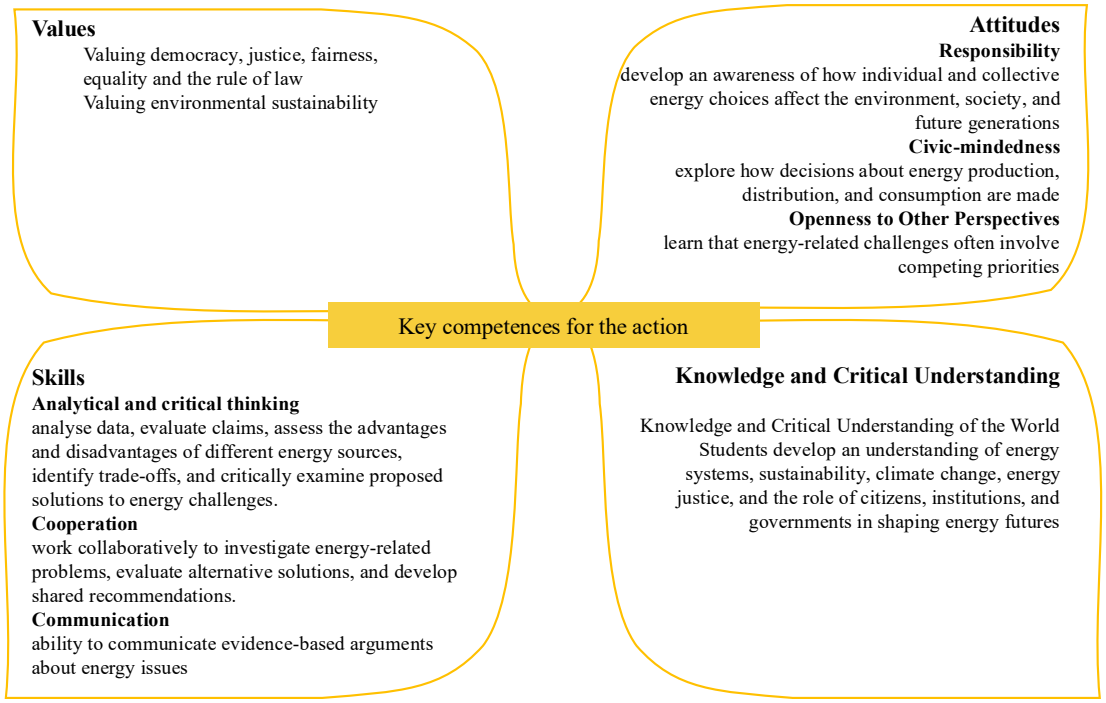
1. Transversal Clean Energy Competence Area

Ethical and Sustainable Thinking (1.2)
System Thinking (1.3)

2. Pragmatic Clean Energy Competence Area

Responsible consumption and production (2.3.)

Key competences in relation to RFCDC



Methodological Steps	
Title	Socio-scientific Issues (SSI)
Description	exploring real-world energy challenges that invite learners to consider different perspectives, discuss possible solutions and make informed decisions.
Title	Inquiry-Based Learning
Description	encouraging learners to investigate where energy comes from, how it is used in everyday life and how different choices can affect people and the environment.
Title	Design-Based Learning
Description	creating, testing and improving ideas that help use energy more efficiently and sustainably in familiar contexts.
Title	Action-Oriented Learning
Description	supporting learners in identifying practical ways to reduce energy consumption and promote more sustainable habits at school, at home and in their communities.

Theme 3: Circular Economy

Driving question

How can we reduce waste and make better use of resources in our school and community?

Possible SSI Questions

- Should schools repair broken materials instead of always buying new ones?
- Should we buy fewer clothes and use them for longer, even if new fashions are available?

Many of the products we use every day are designed to be used for a short time and then discarded. **The circular economy encourages a different way of thinking by helping us consider how materials and products can be used for longer, repaired, reused or transformed into new resources instead of becoming waste.**
Through an iSTEM approach, learners explore how products are designed, how materials move through different stages of their life cycle, and how innovative solutions can help reduce waste and make better use of available resources. By exploring familiar objects and everyday situations, children **develop a better understanding of the**

relationship between consumption, sustainability and responsible decision-making.
This theme encourages learners to think creatively about how resources can be used more sustainably and how individual and collective choices can contribute to more circular and environmentally responsible communities.

Why is this theme important?

In a world facing accelerating resource depletion, biodiversity loss, and climate instability, understanding the Circular Economy becomes essential to empower young learners **to rethink consumption and waste, and to participate in regenerative practices** that protect planetary boundaries and ensure long term societal resilience. As Korhonen et al. (2018) argue, the circular economy is a key "sustainable development strategy" that reduces environmental footprints and promotes intergenerational justice. For children aged 6–11, learning that "on a finite planet, linear growth is impossible" builds foundational scientific and environmental literacy and supports their development from passive consumers into conscious prosumers (producers + consumers) and active agents of change in resource management.

Related Frameworks

GreenComp (Bianchi et al., 2022)

Supports systems thinking and helps learners understand how human choices influence the use of resources and the generation of waste.

Values

- ✓ Valuing sustainability

Embracing complexity in sustainability

- ✓ Systems thinking
- ✓ Critical thinking

Acting for sustainability

- ✓ Collective action

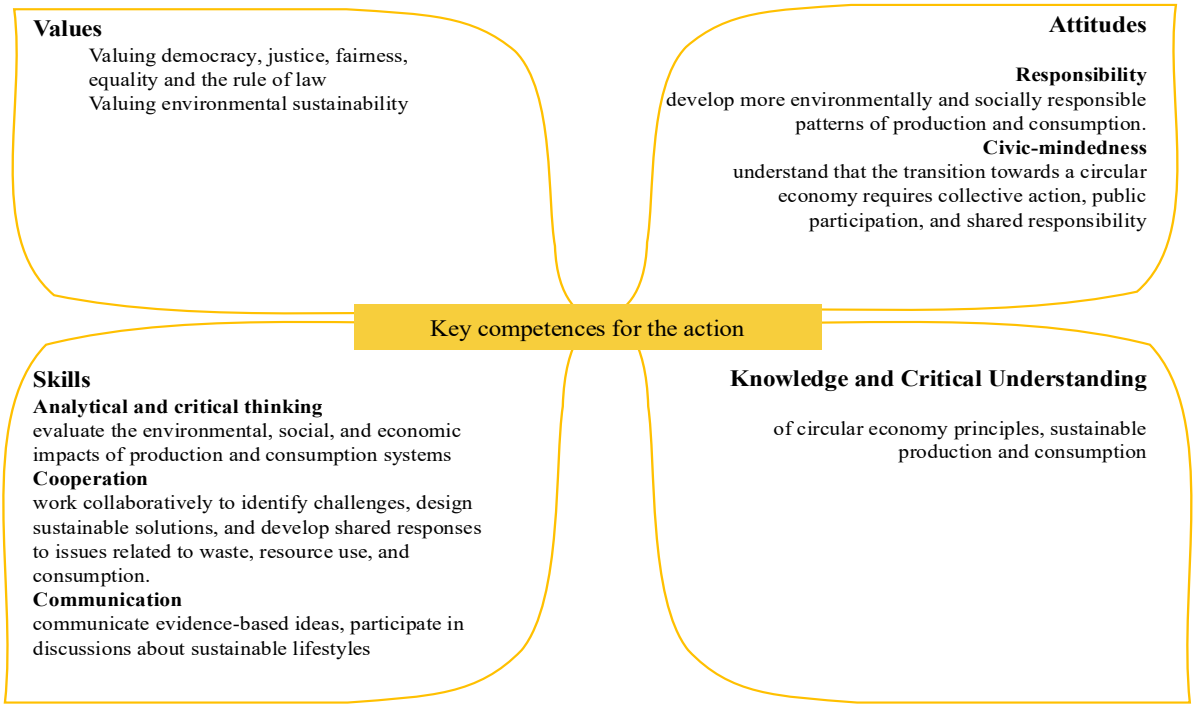
Whole School Approach (WSA)

Encourages schools to integrate circular practices into everyday life through initiatives such as reuse, recycling, composting and sustainable resource management.

Education for Environmental Citizenship

Promotes agency and responsibility, empowering learners to act for more sustainable communities and environments.

Key competences in relation to RFCDC



Methodological Steps

Title	Socio-scientific Issues (SSI)
Description	exploring questions related to consumption, waste and resource management that involve evidence, multiple perspectives and informed decision-making (Zeidler & Nichols, 2009; Zeidler, 2014).
Title	Inquiry-Based Learning
Description	encouraging learners to investigate real-world issues related to consumption, waste and resource use, while exploring possible actions for more sustainable communities (Levinson et al., 2017).
Title	Education for Environmental Citizenship
Description	supporting learners in recognising the environmental and social implications of their actions and encouraging them to participate actively in creating more sustainable and responsible communities (Hadjichambis & Reis, 2020).

Theme 4. Health and Wellbeing

Driving question

How can our choices influence health and wellbeing?

Possible SSI Question

- Should schools introduce limits on screen time to support students' wellbeing?
- Should schools offer more plant-based meals in the cafeteria?

Health and wellbeing are part of children's everyday lives and are influenced by many factors, including their habits, choices, relationships, environment, and use of technology. Through an iSTEM approach, learners explore questions that are meaningful to them, such as how physical activity, sleep, screen time, eating behavior and food choices or the environment can affect wellbeing. **By investigating real-life situations, collecting and analyzing data, and discussing different perspectives, children develop a better understanding of the factors that influence their health and that of others.**
This theme encourages learners to reflect on their daily choices and to consider how individual and collective actions can contribute to healthier and more supportive school and community environments. In this way, children begin to understand that health and wellbeing are not only personal matters, but also issues that affect the wider community.

Why is this theme important?

Health and wellbeing affect the way children learn, play, relate to others and participate in their school community. Exploring issues such as sleep, physical activity, food choices, screen time and environmental quality helps learners understand that wellbeing is shaped by everyday habits, social influences and the conditions around them (Orben & Przybylski, 2019).
Through iSTEM learning, children can collect and analyse data, compare different perspectives and reflect on the consequences of individual and collective choices. This supports more informed decision-making and helps learners recognise that health and wellbeing are not only personal matters, but also shared responsibilities within the school and wider community.

Related Frameworks

GreenComp (Bianchi et al., 2022)
Highlights the connections between human wellbeing, environmental sustainability and systems thinking, helping learners understand how lifestyle choices and environmental conditions influence health.

- ✓ Systems thinking
- ✓ Critical reflection
- ✓ Collective action

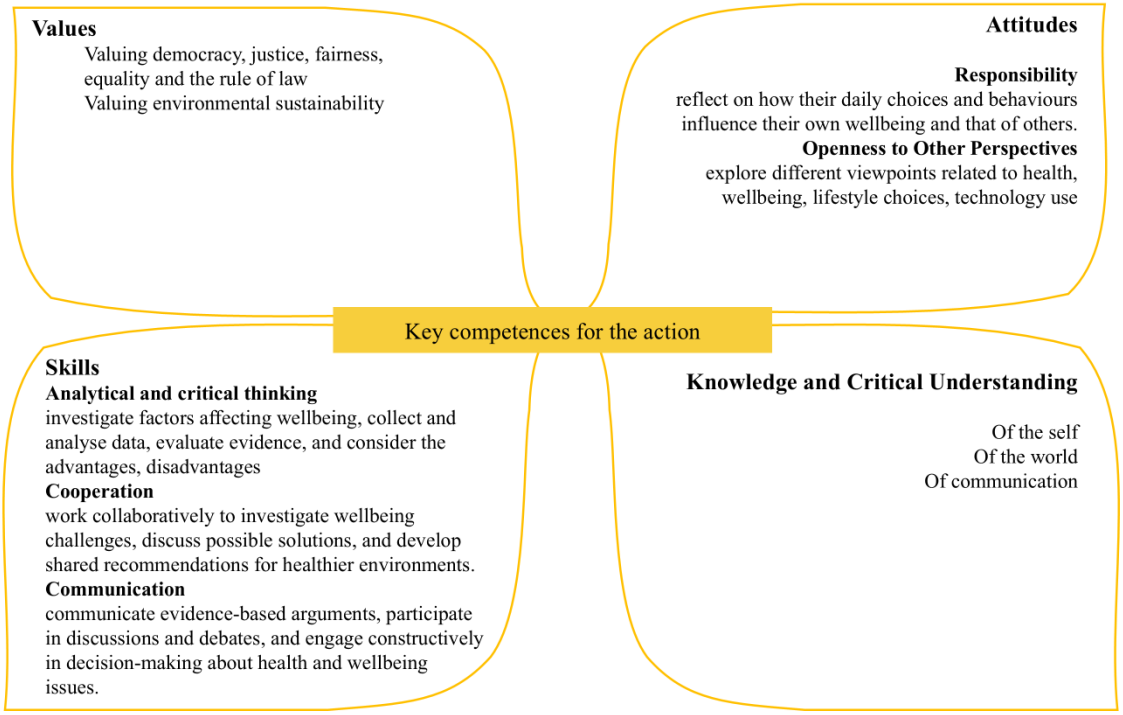
WHO Health Promoting Schools Framework

Emphasises the role of schools in creating healthy and supportive environments and encourages student participation in promoting wellbeing within the school community.

OECD Learning Compass 2030

Recognises wellbeing as a key outcome of education and highlights learner agency, supporting children in making informed choices and contributing positively to the wellbeing of others.

Key competences in relation to RFCDC



Methodological Steps

Title	Education for Environmental Citizenship
Description	helping learners recognise the connections between environmental conditions, health and wellbeing, while encouraging responsible and informed action within their communities (Hadjichambis & Reis, 2020).
Title	Socio-Scientific Inquiry-Based Learning (SSIBL)
Description	encouraging learners to investigate questions related to health and wellbeing, collect and analyse evidence, and explore possible actions that support healthier lifestyles and communities (Levinson et al., 2017).

Title	Socio-scientific Issues (SSI)
Description	exploring health-related questions that involve scientific evidence, personal choices, social influences and different perspectives, supporting informed decision-making (Zeidler & Nichols, 2009; Zeidler, 2014).

3. What Pedagogical Approaches Support iSTEM for Democratic Citizenship Education

The pedagogical approaches promoted in the LTP3 through integrated STEM combined with socio-scientific inquiry, are related to active learning methodologies that aim to create powerful learning environments that foster critical thinking, collaborative problem-solving, ethical reasoning, and active citizenship. These approaches are particularly effective in primary education contexts where interdisciplinary learning and real-world problem engagement can cultivate foundational democratic competences.

It is important to note that there is no single pedagogy for Democratic Citizenship Education (DCE) within iSTEM perspective. Rather, DCE is strengthened through a family of approaches that engage young people in inquiry, participation, collaboration, critical reflection, and action on authentic issues. As was shown in the previous section, these approaches encourage them to investigate real-world problems, analyse evidence, consider multiple perspectives, collaborate with others, deliberate about possible solutions, and take informed action.

Ultimately, the aim is to see democratic education through iSTEM approach as **a practice to be experienced through inquiry, participation, dialogue, collaboration, and action** – the practice that positions young people as **active agents** who can understand and address complex challenges, fostering the sense of efficacy and responsibility central to democratic citizenship.

Next, we will present pedagogical approaches through a number of selected examples, which serve as illustrations of how different pedagogical traditions can support democratic education across diverse contexts and themes.

Project based learning

Project-based learning (PBL) represents a pedagogical approach where students engage in extended investigations of authentic, complex questions or challenges, culminating in the creation of public products or presentations. PBL is characterized by several core features: driving questions or problems, sustained inquiry, authenticity, student voice and choice, reflection, critique and revision, and public presentation.

In STEM education, project-based learning provides a natural framework for interdisciplinary integration, as authentic projects typically require knowledge and skills from multiple domains.

Example: BAD PLASTICS project | Plastic pollution
Nature of the example: Hands-on activity, reflection, actions
Description The activity is based on a STEM project about plastic pollution, aiming to promote discussion and learning about plastic pollution and the reflection on actions to reduce or replace single-use plastic items. The activity is organized in three moments: Start-up; Development and Consolidation. Students are changed to think about the problematic of ocean plastic and the activity aims to empower them to contribute to the solution of that ecological problem. Collectively, in a local beach, students must collect plastic waste. After that, in a lab or classroom, students must organize the plastic waste in categories related with the original materials and register the quantities of items collected (to support that identification they can use the TOP 10 single-use plastics items found on sea shores poster of the European Union). To empower students and the community, in a collaborative way students must identify some actions to reduce or replace each single-use plastics item and share their ideas with the community. For example, they can create an artistical installation at school or share their ideas on a digital resource that can be disseminated online.
Age Group: 8–12 years
TAP-TS (Unit 1 of LTP3: SUSTAINABILITY AND ENVIRONMENTAL EDUCATION)
https://www.europarl.europa.eu/resources/library/images/20181011PHT15769/20181011PHT15769_original.png

Collaborative learning

Collaborative learning is integral to most project-based STEM approaches. Students work in teams to investigate questions, design solutions, and create products, developing communication, cooperation, and conflict resolution skills in the process

Example: Co-designing a Healthy School: Collaborative Wellbeing Project
Nature of the example Project-based collaborative activity (inquiry, co-design and participatory decision-making)
Description Students work in small groups to investigate a wellbeing issue in their school, guided by a question such as “Should schools regulate students’ screen time to improve wellbeing?”. The activity begins by eliciting students’ initial views and assumptions, making visible different perceptions and possible misconceptions. Students then collect and analyse data through observation, simple measurements (e.g., noise levels, time use), and peer surveys, allowing them to compare beliefs with evidence

and reflect on how habits, emotions, and social influences shape behaviour. Based on their findings, students collaboratively interpret the problem, discuss trade-offs (e.g., individual freedom vs collective wellbeing), and co-design and justify practical solutions such as quiet spaces, active breaks, or digital use guidelines. Groups present their proposals, respond to feedback, and participate in collective decision-making to select actions to test, which may then be implemented and reviewed. This activity promotes collaborative problem-solving as a process of negotiation, justification, and shared responsibility, engaging students in evidence-informed decisions and active participation in shaping their environment.
Age Group: 8–12 years
Link: https://www.who.int/health-topics/health-promoting-schools#tab=tab

Socio-Scientific Issue Engagement

SSI pedagogy involves presenting students with complex, controversial issues that have scientific dimensions but also involve ethical, social, political, and economic considerations. Students are asked to understand the scientific evidence, consider multiple perspectives, evaluate arguments, and develop informed positions.

Example: STEPWISE – Social Action Science Projects
Nature of the example: STEM pedagogy oriented toward critical action
Description Although originally designed for older students, the STEPWISE model can be adapted for primary school: students identify a local problem (waste, water use, energy), investigate scientific and technological causes, and propose concrete actions. The focus is on developing critical thinking, scientific literacy, and social awareness, linking science, technology, society, and the environment.
Age Group Adaptable for 8–12 years
Link https://www.oise.utoronto.ca/smt/faculty/jlbencze/stepwise
https://www.oise.utoronto.ca/smt/faculty/jlbencze/stse-education#stse-harms
Example: Primary Science – Socioscientific Issues Activities
Nature of the example: Classroom Activities / Inquiry-Based Learning
Description Students explore real-life issues such as pollution, climate change, and resource use through guided inquiry and discussion. Activities encourage questioning, evaluating evidence, and considering multiple perspectives before making decisions.
Age Group: Primary education
Link: https://pstt.org.uk/theory-practice/

Design Thinking and Engineering Design

Design thinking and engineering design represent complementary pedagogical approaches prominent in STEM education. Design thinking is conceptualized as a holistic, human-centered approach to problem-solving, typically organized into five non-linear stages: empathize (understand users and context), define (articulate the problem), ideate (generate potential solutions), prototype (create tangible representations), and test (evaluate and refine). This approach emphasizes creativity, iteration, and attention to human needs and values.

Engineering design methods approach interdisciplinary problems through systematic processes that include defining problems, researching constraints and criteria, generating and evaluating alternatives, developing prototypes, testing and refining solutions, and communicating results

Example: Designing Sustainable Energy Solutions: Should Our School Use Renewable Energy?
Nature of the example Project-based STEM activity (inquiry, design and participatory decision-making)
Description Students engage in an iSTEM activity based on a real-world question such as "How can our school use energy more sustainably?" or "Should our school install a small wind turbine or solar panels?". They begin by observing and collecting simple data on energy use, linking scientific understanding with basic mathematical analysis. Students then explore renewable energy sources and design simple models (e.g., wind turbines or solar devices), applying engineering thinking. Based on their findings, they compare solutions, considering advantages, limitations, and impacts. Through guided discussion, learners justify their ideas, consider different perspectives and reflect on trade-offs, culminating in a collective decision-making process that connects scientific learning with critical thinking and active citizenship.
Age Group: 8–12 years
Link: https://www.teachengineering.org/activities/view/cub_energy2_lesson07_activity2 https://practicalaction.org/schools/wind-power-challenge/

Inquiry Based Learning

The inquiry process typically involves several phases: engaging with a phenomenon or question, exploring through investigation, explaining findings, elaborating understanding through application, and evaluating learning

Example: Socio-Scientific Inquiry-Based Learning (SSIBL)
Nature of the example Project, activity
Description The Cosmos Project presents some examples of questions to provide students' investigations and actions, such some that are following presented:
(I) Question: Should fossil-fuel-powered vehicles like scooters be restricted in our city? (Netherlands)
Ideas of development: Students explored air quality by measuring particulate matter levels using sensors using sensors on their bike when travelling from home to school. This inquiry was supported by environmental experts who helped students analyse data. The project promoted awareness of air pollution's health impacts and led to student-generated proposals for reducing city traffic emissions.
(II) Question: What do buildings of a sustainable future look like? (Portugal)
Ideas of development: Students investigated sustainable architecture through several activities. Older students researched energy efficient materials and water conservation methods, and they shared their findings with younger students, fostering cross-age learning. The project concluded with students constructing model buildings featuring green roofs and solar panels.
Age Group: Any
Link: https://www.cosmosproject.eu/pt/framework/the-socio-scientific-inquiry-based-learning-approach

Outdoor and Place-Based Education

Outdoor and Place-Based Education (OPE) grounds learning in direct experience with local environments and communities, fostering deep connections to place, environmental awareness, and civic engagement. The theoretical foundations of OPE draw from experiential learning theory, which emphasizes learning through direct experience, reflection, and application.

Outdoor and place-based learning in primary education fosters multiple outcomes relevant to citizenship education, including environmental awareness and stewardship, sense of place and community connection, social and emotional development, and civic engagement

Example	**Circular Schools – Outdoor Circular Practices**
Nature of the example	School wide project with outdoor components
Description	The Circular Schools project collects good practices from European schools, including outdoor composting systems, school gardens using composted waste, and outdoor reuse stations. Students participate in mapping material flows around the school grounds, maintaining compost, and designing improvements to outdoor circular systems.

Age Group	6–12 years
Link	https://www.circular-schools.eu/toolbox/

Education for Environmental Citizenship

Education for Environmental Citizenship aims to develop learners' understanding of environmental systems, awareness of sustainability challenges, and commitment to sustainable practices; and foster action competence - the capacity and motivation to take informed action for sustainability

Example	**School Garden as a Citizenship Hub**
Nature of the example	Project (outdoor, long term)
Description	Students cultivate a school garden while learning about soil, water cycles, composting, and biodiversity. They take responsibility for planning, planting, watering, and harvesting. The garden becomes a space for discussing food waste, local food systems, and community sharing. Environmental Citizenship dimension: acting collectively to improve the local environment; understanding structural causes of environmental problems.
Age Group	6–12 years
Link	https://enec-cost.eu/wp-content/uploads/2021/10/Deliverable-8_Good-examples_final.pdf https://enec-cost.eu/wp-content/uploads/2020/03/EEC-in-Focus-English-Final.pdf https://enec-cost.eu/our-approach/education-for-environmental-citizenship/
Example	**Waste Audit and Action Plan**
Nature of the example	Outdoor, school wide project
Description	Students conduct a waste audit in the schoolyard, classify waste, identify patterns, and design an action plan (e.g., reducing packaging, improving recycling points, creating a reuse station). They present their findings to the school board. Environmental Citizenship dimension: identifying structural causes of waste, taking collective action, influencing school policy.
Age Group	8–12 years
Link	https://enec-cost.eu/wp-content/uploads/2021/10/Deliverable-8_Good-examples_final.pdf https://enec-cost.eu/wp-content/uploads/2020/03/EEC-in-Focus-English-Final.pdf

	https://enec-cost.eu/our-approach/education-for-environmental-citizenship/

Global citizenship education

Education for Global Citizenship (EGC) extends traditional citizenship education to address the realities of global interdependence, transnational challenges, and the need for intercultural understanding and cooperation. In primary education, EGC involves helping young learners develop a sense of belonging to a broader human community while maintaining connection to local contexts and identities.

This includes exploring global issues through age-appropriate content, developing intercultural competence through engagement with diverse perspectives, and fostering empathy and solidarity across differences.

The integration of EGC with STEM education creates opportunities to explore global challenges through interdisciplinary, problem-solving approaches. For example, STEM projects addressing climate change, sustainable energy, or global health connect scientific and technical learning with global citizenship themes

Example	**Co-Creating Global Citizenship: Learning to Think and Act Together**
Nature of the example	Collaborative activity (co-construction + collaborative reflection + STEM-integrated learning)
Description	Students explore global citizenship through a collaborative and reflective process in which knowledge, values and action are co-constructed. Starting from group discussions, they build a shared understanding of the concept and investigate key dimensions through real-world news using a STEM approach. Students analyse issues critically, including biases, and explore who is affected, what values are at stake, and possible solutions. They produce a collaborative output and propose actions at local and global levels, supported by ongoing collaborative reflection. The activity culminates in a digital open letter addressed to a relevant audience, followed by a final reflection. Through this process, students develop key global citizenship competences and practice active and responsible participation.
Age Group	8–14 years
Link	https://unesdoc.unesco.org/ark:/48223/pf0000232993 https://drive.google.com/file/d/1TO-WqMza3z0cBWD331oR1qVnNOqnp-8t/view?usp=sharing

Connecting to the themes, identified in the previous section, Table 1 summarises how iSTEM supports active and responsible citizenship through meaningful real-world contexts, learning processes, pedagogical approaches, and key competences aligned with European frameworks.

Component	Examples
Real-world contexts	e.g. Biodiversity and Climate Action, Energy Literacy, Circular Economy, Health and Well-being
Learning processes	Inquiry, Data collection and analysis, Design and testing, Discussion, Decision-making
Key competences	Critical thinking, Agency; Participation, Responsibility, Collaboration
Pedagogical approaches	Inquiry-based Learning, Socio-scientific Issues (SSI), Collaborative Learning, Outdoor learning, Design-Based Learning, Critical Pedagogy.
Supporting frameworks	GreenComp (Bianchi et al., 2022), RFCDC (Council of Europe, 2018, 2021), OECD Learning Compass 2030 (OECD, 2019), Education for Sustainable Development (UNESCO, 2017).

Table 1. Key components of iSTEM for Active and Responsible Citizenship

3.1. Implementing iSTEM for DCE in Primary Settings

Implementing iSTEM for DCE in primary settings requires **learning environments where inquiry, participation and ethical reflection are part of everyday school life.** International frameworks emphasise that democratic citizenship is strengthened when schools adopt a whole-school approach, integrating democratic values, participation and collaboration across all dimensions of school life (CITIZED, 2023). This perspective reinforces that democratic citizenship is not learned only through isolated activities, but through consistent practices embedded in school culture.

European studies also show that **democracy in early years and primary education is strengthened through participatory, collaborative and problem-focused learning experiences**. Neves et al. (2026) argue that when children engage in inquiry projects, explore issues relevant to their community and take part in decision-making, they develop scientific competences alongside democratic ones. This aligns directly with iSTEM, which integrates investigation, problem-solving and socio-scientific issues with values such as responsibility, fairness and participation.

Several international initiatives illustrate how iSTEM and DCE can be implemented in primary settings. Projects such as **Open Schools for Open Societies** (https://www.openschools.eu), **Make it Open** (https://makeitopen.eu) and **Schools as Living Labs** (https://www.ecsite.eu/Schools-as-living-labs) demonstrate how *project days, interdisciplinary challenges and community partnerships create authentic learning experiences.* These initiatives show that when children work on real-world problems - such as energy, biodiversity or wellbeing - they develop not only STEM knowledge but also competences in deliberation, collaboration and responsible action. The **Scientix** platform (https://www.scientix.eu) also provides numerous primary-level examples of inquiry-based STEM projects connected to sustainability and citizenship.

Assessment in iSTEM for DCE

Assessment in iSTEM for DCE should prioritise **formative strategies that capture both cognitive learning and citizenship competences.** Recent studies indicate that teachers tend to assess democratic attitudes indirectly, through **indicators such as participation, collaboration, critical thinking and the ability to justify decisions** (Mohammad-Roe et al., 2025).

Tools such as learning journals, observation, rubrics for collaboration and inquiry, and student self-assessment help children monitor their progress and reflect on their choices - practices considered essential in democratic learning environments (Damiani, 2026).

Taken together, these international findings show that implementing iSTEM for DCE in primary education requires:

- a whole-school approach that promotes participation and shared responsibility;
- interdisciplinary, inquiry-based projects grounded in real socio-scientific issues;
- formative assessment practices that value agency, ethical reasoning and collaboration.

These principles offer a strong foundation for supporting teachers in designing learning experiences that integrate science, technology and democratic citizenship in meaningful and accessible ways.

4. Challenges and Prerequisites for implementing iSTEM for active and responsible citizenship

Implementing iSTEM for active and responsible citizenship presents several interconnected challenges related to school organization, resources, pedagogical approaches, and stakeholder engagement.

Rigid school structures and time constraints: Implementing iSTEM for responsible citizenship is often hindered by rigid school structures, limited interdisciplinary planning time, and fragmented schedules that prevent teachers from designing inquiry-rich, socially relevant learning experiences. Research on interdisciplinary STEM for citizenship shows that teachers need dedicated time to integrate real-world societal issues such as climate change or social justice into STEM tasks, yet such time is rarely available in traditional school timetables.

Source: https://link.springer.com/chapter/10.1007/978-981-97-2728-5_18

Resource limitations: Schools frequently lack adequate materials, outdoor learning spaces, or digital tools to support hands-on inquiry, citizen-science activities, or environmental monitoring. Studies in citizen science highlight that meaningful participation requires accessible tools and infrastructures that allow students to collect data, collaborate, and engage with authentic environmental problems.

Source: https://www.frontiersin.org/journals/sociology/articles/10.3389/fsoc.2020.613814/full

Techno-solutionism vs. meaningful learning: A risk of equating "innovation" solely with the presence of high-tech tools (robotics, tablets), ignoring the social negotiation and critical thinking required to use those tools for the common good.

Source: https://unesdoc.unesco.org/ark:/48223/pf0000385723

Teacher Isolation and Burnout: The lack of collaborative spaces, combined with the increasing demands associated with digital and sustainability transitions, may create additional pressure on teachers and negatively affect their wellbeing. Without a supportive school culture, changes in teaching practices risk becoming an individual responsibility rather than a collective process of learning and improvement. In this context, the LifeComp framework highlights the importance of competences such as self-regulation, flexibility, collaboration and wellbeing, which can support teachers in navigating change and sustaining their professional development.

Source: https://op.europa.eu/pt/publication-detail/-/publication/7d9c9dcd-bf31-11ea-901b-01aa75ed71a1; https://link.springer.com/chapter/10.1007/978-981-97-2728-5_18

Student agency gap: A systemic failure to listen to and involve students in decision-making. Education is often a reactive process where students consume information rather than a proactive process of shaping their environment.

Source: https://www.oecd.org/en/data/tools/oecd-learning-compass-2030.html

Ethical complexity: iSTEM projects that address climate change, biodiversity loss, or energy transitions require students to engage with ethical dilemmas, uncertainty, and competing social values. Recent STEM education research (Christodoulou & Osborne, 2024) shows that socioscientific issues inherently involve tensions between technological innovation, environmental responsibility, and community needs. Students must weigh evidence, consider diverse perspectives, and make value-based decisions — processes that demand careful teacher facilitation and structured opportunities for ethical reasoning. Without explicit support, learners may struggle to navigate the moral and civic dimensions embedded in real-world STEM problems. Source: https://www.researchgate.net/publication/263470200_STEM_education_A_deficit_framework_for_the_twenty_first_century_A_sociocultural_socioscientific_response https://www.researchgate.net/publication/381959590_Teaching_Socioscientific_Issues_A_Systematic_Review
Community partnerships: Citizen-science literature highlights that collaboration with local organisations, municipalities, and environmental groups is essential for authentic learning, yet schools often lack mechanisms to build and sustain these partnerships. This limits opportunities for students to engage with real environmental challenges. Source: https://www.frontiersin.org/journals/sociology/articles/10.3389/fsoc.2020.613814/full
Leadership and teacher well-being: Sustaining iSTEM initiatives requires supportive school leadership and attention to teacher well-being. Studies on STEM equity and participatory approaches show that teachers working with socioscientific issues face emotional and cognitive demands, making leadership support crucial for long-term implementation. Source: https://ojed.org/STEM/article/view/7903

Possible Supportive Mechanisms

Implementing iSTEM with a focus on active and responsible citizenship can be challenging in everyday school life. Time pressure, limited resources, complex socio-scientific topics and the need for new teaching approaches often make this work demanding. However, these challenges can be eased through supportive mechanisms that **strengthen collaboration, reflection and student participation**. The strategies below offer practical ways to help teachers create meaningful learning experiences while engaging learners with real-world sustainability issues.

Table 2. Alignment between the main challenges identified in implementing iSTEM and the corresponding supportive mechanisms

Challenge	Supportive Mechanism
Rigid school structures and time constraints	Communities of Practice; collaborative planning; flexible implementation strategies
Resource limitations	Use of low-cost materials; Outdoor education; partnerships with local organizations
Techno-solutionism in education	Inquiry & Outdoor Education; SSIE approaches; focus on critical thinking and pedagogical purpose
Teacher isolation and burnout	Communities of Practice; professional development; peer support; Personal development programmes
Student agency gap	Participatory approaches; Inquiry & Outdoor Education; student decision-making activities
Ethical and socio-scientific complexity	Structured discussion and reflective dialogue; SSIE; guided debate
Leadership support and teacher well-being	Whole-school approaches; leadership engagement; supportive organizational culture

The table above highlights a range of possible supportive mechanisms that can help to address main challenges identified. The examples described below provide a closer look at some of these approaches and illustrate how they can support teachers and learners in different educational contexts.

Communities of Practice (Teacher Collaboration): Communities of Practice help teachers collectively design interdisciplinary iSTEM tasks, share reflections, and integrate citizenship themes. Research shows that collaborative PD strengthens teachers' self-efficacy in using real-world societal contexts and improves their ability to connect STEM with responsible citizenship. https://link.springer.com/chapter/10.1007/978-981-97-2728-5_18
Professional development programmes (Reflective Teacher): Structured PD grounded in inquiry and reflection supports teachers in analysing their practice, addressing ethical dimensions of STEM, and improving facilitation of socio-scientific discussions. Citizen-science and STEM-citizenship studies emphasise that reflective cycles help teachers adapt activities to students' needs and community contexts. https://www.frontiersin.org/journals/sociology/articles/10.3389/fsoc.2020.613814/full
Personal development programmes (Active Participation & Well-being): Personal development programmes are essential for supporting teachers who work with inquiry-based iSTEM projects that address complex and emotionally demanding topics such as climate change, sustainability, or community challenges. Research in STEM education shows that teachers often face significant emotional

and cognitive demands when facilitating open-ended investigations and socio-scientific discussions. Programmes that strengthen emotional resilience, reflective capacity, and professional identity help teachers manage this complexity and maintain the conditions needed to promote student agency and active participation. https://d-nb.info/1369335156/34
Inquiry-based and outdoor education approaches (Inquiry & Outdoor Education) Inquiry-based iSTEM learning combined with outdoor education gives students real opportunities to investigate environmental phenomena, collect data in authentic settings, and connect STEM concepts to local issues. Research in outdoor science education shows that learning outside the classroom strengthens inquiry skills, observation, and environmental responsibility. By engaging directly with their surroundings, students develop a deeper understanding of real-world problems and are encouraged to take active, responsible roles in their communities. https://www.tandfonline.com/doi/abs/10.1080/14729679.2013.769887
Ethical and socioscientific reasoning Integrating SSIE perspectives helps students critically analyse the societal, cultural, and environmental implications of STEM solutions. Research on socioscientific issues in STEM education shows that this approach deepens conceptual understanding and strengthens civic reasoning. https://link.springer.com/chapter/10.1007/978-981-97-2728-5_18
Structured discussion and reflective dialogue within iSTEM learning, allowing students to critically analyse challenges, consider multiple perspectives, and engage with uncertainty and ethical dilemmas. These approaches support informed decision-making and help develop students' agency to participate in responsible action. (Zeidler & Nichols, 2009).

Glossary

1. Core Concepts

Active citizenship can be defined as individuals' engagement with and participation in the political sphere, civil society, workplaces, and community life in accordance with human rights and democratic values and for the benefit of broader society. (Boyadjieva et al., 2024). https://doi.org/10.3390/socsci13010048.

Education for Global Citizenship - Refers to an educational approach that aims to develop learners' critical awareness of global interdependencies and to empower them to act as active, responsible and engaged citizens. It integrates knowledge, skills, values and attitudes that enable learners to understand and critically analyse global issues (such as human rights, sustainability and inequality), and to contribute to more just, inclusive and sustainable societies. It encompasses cognitive, socio-emotional and behavioural dimensions of learning and is implemented through participatory, reflective and action-oriented pedagogies. Within this framework, iSTEM approaches support interdisciplinary understanding and problem-solving, enabling learners to develop informed, critical and socially responsible responses to complex global challenges (UNESCO, 2014). https://unesdoc.unesco.org/ark:/48223/pf0000227729

iSTEM (integrated Science, Technology, Engineering and Mathematics) is an interdisciplinary educational approach that connects STEM domains to address real-world problems through inquiry, design, and problem-solving, fostering meaningful learning and links to societal and civic contexts. Thibaut et al. (2018); Roehrig et al. (2021)

2. Thematics Concepts

Biodiversity: is the variety of life on Earth, in all its forms, from genes and bacteria to entire ecosystems such as forests or coral reefs. The biodiversity we see today is the result of 4.5 billion years of evolution, increasingly influenced by humans (European Commission, 2024). https://knowledge4policy.ec.europa.eu/glossary-item/biodiversity_en

Circular Economy: A restorative economic system that replaces the linear "take-make-dispose" model by keeping resources in use for as long as possible. It employs strategies such as reducing, reusing, recycling, and recovering to minimize waste. This systemic transformation operates across all levels—from products to the global economy—aiming to decouple growth from resource consumption while ensuring environmental sustainability, economic prosperity, and social equity (Kirchherr et at., 2017). https://doi.org/10.1016/j.resconrec.2017.09.005; https://environment.ec.europa.eu/strategy/circular-economy_en

Climate Action: Create action to combat climate change and its impact. According to UN () education plays an important role on climate action providing knowledge to meet climate change: "Improve education, awareness-raising and human and institutional

capacity on climate change mitigation, adaptation, impact reduction and early warning" https://globalgoals.org/goals/13-climate-action/

Climate Change: According to UN, climate change refers to long-term shifts in temperatures and weather patterns. These changes may have natural causes, such as the sun's activity or major volcanic eruptions. Human activities are also responsible for these changes and have been the primary factor since the 19th century, mainly due to the burning of fossil fuels such as coal, oil, and natural gas. https://www.un.org/en/global-issues/climate-change

Critical energy literacy: extends traditional energy literacy by incorporating critical, socio-political, and ethical dimensions, enabling learners to analyze power relations, inequalities, and decision-making processes in energy systems and to engage as active citizens. Lowan-Trudeau and Fowler (2022). https://doi.org/10.1017/aee.2021.15

Digital wellbeing: refers to the impact of digital technologies and media use on individuals' physical, mental, and social health. It involves the ability to critically reflect on digital habits, balance opportunities and risks, and make informed decisions about technology use. In educational contexts, it connects scientific understanding with ethical reflection and democratic participation, particularly in relation to shared norms and collective wellbeing (European Commission, 2025). https://publications.jrc.ec.europa.eu/repository/handle/JRC144412

Energy citizenship: refers to individuals' active participation in energy-related issues, combining knowledge, critical thinking and responsible action to contribute to sustainable and informed decision-making (Wagner et al., 2024).

Energy justice: refers to the application of justice principles to energy systems, aiming to ensure the fair distribution of energy-related benefits and burdens, equitable access to energy, and inclusive participation in decision-making processes (Jenkins et al., 2016; Sovacool & Dworkin, 2015).

Energy literacy: refers to a broad understanding of energy that encompasses knowledge, attitudes, and behaviours, enabling individuals to make informed decisions and act responsibly in relation to energy use (DeWaters & Powers, 2011).

Energy poverty: refers to the inability of households to access or afford adequate energy services necessary for a decent standard of living (Bouzarovski & Petrova, 2015). Within European policy frameworks, it is understood as a multidimensional issue shaped by factors such as low income, high energy expenditure, and poor energy efficiency (European Commission, 2020).

Energy transition: is defined as a shift from energy systems dominated by fossil-based sources towards systems based largely on renewable energy and improved energy efficiency (European Commission, n.d.). Within European policy frameworks, it is further conceptualized as a profound transformation of the energy sector towards a climate-neutral, low-carbon economy (European Parliament, 2024).

European Green Deal: The European Green Deal is the European Union's growth strategy that aims to transform the EU into a modern, resource-efficient, and competitive economy, ensuring no net emissions of greenhouse gases by 2050, decoupling economic growth from resource use, and promoting a just and inclusive transition (European Commission, n.d.). https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

Health and wellbeing: refer to the dynamic interaction between physical, mental, and social dimensions of individuals' lives, shaped by biological, environmental, technological, and socio-economic factors. Within an iSTEM and democratic citizenship perspective, health is understood not only as an individual condition but as a collective and societal issue, involving informed decision-making, responsibility, and participation in shaping healthier environments (World Health Organization, 2021). https://iris.who.int/server/api/core/bitstreams/96da8799-4938-4d66-b171-04770ed4b243/content

Renewable energy: refers to energy derived from natural processes that are continuously replenished, such as solar, wind, hydro, or biomass (International Energy Agency, 2022; European Parliament & Council of the European Union, 2018).

Sustainability Literacy: refers to the knowledge, skills, values and competencies that enable individuals to understand complex sustainability challenges and make informed decisions that support environmental integrity, social equity and economic viability. https://doi.org/10.3389/feduc.2025.1490791

3. Cross-Cutting Concepts

Agents of Change: environmental citizens capable of acting as catalysts for ecological and social transformation. They take an active role in decision-making processes and act as influential educators for both peers and adults, driving the collective action necessary to protect our planet's future (GreenComp + ENEC) https://enec-cost.eu/wp-content/uploads/2020/03/EEC-in-Focus-English-Final.pdf

Collaborative work: Refers to a learning process in which individuals work together towards a shared goal, co-constructing knowledge through dialogue, negotiation and mutual support. It involves active participation, shared responsibility, respect for diverse perspectives and joint decision-making. Collaborative work fosters communication, empathy and problem-solving skills, and enables learners to engage with complex tasks in a more meaningful way. It is a key competence for democratic participation and for addressing global challenges in interconnected contexts. In this context, collaborative work is both a learning strategy and a core component of global citizenship, as it reflects the values and practices of democratic participation (UNESCO, 2014). https://unesdoc.unesco.org/ark:/48223/pf0000227729

Critical Thinking: Refers to the ability to analyse, evaluate and interpret information, arguments and evidence in a reflective and reasoned way. It involves questioning assumptions, identifying biases, considering multiple perspectives and making informed judgments. Critical thinking enables learners to understand complex issues, assess the reliability of information (including media sources), and make responsible decisions. It is a key competence for active participation in democratic societies and for addressing global challenges. In STEM contexts, critical thinking supports interdisciplinary problem-solving and the evaluation of solutions from scientific, technological and ethical perspectives (OECD, 2019) https://www.oecd.org/content/dam/oecd/en/about/projects/edu/education-2040/1-1-learning-compass/OECD_Learning_Compass_2030_Concept_Note_Series.pdf

Informed decision-making: refers to the process of making choices based on the critical evaluation of evidence, while also considering values, perspectives, and potential consequences. In health and wellbeing contexts, it involves recognising the influence of perceptions, emotions, and social norms, and using data and scientific understanding to support reasoned and responsible decisions. Within iSTEM and democratic citizenship education, it is a key competence that enables learners to participate actively and responsibly in issues that affect both individual and collective wellbeing (Andermann et al., 2016). https://link.springer.com/article/10.1186/s12961-016-0085-4

Perception and Evidence in Health-related Decision-Makin: Health-related decisions are often influenced not only by scientific evidence but also by perceptions, emotions, and social influences. This concept highlights the importance of critically examining initial beliefs, confronting misconceptions, and using evidence-based reasoning to inform decisions. In iSTEM contexts, it supports learners in understanding how knowledge is constructed and how informed judgement is essential for responsible and democratic participation (Kahan, 2015). https://onlinelibrary.wiley.com/doi/10.1111/pops.12244

Socioscientific issues (SSI): involve the deliberate use of scientific topics that require students to engage in dialogue, discussion, and debate. They are usually controversial in nature but have the added element of requiring a degree of moral reasoning or the evaluation of ethical concerns in the process of arriving at decisions regarding possible resolution of those issues (Zeidler& Nichols, 2009, p. 49). https://files.eric.ed.gov/fulltext/EJ849716.pdf

References

Bianchi, G., Pisiotis, U., & Cabrera Giraldez, M. (2022). *GreenComp: The European sustainability competence framework*, Punie, Y. and Bacigalupo, M. editor(s), EUR 30955 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-76-46485-3, https://doi.org/10.2760/13286, JRC128040.

Bodzin, A. (2012). Investigating urban eighth-grade students' knowledge of energy resources. *International Journal of Science Education, 34*(8), 1255–1275. https://doi.org/10.1080/09500693.2012.661483

Boyadjieva, P., Ilieva-Trichkova, P., & Todorov, V. (2024). Justice in achievement matters: The fairness of educational opportunities and active citizenship. *Social Sciences, 13*(1), 48. https://doi.org/10.3390/socsci13010048

Chen, B., Chen, J., Wang, M., Tsai, C.-C., & Kirschner, P. A. (2025). The effects of integrated STEM education on K–12 students' achievements: A meta-analysis. *Review of Educational Research*. https://doi.org/10.3102/00346543251318297

CITIZED (2023). CITIZED: Guidelines and toolbox for a whole-school approach in citizenship education. CITIZED project. https://school-education.ec.europa.eu/en/teach/teaching-materials/citized-guidelines-and-toolbox

Cotton, D., Shiel, C., & Paço, A. (2016). Energy saving on campus: A comparison of students' attitudes and reported behaviours in the UK and Portugal. *Journal of Cleaner Production, 129*, 586–595. https://doi.org/10.1016/j.jclepro.2016.03.136

Council of Europe. (2010). *Charter on education for democratic citizenship and human rights education*. https://rm.coe.int/16803034e5

Council of Europe. (2018). *Reference framework of competences for democratic culture. Volume 1: Context, concepts and model*. Council of Europe Publishing. https://rm.coe.int/prems-008518-gbr-2508-reference-framework-of-competences-vol-1-8573/16807bc66c

Council of Europe. (2021). *The reference framework of competences for democratic culture in brief*. Council of Europe Publishing. https://rm.coe.int/prems-004721-the-reference-framework-of-competences-for-democratic-culture/1680a27f24

Council of Europe. (2023). *Manual of the reference framework of competences for democratic culture*. https://www.coe.int/en/web/education/-/manual-of-the-reference-framework-of-competences-for-democratic-culture-introductory-course

Damiani, V. (2026). Democratic learning environments for civic and citizenship education. In Experiencing Democracy in the Classroom (pp. 23–45). Springer. https://doi.org/10.1007/978-3-032-25449-8_2

DeWaters, J., & Powers, S. (2011). Energy literacy of secondary students in New York State (USA): A measure of knowledge, affect, and behavior. *Energy Policy, 39*(3), 1699–1710. https://doi.org/10.1016/j.enpol.2010.12.049

European Commission. (2020). Commission recommendation (EU) 2020/1563 of 14 October 2020 on energy poverty. *Official Journal of the European Union, L 357*, 35–41. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020H1563

European Commission. (n.d.). *Energy transition: Definition and context*. Urban Innovative Actions.

European Commission. (n.d.). *The European Green Deal*. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

European Commission. (2022). *REPowerEU Plan*. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/repowereu_en

European Commission, Joint Research Centre. (2025). *STEM and STEAM education, and disciplinary integration: A guide to informed policy action*. Publications Office of the

European Union. https://publications.jrc.ec.europa.eu/repository/handle/JRC141438

European Network for Environmental Citizenship (ENEC). (2020). *Education for environmental citizenship in focus*. https://enec-cost.eu/wp-content/uploads/2020/03/EEC-in-Focus-English-Final.pdf

European Parliament. (2024). *Energy transition in the EU*.

Gladwin, D., & Ellis, N. (2023). Energy literacy: Towards a conceptual framework for energy transition. *Environmental Education Research, 29*(10), 1515–1529. https://doi.org/10.1080/13504622.2023.2175794

Heigl, F., Kieslinger, B., Paul, K. T., et al. (2020). Opinion: Toward an international definition of citizen science. *Frontiers in Sociology, 5*, 613814. https://doi.org/10.3389/fsoc.2020.613814

Hadjichambis, A. C., & Reis, P. (Eds.). (2020). *Conceptualizing Environmental Citizenship for 21st Century Education*. Springer

Hilton, A., & Hilton, G. (2024). The importance of STEM education to responsible citizenship within a democracy. In *The contribution of mathematics to school STEM education* (pp. 257–275). Springer. https://doi.org/10.1007/978-981-97-2728-5_15

Jenkins, K., McCauley, D., Heffron, R., Stephan, H., & Rehner, R. (2016). *Energy justice: A conceptual review*. *Energy Research & Social Science, 11*, 174–182. https://doi.org/10.1016/j.erss.2015.10.004

Julià, C., & Antolí, J. Ò. (2019). Impact of implementing a long-term STEM-based active learning course on students' motivation. *International Journal of*

Technology and Design Education, 29(2), 303–327. https://doi.org/10.1007/s10798-018-9441-8

Kahan, D. M. (2015). Climate-science communication and the measurement problem. *Political Psychology, 36*(S1), 1–43. https://doi.org/10.1111/pops.12244

Korhonen, J., Honkasalo, A., & Seppälä, J. (2018). Circular economy: The concept and its limitations. *Ecological Economics, 143*, 37–46. https://doi.org/10.1016/j.ecolecon.2017.06.041

Lowan-Trudeau, G., & Fowler, T. A. (2022). Towards a theory of critical energy literacy: The Youth Strike for Climate, renewable energy and beyond. *Australian Journal of Environmental Education, 38*(1), 58–68. https://doi.org/10.1017/aee.2021.15

Mohammad-Roe, S., Paaske, N., Van Hoof, N., & Amitai, A. (2025). Nurturing student engagement: Towards democratic values and attitudes. Journal of Social Science Education, 24(3). https://doi.org/10.11576/jsse-7680

Moreno, H. O., Godoy-Rangel, C., & Ahumada-Lazo, R. (2025). From lectures to active learning: A case study on problem-based learning in the material balances course. le*International Journal of Mechanical Engineering Education*. Advance online publication. https://doi.org/10.1177/03064190251356618

Neves, C., Pažur, M., Oliveira, J., Abrantes, P., Abelha, M., Almeida, A. P., & Slovaček, K. A. (2026). Democracy-as-becoming in early years and primary education: Aesthetic, embodied, and digital pedagogical ecologies. Frontiers in Education, 11, 1799195. https://doi.org/10.3389/feduc.2026.1799195

OECD. (2019). *OECD Learning Compass 2030*. https://www.oecd.org/education/2030-project/teaching-and-learning/learning-compass-2030/

Orben, A., & Przybylski, A. K. (2019). Screens, teens, and psychological well-being: Evidence from three time-use-diary studies. *Psychological Science*, *30*(5), 682–696. https://doi.org/10.1177/0956797619830329

Roehrig, G. H., Dare, E. A., Ellis, J. A., & Ring-Whalen, E. A. (2021). Beyond the basics: A detailed conceptual framework of integrated STEM education. *Disciplinary and Interdisciplinary Science Education Research, 3*(11). https://doi.org/10.1186/s43031-021-00041-y

Thibaut, L., Ceuppens, S., De Loof, H., Depaepe, F., & De Cock, M. (2018). Integrated STEM education: A systematic review of instructional practices in secondary education. *European Journal of STEM Education, 3*(1), 02. https://doi.org/10.20897/ejsteme/85525

Tomassi, S., Bonura, F., Costantino, F., De Carolis, A., Falcone, P. M., Hölker, F., Mazzocchi, F., Nicolosi, R., Roversi, R., & Vona, F. (2024). *A competence framework for the European Green Deal*. The Journal of Environmental Education, 55(1), 1–18. https://doi.org/10.1080/00958964.2023.2259846

UNESCO (2014). *Global citizenship education: preparing learners for the challenges of the 21st century.* https://unesdoc.unesco.org/ark:/48223/pf0000227729

UNESCO. (2017). *Education for Sustainable Development Goals: Learning objectives*.

UNESCO. (2019). *Exploring STEM competences for the 21st century*. UNESCO IBE. https://unesdoc.unesco.org/ark:/48223/pf0000368485

UNESCO. (n.d.). *Science, technology, engineering and mathematics (STEM)*. https://www.unesco.org/en/stem

Wagner, O., Tholen, L., Albert-Seifried, S., & Swagemakers, J. (2024). Empowering students to create climate-friendly schools. *Energies, 17*(9), 2199. https://doi.org/10.3390/en17092199

Zeidler, D. L. (2014a). Socioscientific issues as a curriculum emphasis: Theory, research, and practice. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education* (Vol. 2, pp. 697–726). Routledge.

Zeidler, D. L. (2014b). STEM education: A deficit framework for the twenty-first century? A sociocultural socioscientific response. *Cultural Studies of Science Education, 9*(2), 409–416. https://doi.org/10.1007/s11422-014-9578-z

Zeidler, D. L., & Nichols, B. H. (2009). Socioscientific issues: Theory and practice. *Journal of Elementary Science Education, 21*(2), 49–58. https://files.eric.ed.gov/fulltext/EJ849716.pdf