SDG, a new path to go by

The current world is facing challenges that set objectives to be addressed. One of the great current challenges is related to sustainability and the implication that our actions have on the world that we will leave in inheritance to future generations.

Concepts of sustainability and sustainable development appeared in the 80s, under the idea of generating a collective responsibility that allows confronting the problems and challenges that humanity faces and that seriously threaten its future (Orr, 2013).

This concept has evolved until it is presented as a crucial challenge that must promote practical actions so that everyone around the world can build a better future together (UNESCO, 2015), focusing these actions on three dimensions: economic, social and environmental, around which the 17 Sustainable Development Goals (SDGs) that make up the 2030 Agenda for Sustainable Development revolve, approved in 2015 at the UN. It is a plan for peace and prosperity for peoples and the planet in the present and in the future.

Figure 1. Sustainable Development Goals. Source: Unesco

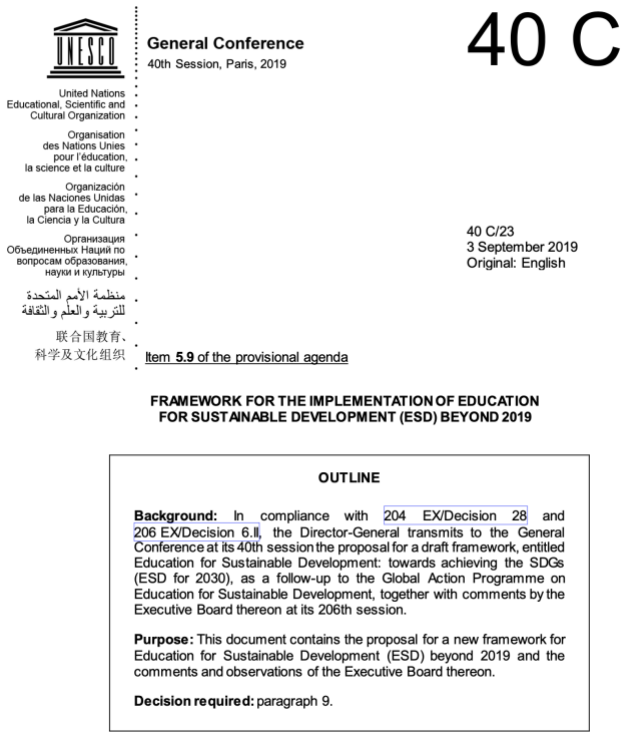
These SDGs are only possible with a commitment to education, but an education focused on developing competencies in sustainability. That is, promoting an Education for Sustainable Development (ESD) that develops competencies in sustainability characterized by their transversality, multifunctionality and independence (Vásquez and García-Alonso, 2020). But it is necessary to develop them at a global level, although they replace the specific competences for certain situations and contexts, understand them and have a greater scope (Rychen, 2003).

In addition, according to UNESCO (2017), we will be able to achieve these objectives if we achieve a holistic, inclusive and transformative education that includes:

a) The contents and learning outcomes in which the curricula are integrated with sustainability themes.
b) Pedagogy and student-centered, action-oriented learning environments based on interaction and exploratory learning.

c) The fruits of learning are aimed at promoting competencies such as critical and systemic thinking, joint decision-making and taking responsibility for current and future generations.
d) Seek social transformation, both the transformation itself and that of the social environment in which we live.

This is an enormous challenge for teachers, and even greater for teachers of physics, chemistry and mathematics, who are not aware of their competencies to implement training in this line (Uitto & Saloranta, 2017; Dahl, 2019; Vásquez, Seckel & Alsina, 2020).



United Nations Educational, Scientific and Cultural Organization
Organisation des Nations Unies pour l'éducation, la science et la culture
Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura
Организация Объединенных Наций по вопросам образования, науки и культуры
منظمة الأمم المتحدة للتربية والعلم والثقافة
联合国教育、科学及文化组织

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Item 5.9 of the provisional agenda

FRAMEWORK FOR THE IMPLEMENTATION OF EDUCATION FOR SUSTAINABLE DEVELOPMENT (ESD) BEYOND 2019

OUTLINE

Background: In compliance with 204 EX/Decision 28 and 206 EX/Decision 6.II, the Director-General transmits to the General Conference at its 40th session the proposal for a draft framework, entitled Education for Sustainable Development: towards achieving the SDGs (ESD for 2030), as a follow-up to the Global Action Programme on Education for Sustainable Development, together with comments by the Executive Board thereon at its 206th session.

Purpose: This document contains the proposal for a new framework for Education for Sustainable Development (ESD) beyond 2019 and the comments and observations of the Executive Board thereon.

Decision required: paragraph 9.

Figure 2. Framework for the implementation of ESD. Source: United Nations

ESD, developing competent citizens in sustainability.

Throughout these years it has been seen that it is necessary to carry out a specific training that allows to clarify how to carry out a ESD, so UNESCO has identified four main approaches: *integrative, critical, transformative and contextual* (UNESCO, 2012). These approaches serve as a guide for the didactic proposal that we can consider when implementing ESD.

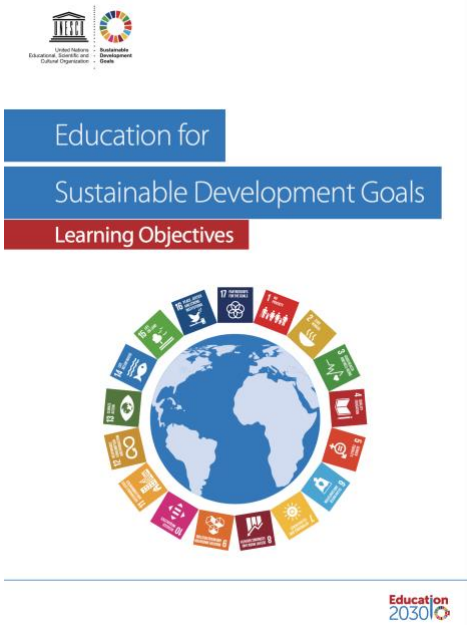


Figure 3. Education for Sustainable Development. Source: Unesco, 2017

We understand that the ESD developed has an *integrative* approach when it presents a holistic perspective that integrates various aspects of sustainability. This happens when teaching is directed at understanding the factors that promote sustainability from different perspectives, e.g., economic, environmental, and social. Not only the description but also the analysis of their interrelationship is carried out to understand the reasons that contribute to sustainability. A *critical* ESD approach focuses on critical thinking that questions the dominant paradigm, such as production-consumption or energy-welfare models, for example, and through awareness-raising promotes alternatives in line with the SDGs. The third approach, *transformative*, is close to the previous ones, but in this case, it has a more pragmatic view and seeks real transformation, responsibility, and empowerment to achieve changes in lifestyles, values, companies, etc. in order to achieve sustainability. Finally, the *contextual* approach focuses teaching on the implications of context for sustainability. There is no one-size-fits-all model of sustainability, and each place and each community may approach the development of the SDGs in a different way, adapted to the natural resources and needs it possesses. The contextual approach emphasizes what is available to us to promote sustainability competences.

These approaches seek to contribute to the development of key competences for sustainability in an integrated manner with the SDGs. Undoubtedly, designing and implementing learning experiences that incorporate such approaches represents a challenge that requires adopting disciplinary, interdisciplinary, and transdisciplinary teaching perspectives on sustainability issues, which converge in a trans-formative action-oriented pedagogy "that engages learners in participatory, systems, creative and innovative thinking and action processes in the context of local communities and students' everyday lives" (UNESCO, 2017, p. 52). This poses a challenge for teachers and teacher educators, especially in the areas of physics, chemistry, and mathematics, as they may be less aware of their competences to implement ESD education (Vásquez, et al., 2020; Uitto & Saloranta, 2017; Dahl, 2019), even more so if we consider that according to UNESCO (2018) there is great complexity in incorporating ESD into the educational practice. Therefore, it is necessary to have a specific training that guides the

mathematics teachers in the incorporation of these teaching strategies aimed at sustainable development. And higher education, as the standard-bearer of knowledge and training of those responsible for the future society, must take the initiative and carry out this work.

Figure 4. Relation between Education and Sustainable Development. Source: Unesco, (2017)

ESD aims to empower learners to take informed decisions and responsible actions for environmental integrity, economic viability and a just society, for present and future generations. ESD entails four dimensions (UNESCO, 2016, p. 9):

- **Learning content.** Integrating critical issues such as climate change, biodiversity, disaster risk reduction and sustainable consumption and production into the curriculum.
- **Pedagogic and learning environment.** Designing teaching and learning in an interactive and learner-centred way that enables exploratory, action-oriented and transformative learning. Rethinking learning environments -physical as well as virtual and online- to inspire learners to act for sustainability.
- **Societal transformation.**
    - Empowering learner of any age, in any education setting, to transform themselves and the society they live in.
    - Enabling a transition to greener economies and societies, equipping learners with skills for "green jobs", motivating people to adopt sustainable lifestyles.
    - Empowering people to be "global citizens" who engage and assume active roles, both locally and globally, to face and to resolve global challenges and ultimately to become proactive contributors to creating a more just, peaceful, tolerant, inclusive, secure and sustainable world.
- **Learning outcomes.** Stimulating learning and promoting core competencies, such as critical and systemic thinking, collaborative decision-making and taking responsibility for present and future generations.

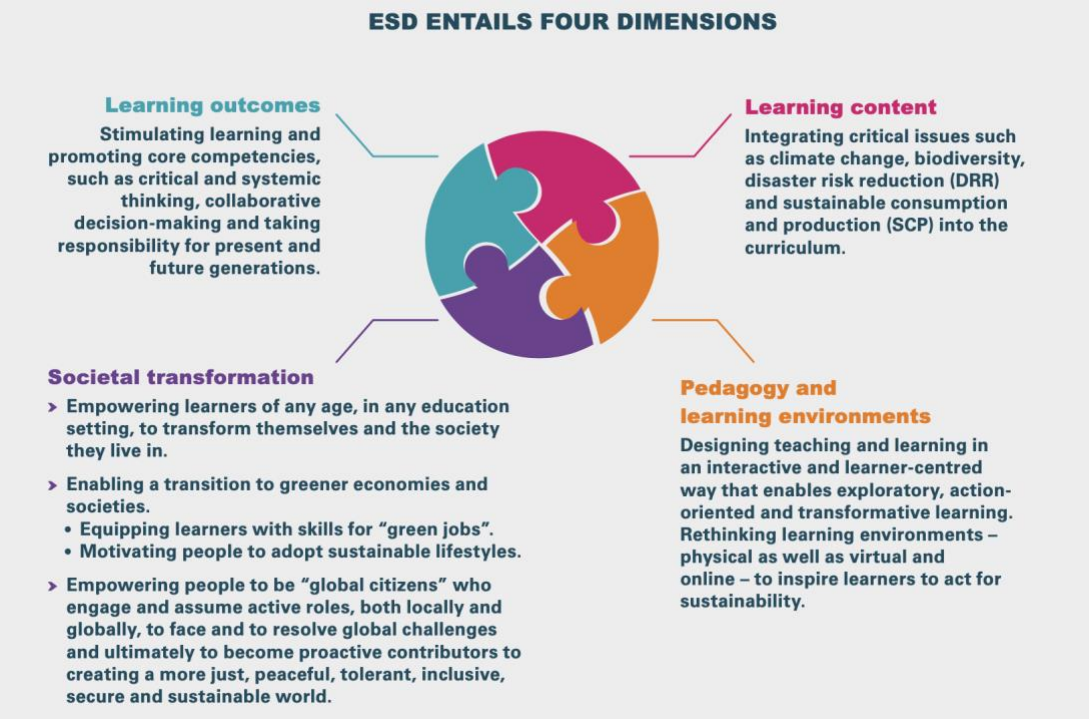
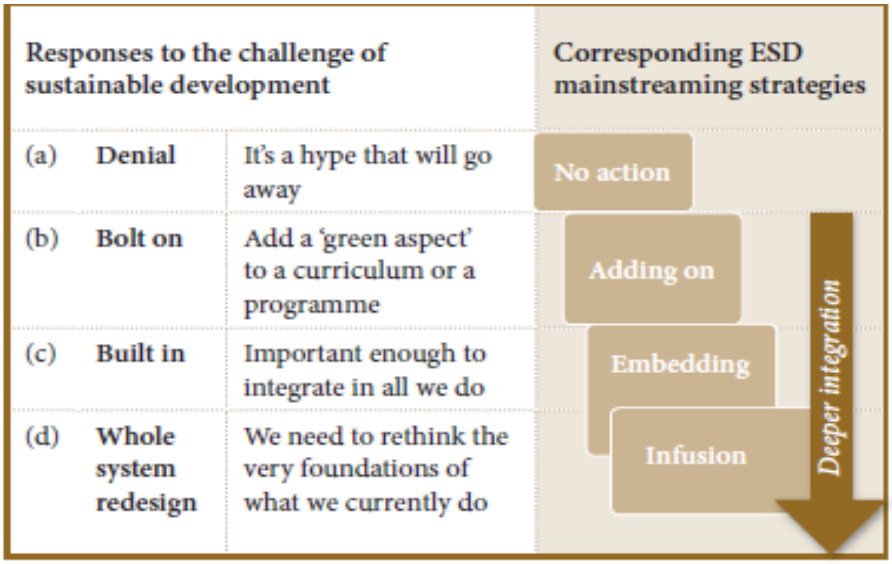


Figure 5. ESD dimensions. Source: Unesco (2016)

How can the SDGs be incorporated to our mathematical classes? There has been a long-standing international consensus that ESD should be "embedded in the whole curriculum, not as a separate subject" (UNESCO, 2006, p. 17). We mean for embedding to incorporate ESD as an integral element of curricula and other aspects of formal education, not as an "add-on". Embedding does justice to the concept of education "for" sustainable development, by putting its values and principles at the core of education.

Stephen Sterling's model of responses to the challenge of sustainability is useful in helping us position embedding: while being critical of the "bolt-on" approach, embedding can be seen as located in the "built-in" approach but with the long-term goal of achieving "whole-system redesign" (Sterling, 2011).



Source: Responses to the challenge of sustainable development, adapted from Sterling 2004 as cited in Lotz-Sisitka et al (2015) p.73

How to embed ESD?

There are some clues to keep into account when teachers decide to embed the SDGs in their current teaching, to transform their teaching into an ESD approach. Let's see some of the ideas (UNESCO, 2017b):

a) Developing competency-based learning units

Whereas calls for 21st century skills or transversal competences have increased in recent years (UNESCO, 2015), competency-based learning is neither established in all national curricula nor applied equally in all subjects (some focus on academic standards, others concentrate on topics and learning objectives).

Keep in mind that a competency-based unit needs teachers properly trained in pedagogies conducive to deeper learning and adequately supported to create an environment that allows students to develop these competencies.

b) Selecting themes, topics and issues

For that, it is very important to define some criteria for selecting ESD topics. As an examples (UNESCO, 2017b, p. 26):

- Be meaningful and significant to the learner (relevant to their real life).
- Be problem oriented and explore the possibilities of sustainable solutions.
- Be linked to one or more SDGs of the 2030 Agenda for Sustainable Development.
- Encourage to investigate and discuss the interconnectivity between local, national and global issues or development.
- Address the fundamental challenges and tensions facing humanity, with particular attention to:
    - Ecological stress and unsustainable patterns of economic production and consumption.
    - Greater wealth but rising vulnerability and growing inequalities.
    - Growing interconnectedness but rising intolerance and violence.
    - Progress and challenges in fulfilling human rights.
- Be conductive to fostering selected ESD competencies.

c) Making issues 'matter' to students

Education traditionally makes students to understand and conceptualize problems but rarely prepare them to enact solutions. But now, teachers should encourage student participation by prompting learners to act on the results of their inquiries.

SDGs have broad aims and ideals that don't show directly the context in which education and social change take place. Teachers need to be encouraged and supported to connect the principles to their students' local place or community and lived experience, while also connecting to the respective influences of the 'global on the local' and the 'local on de global' (Stevenson, 1997).

ESD "entails more than simply knowing things about the environment, economics, or equity and social justice issues, but rather involves a willingness and ability to engage intellectually and personally with the tensions that are created by the interconnectedness of these systems" (Nolet, 2009, p. 421).

d) Assessment aligns with the ESD

This part is the most difficult and the essential part of the teaching. For that reason, teachers should stop in this part and make a deep reflection on how to incorporate or modify the assessment to be aligned with the ESD. Here will see some ideas to take into account (UNESCO, 2017b):

- Tasks that ask students to demonstrate the development of ESD competencies.
- Group activities that offer opportunities to apply ESD competencies to real-world situations or collaborations with external actors and organizations.
- Tasks that ask students explicitly to study and address the relationship between the subject and sustainable development.
- Peer review and self-assessments that ask students to monitor their learning and reflect critically on their progress as well as that of their peers.
- Assessment through interactive dialogue between the teacher and learner, aided using rubrics or competence grids.

All these ideas should be transformed to ones that can be applied to high education and make it possible to develop an ESD approach.

SDGs in High Education: training teachers, training citizenship.

Sustainable Development Goals are a source of contexts that offer the opportunity to develop a teaching focused on our environment and allows us to try to achieve solutions to current problems in order to change habits and, with it, achieve the desired objectives. But Higher Education has a role of enormous relevance because it will be the institution that offers the opportunity to train citizens committed to a sustainable world (Vilches & Gil, 2012), responsible for training professionals who will develop positions of responsibility in our society, whose decisions will have very relevant repercussions on the whole of society or the environment in which they develop. Here we analyze two fields of special relevance for the future: teacher training, as those responsible for building future societies competent in sustainability; and, on the other hand, the future leaders of the social, economic and environmental environments who must make the appropriate decisions aimed at achieving the SGDs.

Training teachers

UNESCO (2017) identifies eight key competencies in sustainability: *Systems Thinking competence; Anticipation competence; Normative competence; Strategic competence; Collaboration competence; Critical Thinking competence; Self-Awareness competence; and Integrated Problem Solving competence.* These are transversal, multifunctional and independent competences that must be developed in all citizens at different levels according to their age (UNESCO, 2017a). And although their achievement is the responsibility of all citizens, teachers have a greater challenge, since they are the true agents of change, responsible for their students achieving the skills, attitudes and behaviors aimed at promoting more sustainable societies (Alperovitz, 2014; UNESCO, 2018; Vásquez & García-Alonso, 2020). In addition, teachers have "their knowledge and competences, essential to restructure educational processes and institutions in pursuit of sustainability" (UNESCO, 2017a, p. 51), through "teaching, learning and assessment activities aligned and designed to meet key competences in sustainability and learning outcomes" (QAA, 2020). On the other hand, teachers, in turn, must acquire the skills in

sustainability, because without them they will hardly be able to promote an ESD in their classrooms (Ull Solís, 2015; Vega-Marcote et al., 2015).

Therefore, we must think about initial and continuous teacher training that, in parallel, builds sustainability competencies in students and suggests didactic strategies that facilitate the integration of sustainability competencies in their classrooms (UNECE, 2016; UNESCO, 2017a). Even more so when, teachers in the scientific field consider their teaching far from the challenges of sustainability, and only address activities in the ecological or sociocultural field (Uitto & Saloranta, 2017). Therefore, future mathematics teachers should be especially aware as builders of competencies in sustainability (Vásquez & Alsina, 2021).

Mathematical competence is mathematical knowledge aimed at building critical thinking, decision-making and problem solving in different contexts (Alsina, 2022; NCTM, 2000; Niss, 2002). Among the strategies to promote mathematical competence, the use of active, participatory and experimental learning methods is suggested (Sterling, 2011, p. 36) that favor the integration of analysis in complex environments and the promotion of systemic thinking in the classroom (Lozano et al., 2013). In this sense, Project-Based Learning (PBL) is presented as a teaching model that facilitates transdisciplinarity and that allows working on the resolution of real problems contextualized in their social, environmental and economic dimensions (UNESCO, 2022b), which ESD seeks.

Training citizenship

Having high levels of education is no guarantee of greater awareness of sustainability (Orr, 2013) because, although many world leaders have higher degrees, sustainability is not their main policy (Sibbel, 2009). In this sense, the initial training of future teachers is especially critical (Geli, 2002) since it will be responsible for raising awareness of sustainability of future citizens (Cardeñoso-Domingo et al., 2013). But, there is no doubt that Higher Education must be the bearer of sustainability skills effectively in order to achieve a citizenship committed to sustainability and capable of introducing the necessary changes for its achievement.

As we have been pointing out, mathematics is a learning environment that must attend to the development of these competences in sustainability and must do so from an embedded process in which it connects mathematical knowledge with the problems of reality, in contexts proposed by the SDGs. In this sense, we find some manuals that offer us ideas to carry out this work, such as Mathematics for action (UNESCO, 2022), in which, through different contexts, the changes that can be introduced and the contributions that this knowledge offers to solve these problems are analyzed with mathematical tools. Some examples are shown in Table 1.

SDG	**Project**
1	Visualizing poverty: AI-Powered maps improve estimates and predictions
2	Strengthening food security: Food system resilience and sustainability
3	Modeling infectious diseases: Forecasting the spread of an epidemic
4	Teaching mathematics: Mathematics Education for Sustainable Development

5	Tracking gender parity: Mathematical foundations of gender equality indicators
6	Shifting lake turbidity: alternative states in shallow lakes
9	Reckoning with uncertainty: Social sciences lessons for mathematical modeling
11	Preparing for a crisis: Improving the resilience of digitized complex systems
12	Allocating scarce resources: modeling to support food-energy-water sustainability
13	Forecasting cyclones: the mathematics of tropical cyclone prediction
14	Sustaining fisheries: bioeconomic models for fisheries management
15	Listening in on wildlife: animal sound classification with deep learning
16	Preserving privacy: the power of many with collaborative machine learning

Mathematics and SGDs

Sustainability usually moves us to think about generating environmental awareness and, in some way, it seems far from what is usually developed in the mathematics classroom. That is why, several studies indicate that mathematics teachers do not consider that they have the necessary tools to address sustainability in their classrooms (Vásquez et al., 2020). But several manuals have been published from UNESCO that address this situation and try to help teachers in general, but mathematics in particular, to carry out the task of integrating this knowledge into their classrooms. Only in this way we will be able to talk about an authentic ESD, that is, a teaching aimed at developing the sustainability skills that allow citizens to lead towards the achievement of the SDGs.

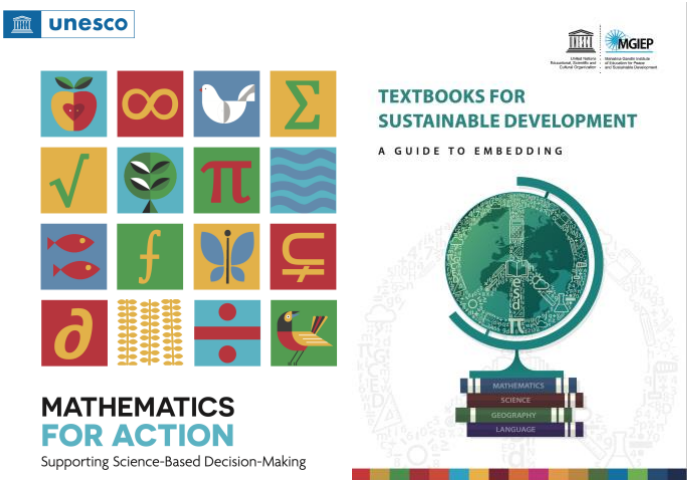


Figure 6. Two manuals for mathematics and GSD

Alan Bishop (1988) described six categories of human activity for examining cultural practices to identify mathematics. Mathematics is counting, measuring and locating. These mathematical actions indicate clear connections between people and their

environments and for that reason we consider that mathematics has a lot to do with SDGs and is connected to the problems that our society has.

Also, abstractions are powerful tools for the deeper evaluation of human challenges because they allow us to make predictions and to design physical and conceptual structures that meet our needs and desires. The sustainable development framework balances immediate needs with long-term and societal needs.

To balance conflicting needs, decision makers consider various measures that identify the goal and assign numeric values to things that are not straightforward to measure.

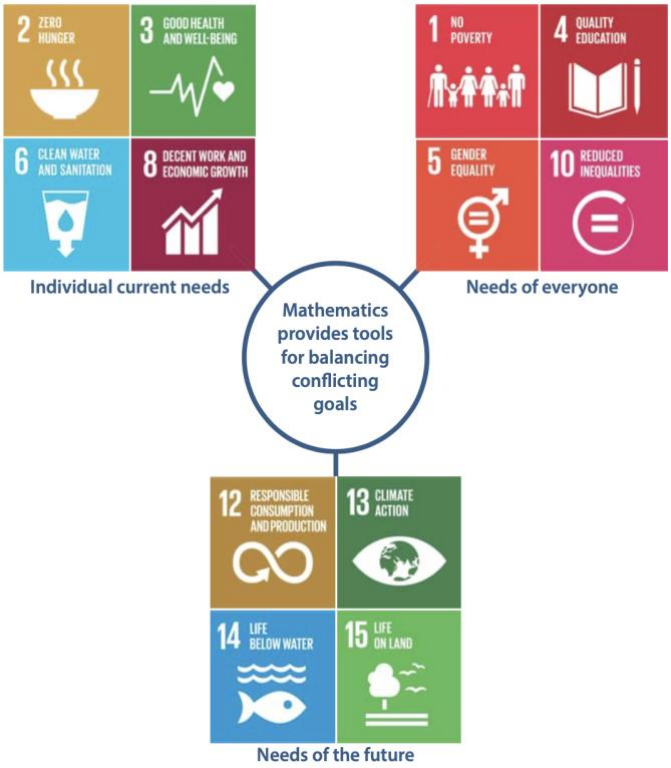


Figure 7. Managing conflicting goals with mathematics. Source: UNESCO, (2017b), p. 39.

Figure 8. Integrated knowledge systems. Source: UNESCO (2017b), p. 40

MATHEMATICS	THEMATIC AREA	SAMPLE TOPICS
FUNCTIONS AND RELATIONS	Illness and health	Frequency and dissemination of diseases (comparing countries and/or historical development)
	Protection and use of natural resources and energy generation	Presentation of energy resources, generation and consumption of energy in the course of time, future prognoses
	Opportunities and risks of technological progress	Radioactive decay, for example, atomic power plants
	Global environmental changes	Climate data and climate change, for example, global warming
	Mobility, urban development and traffic	Development of street traffic, traffic fatalities and exhaust emissions in different countries and/or over the course of time
	Globalization of the economy and labour	Interest and repayment for private and public loans, developments at the stock exchanges
	Gemographic structures and developments	Population growth in different world regions
	Sustainable Development Goals	Developing indicators for specific SDGs, applying them over a time period, using them for prognoses
DATA AND STATISTICS	Food and agriculture	Household water demands in certain countries and worldwide
	Illness and health	Availability of physicians, midwives and medicine in industrialized and developing countries
	Water	Water scarcity, sources of consumption, availability of potable water in certain countries, regions or according to socio-economic status
	Education	Education and professions in industrialized and developing countries, child labour, status of universities
	Child labour	Distribution of child labour by region and products, comparative conditions and wages of child workers, profits of corporations using child labour
	Leisure time and globalization	Influence of holiday travel on environment and economy in the target countries
	Protection and use of natural resources and generation of energy	Generation and consumption of energy in the household (regionally, nationally, internationally)
		The ecological footprint
	Globalization of economy and labour	Crises and upswings, data on public debts, per-capita debts, gross national products, labour markets, labour mobility
	Demographic structures and developments	Trends and consequences of demographics (national, cross-border, rural/urban)
	Poverty and social security	Financing of social systems such as pension schemes, unemployment insurance
GEOMETRY	Architecture	Symmetry and pattern in architecture (tiling, windows, etc), comparing across cultures
	Rights of people with special needs	Design of ramps for wheelchairs

Figure 8. Potential ideas for embedding an ESD approach in mathematical classes. Source: UNESCO (2017b), p. 47.

What is next?

So far, we have seen that the SDGs provide an opportunity for mathematics education in any context, including higher education. From this point on, we connect these findings with two aspects to be developed in this project as toolkits: digital tools in mathematics education and project-based methodology. The following figure illustrates the process of developing and implementing the selected ideas in this toolkit in the classroom.

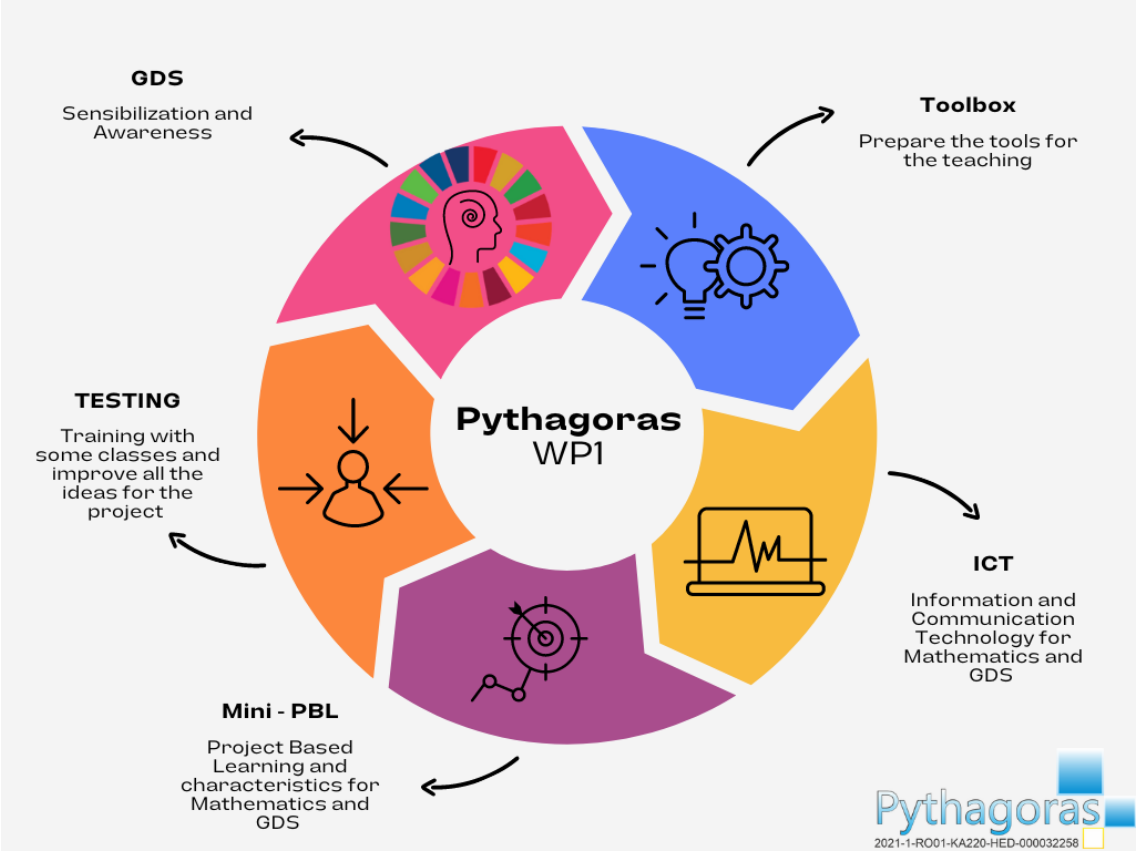


Figure 9. Process followed in Pythagoras project intellectual output 1.

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