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Sustainability in formal education: ways to integrate it now

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1. Setting the scene: 21st century challenges meet sustainability[1]

The 21st century reality is a complex and interconnected one. Among the complexities that current societies are facing, climate change is arguably one of the most pressing, multifaceted, and comprehensive challenges (Bacon et al., 2011). The increase in traumatic environmental events and steadily changing climatic patterns, interlinked with social distress, food and water scarcity, migration, have motivated an awakening on the detrimental anthropogenic impacts on ecosystems (pollution, deforestation, overexploitation), and on the interdependence of human-nature relationship (McFarlane & Ogazon, 2011). In this age of finite and scarce resources battling with mounting population growth and economic development (Yanarella et al., 2009), calls for achieving more sustainable societies have grown at the local, national, and international level.

But what does *sustainable society* mean? Sustainability is a broad umbrella term, hard to pinpoint given the lack of agreement in literature, and the consequential soaring amount of definitions and angles it can be looked from (Hopwood et al., 2005). In general, the current idea of broad sustainability moves beyond simple environmentalism to include economy, culture, sociality, and politics (McFarlane & Ogazon, 2011). Hence, sustainability tries to balance the social (culture, livelihoods, well-being), the economic (growth, poverty) and the environmental (conservation, enhancement of marine and terrestrial ecosystems) (Lehtonen, 2004). Moreover, a well-rounded take on sustainability and sustainable development integrates their intra- and intergenerational aspects: following the definition of the Brundtland report (World Commission on Environment and

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Development [WCED], 1987), sustainability refers to the fulfilment of the needs of people today, without compromising the capacity of future generations to benefit from nature and its services. This overarching conceptualization of sustainability is the one adopted in this paper, as it represents the less segregated and most far-reaching understanding of the term.

2. Calling culture into play: brief historical overview of education and sustainable development

If defining sustainability is *per se* already challenging, its implementation is a vast myriad of different approaches and solutions, going from the individual to the structural level, from day-to-day practices to systemic changes (Robert et al., 2015). When addressing personal inclinations and attitudes towards sustainability, culture and, specifically, education, are two major determining factors (McFarlane & Ogazon, 2011). Indeed, the appreciation of what sustainability means very much depends on the level of literacy on topics like science, technology, politics, and economy. For this reason, now more than ever before, given the era of tremendous transitions humanity is facing, there is a need for education that creates awareness around the interdependence between nature and socio-economic activities (McFarlane & Ogazon, 2011).

The need for education for sustainability has been recognized for more than fifty years, dating back to the late 1960s (Rieckenberg, 2014). Then, environmental education was promoted to create awareness around consumption patterns and ecologically unsustainable behaviours. At that time, concerns for ecological degradation were surging among the public, also due to publications denouncing environmental pollution such as Rachel Carson's *Silent Spring* (1962). This public unrest gave rise to the environmentalist movements of the 1970s (McFarlane & Ogazon, 2011). Since then, education has increasingly been accepted globally as a fundamental instrument to combat climate change and enhance sustainability. After the 1992 Rio de Janeiro "Earth Summit", the first United Nations conference combining environment and development, the *Agenda 21* emerged, proposing, among others, a plan of action to couple education and sustainable development (United Nations Conference on Environment and Development [UNCED], 1993**).** From there, thanks to the activism of the United Nations Educational, Scientific, and Cultural Organization (UNESCO), the 2005-2014 UN Decade of Education for Sustainable Development (ESD) was established.

The goal of Education for Sustainable Development (ESD) is to empower individuals to deal with the challenges of sustainable development by promoting social, economic, and political transformation (Leicht et al., 2018). Hence, with the Decade, UNESCO aimed to underlie the pivotal role education can play in supporting high-quality lifestyles for today's and future's generations, and the need for respecting and enhancing human and natural heritage as one of the most pressing challenge for humanity. In this time frame, much work has appeared linking education to the lifelong achievement of sustainable development, especially

regarding the potential for education to stimulate sustainable individual behaviours and values (UNESCO, 2016). Now, the fundamental role played by teachers and schools for the achievement of sustainable education is under the international spotlight thanks to, amongst others, the Global Action Programme on Education for Sustainable Development (Timm & Barth, 2020). To summarize, there has been an emerging international appreciation of the role of education for sustainable development, and an active institutional engagement to see that implemented more and more.

Education supports the share of knowledge, and it increases literacy levels. In schools, formal education plays a fundamental role in shaping the citizens of tomorrow by providing students with a capacity to navigate the world through a set of skills linking back to sciences, humanities, and overall critical thinking. We believe that education can foster sustainability theories and practices, as well. Through a heightened understanding of human-ecosystem interactions and improved environmental awareness, it can enhance a sense of responsibility among students towards their natural surroundings, this way helping them comprehend and confront an ever-changing global reality. At the same time, we maintain that sustainability can enrich educational practices and accelerate innovation in schools. Its interdisciplinary and holistic nature can encourage cooperation among school subjects and educational institutions. Addressing sustainability in classrooms can help educators in preparing their students for the challenges and opportunities of the future.

In the remainder of this paper, we will look at the theories and practices of sustainability education. First, we will overview the literature on the relationship between sustainability and formal education to analyse why they are mutually enriching and build upon the other. Then, we will discuss how to achieve more effective interplay between the two, concentrating on interdisciplinarity and STEAM; student-centred, research-based, and place-based pedagogies; and the role of teachers as agents of sustainability. With an eye on the latter, we will use three projects on topics of sustainability as our case studies. We will argue that a specific subset of tools (learning scenarios, massive online open courses, teachers' competitions) can skill teachers for the inclusion of complex topics, such as sustainability, in their classrooms, helping their dissemination among peers and in society.

3. Education for sustainability and sustainability in education: Why

The relevance of tackling topics of sustainability in schools is an understanding shared by educational institutions worldwide (Laurie et al., 2016). Scholars agree on the fact that education plays a central role in supporting the advancement of sustainability practice (as we will discuss later, with an analysis of relevant pedagogies and case studies). Education can support the formation of civically engaged pupils that value environmental stewardship, social equality, and tolerance (UNESCO, 2005). Without proper knowledge, students cannot fully understand the

detrimental consequences of specific choices for the environment. But thanks to environmental education, they can develop *environmental literacy*. This term, as Rieckenberg (2014) argues, refers to the ability to understand complex and interrelated socio-ecological systems and their problems, demonstrating a willingness to work towards the achievement of healthy nature and societies by maintaining or restoring the wellbeing of these systems. Environmental literacy, then, positively correlates with environmental care and conservation, proactive behaviours, and active citizenry. This shows how an understanding of the science of sustainability is required to support sustainability practice (Pe'er et al., 2007; Murphy, 2008).

In societies that experience soaring disconnection from nature (Berry, 1999), understanding its value becomes even more relevant. Children with limited to no access to the outdoors tend to underestimate the value of nature and biodiversity conservation, as they do not interact with it anymore (Kahn & Kellert, 2002; Louv, 2005; McLean, 2009). This detachment – also called "nature deficit disorder" (Louv, 2005) – is problematic because the natural world offers opportunities for critical thinking and inquiry, problem-solving, and reflection (Rieckenberg, 2014). By calling different subjects to action, formal education can mend this trend by supporting a critical understanding of nature, which in turns promotes sustainable behaviours, and emphasizes the responsible use of environmental resources (McLean, 2009; Timm & Barth, 2020). In essence, then, education has the potential to foster harmonious relationships among humans and their surroundings, by shaping positive attitudes towards nature conservation and critical awareness on the many challenges posed by climate change and natural degradation.

Teaching environmental and societal awareness, then, does not only influence the students in the classroom, but it provides future generations with the skills, tools and training to understand and prepare for a complex and interconnected global reality (Hale et al., 2017). As a matter of fact, school education has long been a champion of civic education, which now include sustainability practices (Carney, 2012). This role is particularly relevant in times of public distrust in science and sense of impotence towards the intricate societal challenges faced by humanity (Lagos, 2011; McFarlane & Ogazon, 2011). By applying a pedagogy of (strategic) responsibility, education can spur understanding on the relationship between societies and nature, and the importance of protecting the latter for social wellbeing (UNESCO, 2012; Rieckenberg, 2014). Practices of responsibility can include questioning diversity, human behaviours, natural resources exploitation, and this daily classroom reflection can expand to the broad society. For example, students that perceive the relevance of sustainability issues at the school level are then able to apply this understanding in their community, and perhaps to the entire planet. These transformative learning processes fostered in class allow for students (and teachers, for that matter) to think and develop the innovations needed for a deeper connection with nature. Schools, seen as micro-societies, can become hubs for the formation of agents of sustainability attentive to issues such as quality of life, wildlife conservation, and cultural understanding (Carney, 2012). These agents of

change can then influence the people living around them towards increasingly sustainable behaviours. Hence, education for sustainability supports a culture of care towards the environment and the community, a culture of sustainability that could diffuse at broader societal levels.

We have just explored the importance of education for the advancement of sustainability. It is equally important to offer a view on the role of sustainability in education. Sustainability and sustainable development are inextricable from our cultures, values, and human experiences (UNESCO, 2012). These concepts recognize the role of traditional, local, and scientific knowledge and innovation in the promotion of a more just society (Tilbury & Mulà, 2009). Hence, sustainability has the potential to enhance and widen teaching approaches for various academic subjects, starting from the awareness that the segregation of subjects is no longer ideal to answer to real-world changes (Godemann, 2008). The very concept of sustainability, integrated in its approach and transdisciplinary, attentive to both social and ecological issues, and inclusive of various actors and spaces of decision-making, enriches education with the perspectives of system thinking and multi-causality (UNESCO, 2012; Bacon et al., 2011; Hale et al., 2017; Merritt et al., 2018). A study by Laurie et al. (2016) on ESD schools reveals that linking sustainability and education develops students' critical thinking, research, communication, writing, and mathematical skills. Moreover, a focus on sustainability seems to increase students' commitment to the curriculum and in the wide society (Gosselin et al., 2013). By becoming aware of and engaging with local issues, students realize the significance of global problems and understand that in order to solve them sustainably, they must employ all fields of knowledge. In other words, students that are sustainability literate can see the connections between social justice, local thinking, global citizenship, nature stewardship, intergenerational concerns, and economic restructuring (Nolet, 2009). A holistic knowledge that inspires them to come up with solutions integrating social, cultural, economic, ecological, and political aspects (Bacon et al., 2011; Laurie et al., 2016).

Sustainability can be the key to tackle relevant current topics with students, being it linkable to each school subject (Sullivan & Walter, 2010; Hale et al., 2017). For example, science sustainability can set the standards for an integrated transition towards sustainable societies, using a combined set of tools and insights coming from sciences, social sciences, and engineering (Mihelcic et al., 2003). Or, coupling sustainability and Geosciences allows for complete examinations of flora-fauna-land physical interactions with socio-technological-environmental insights (Hale et al., 2017). Sustainability becomes a meeting point across school subjects, and it favours a cross-disciplinary dialogue, a sort of bridge in current educational curricula that allows students to implement in practice the theoretical instances learnt in the classrooms (Leicht et al., 2018). Pupils learning about sustainability understand that there is no easy solution for complex problems and that solving these issues requires complementing scientific education with social perspectives, and vice versa. In this way, they also learn about the importance of collaboration and to avoid "either/or" simplistic explanations to complex problems such as

pollution and environmental degradation (Bacon et al., 2011). This not only allows for a deeper understanding of real-world sustainability concerns, but it also skills future workers and thinkers with the competencies needed for the emerging green work sector and for the elaboration of disruptive innovation (Orr, 2002; Hale et al., 2013; Laurie et al., 2016). Finally, on a side note, there is some research currently gaining momentum that links happiness with sustainable development in that people can find happiness through contribution to community life, environmental respect, and detachment from material wants (O'Brien, 2010). Thus, teaching sustainability in schools could also contribute to greener and happier lifestyles for students, coupling positive societal outcomes with individual wellbeing.

4. Education for sustainability and sustainability in education: How

Having explored the reasons behind a closer dialogue between sustainability and education, it is now crucial to examine how to achieve it. To do so, however, a premise is necessary: changing national educational curricula to include sustainability would turn into a lengthy, slow-paced process. For this reason, this paper discusses ways to integrate issues of sustainability in class maintaining the existing curriculum, an option deemed more flexible and adaptable to the urgency of tackling the topic in schools.

Thanks to the increasing interest at multiple scales of decision-making, sustainable education is being steadily incorporated in class discussions through topics such as climate change, cultural diversity, and fundamental rights, for example, by addressing issues of poverty in social studies classes, or water scarcity in science classes (Hale et al., 2017). Nevertheless, more efforts are needed to integrate sustainability in primary and secondary education (Laurie et al., 2016). For this to happen, the strategy to achieve greater sustainable education must have students at its core (Barr et al., 2014; Timms et al., 2020). Students, as actors of sustainable change, can mobilize new knowledge and innovative approaches by participating in school projects, interactive lessons, and practical experiments (Schelly et al., 2012). It is because of this that we will briefly explore a number of tools, approaches, and student-centred techniques that can help promote the understanding of sustainability and achieve its smooth inclusion into everyday classroom activities.

4.1. STE(A)M Approches

First and foremost, as stressed above, education and sustainability require a multiple-perspective approach and interdisciplinary thinking connecting concepts and knowledge from different academic traditions, i.e. science, history, geography, gender equality, cultural diversity, or human rights, amongst others (UNESCO, 2012). STEAM – defined in the study by Clark and Button (2011) as the convergence of science, art, and aesthetics, is an example of this integration. Clark and Button recount how the STEAM approach helps students of all ages to reinforce their understanding of socio-environmental linkages, and of the impacts of humans

on nature. Because of this, students developed a sense of environmental (in)justice and a willingness to promote sustainability. As described by Tasiopoulou et al. (2020), for STEM to improve our lives and the needs for our future, we need STEM to be taught in an integrated way. We need all the components of S (science) to work together. All the letters in STEM to work together. And even better, for all the subjects to work together, with STEM and STEAM becoming STE(A)M. STE(A)M, as an educational model, responds to the needs for trans-disciplinarity when teaching sustainability. By connecting science, technology, engineering and mathematics disciplines between themselves and with all other subjects, STE(A)M enhances problem-solving skills applied to real societal problems: art becomes the bridge between scientific understanding and sustainable actions. From a more scientific point of view, Pecen et al. (2021) stress that the scientific and technical knowledge, and the inquiry skills associated with STEM subjects, enrich the approach to sustainability in class, especially when referring to environmental protection, and sectors such as energy provision and green technologies. In general, then, the need for STE(A)M subjects to integrate topics of sustainability has emerged (Smith & Warson, 2016), and the compatibility among the fields exists and holds a lot of potential. Sustainability opens up ways for STE(A)M subjects to reach new levels of organic and integrated knowledge (Rogers et al., 2015; Zoller, 2015). And the STE(A)M approach, which is already widely accepted among educational institutions, can include issues of sustainability quite easily – when it does not address them already.

4.2. Place-based education

Another relevant approach for the integration of sustainability in schools is place-based education, i.e. the connection of students to their surroundings (Barr et al., 2014). *Place* can be defined as both the physical and natural environment, and the culture and history embedded in a community (Stedman, 2003). When students connect well with their surroundings, they can gain a more profound sense of the problems that exist, and the potential for amelioration. For example, students may perceive a topic such as climate change as distant, and thus disempowering. However, educational activities highlighting visible local impacts of global warming and environmental degradation can help students to acknowledge these problems, and reflect on their solution (UNESCO, 2005). Hence, through place-based education, students understand environmental and societal challenges better, thanks to theoretical reflection and hands-on experimentation in their schools and communities. Moreover, they appreciate the role of sustainability in addressing these issues, and they develop a sense of efficacy and empowerment (Henderson & Tilbury, 2004). Furthermore, place-based education is beneficial to more strictly curricular objectives as well, as it results in improved academic performance in all subjects, more discipline, and increased enthusiasm towards learning (Rieckenberg, 2014).

4.3. Problem- and project-based learning

Two pedagogies applicable both to STEAM and place-based education, problem- and project-based learning allow students to handle real-world sustainability challenges through questioning, inquiry, practical experiences and experimentation (Cortese, 2003; Bacon et al., 2011). As both pedagogies encourage active student engagement in the learning process, they also provide avenues through which students can transfer their skills to varied and diverse communities outside of the classroom (Gras-Velázquez, 2020). By working on a problem/project in a team, students can stimulate innovative solutions using collaborative and peer learning. Thus accountability, interdependence, and group interactions spur from these approaches and enrich students with skills needed for addressing current real-life issues (Laurie et al., 2016). An example of this is community investigation. Students can investigate local problems through a case-study framework coupling place-based education and problem-based learning. This experience will skill them with research design abilities, identification of relevant information, and engagement with the community (UNESCO, 2012). Moreover, the projects included in project-based learning are opportunities for schools and student bodies to contribute directly to their surrounding communities with tangible outcomes.

4.4. The role of teachers

The methodologies delineated above all focus on students learning. Nevertheless, the role of teachers as changemakers has been widely studied, emphasized, and prioritized (O'Brien, 2010; McFarlane & Ogazon, 2011; Timm & Barth, 2020). In general, teachers are prominent in bringing innovation to schools, and their competency in vehiculating knowledge and creating an enriching learning environment correlates positively with students' learning achievements and with their engagement to the subject (Timm & Barth, 2020). To attain these results in the field of sustainability as well, teachers need to be passionate about sustainability and to perceive its necessity, which makes the lack of clear understanding about what sustainability is among teaching bodies (O'Brien, 2010) a serious issue to be addressed.

Indeed, multiple studies have been published underlying the relevance of (pre-service) teachers' sustainability and environmental knowledge (Boon & Wilson, 2011; Boubonari et al., 2013). Teaching sustainability does not happen in a vacuum. Teachers should be the first to realize both the importance of the topic and of new and diverse teaching methods if they want to include sustainability in their classrooms efficiently. This means that educators should be able to grasp the comprehensive nature of sustainability (Rahm & Gorges, 2018), at the same time appreciating the necessity to teach in ways that go beyond information transfer and having the students sitting down and listening (Clarke et al., 2014). Only when teachers are familiar with innovative pedagogies, they can recognize their value and implement them in schools. The latter implies a willingness to engage students to look at issues from different perspectives, which is crucial to the development of

sustainability literacy, the acquisition of a sense of place, and the understanding of environmental dynamics, among others (Clarke et al., 2014, Stratton 2015). For instance, Stratton (2015) proposes linking science subjects to outdoor education: this combination will allow teachers to present students with real-life scenarios and data, and to connect the latter with sustainability concerns – a connection that lies at the core of the development of a sense of place.

We have hinted at how educated teachers can stimulate student reflection, decision-making and inquiry, and the acquisition of transversal and transferable skills (Leicht et al., 2018). Given the need for familiarity with topics of and pedagogies for sustainability, as Timm & Bart (2020) suggest, teachers should be provided with the possibility to master their sustainability competencies. More and more educational programs and courses exist at the university level, rooted in environmental and sustainability education, that prepare future teachers for the exciting challenge to teach sustainability education (Stratton, 2015). Nevertheless, for teachers who are already finished with their studies and work in schools, going back to university is often not an option. But the ability to include sustainability in class remains a concern for them too. It is with this broad category in mind that we want to stress the role of available educational resources and accessible training for teachers' professional development, knowledge enhancement and skills acquisition. Through a case-study approach, we will look at three projects on topics of sustainability to identify existing tools that can support teachers in integrating sustainability in their classrooms and schools and can enhance the reach of sustainability education in European educational institutes.

5. Integrating sustainability in education: insights from practice

The theoretical overview in the previous sections showed the potential of sustainability education for boosting students' understanding of both sustainable development and traditional STEM and non-STEM subjects, as well as the feasibility of coupling sustainability education with innovative student-centred and inquiry-oriented teaching methods. Moving forward, however, we analyse some concrete cases that can provide useful insights on how to achieve optimal results when introducing sustainability education in the classrooms of teachers all over Europe. These success stories belong to the efforts in which European Schoolnet (EUN) has been involved to *sustain* sustainability topics in education. EUN is a network of 34 European Ministries of Education, and it acts as the interface between education policy and practice, bringing Ministries of Education, schools, teachers, European Union institutions, research and industry into contact for fruitful exchange and collaboration. One of the ways their mission to support education in the participating countries is done by identifying and testing promising innovative practices, sharing evidence about their impact, and supporting the mainstreaming of teaching and learning practices aligned with 21st century standards. As sustainability and climate change are key factors shaping current socio-economic dynamics, these topics are currently being implemented throughout their

educational programs and are grounding EUN's STEM agenda for the next years. Nevertheless, as mentioned above, it is unlikely to obtain a curricular change to integrate sustainability education in national formal education swiftly. The following analysis of three EUN projects will look at existing possibilities for the introduction of sustainability in European classrooms by focussing on teachers' peer-learning, training, and ideas sharing.

The three projects analysed here are *The Three R's and Animal Use in Science* (3Rs); *Boosting European citizens knowledge and awareness of bioeconomy* (BLOOM); and *Nature-Based Solutions* (NBS). These projects deal with themes relevant to sustainability, and they provide thorough models of efficient strategies for sustainable education.

The 3Rs project[2] focused on building learning activities for secondary schools to introduce the principles of the 3 Rs – Replacement, Reduction and Refinement of animal use for scientific purposes, and raise awareness about existing high-tech non-animal tools available as alternatives. The goal of the project was to inspire students to develop their critical thinking and science literacy skills by exploring topics such as ethics and research methods in science, and to stimulate new understandings on how to improve the animal welfare in general.

The BLOOM project[3] also aimed at raising awareness, focusing on how best present the potentials of bioeconomy innovation processes to the European civil society, i.e. all those private actors, such as producers, NGOs, movements, research institutions, private citizens, that inform the European public life. The project brought together partners from across Europe to debate and engage the public with the possibilities for climate change mitigation, circularity, and reduced dependence from fossil fuels offered by an economy based on biomass. The project thus engaged a wide array of actors, as is usual when talking sustainability, involving European citizens, bioeconomy innovation networks, local research centres, business and industry stakeholders and various levels of government including the European Commission. BLOOM also involved schools and the youth. As an educational program, BLOOM worked to inspire students into having conversations with, and being able to relate to different social, political, educational, and environmental agencies.

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[2] The 3Rs project was funded by the European Commission's Joint Research Centre. The formal education activities were carried out by European Schoolnet, in collaboration with ECORYS (international company providing research, consultancy and management services) and SYRCLE (Systematic Review Center for Laboratory Animal Experimentation). For more information see http://www.scientix.eu/projects/project-detail?articleId=896055.

[3] The BLOOM project received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 773983. For more information see https://bloom-bioeconomy.eu/.

Finally, the NBS Pilot project[4], which is currently ongoing, aims at promoting problem-solving using nature and natural resources – namely, those solutions that are inspired by and use nature and its ecosystem services to respond to current societal, economic, and environmental challenges in a resilient and sustainable way. NBS move beyond mere environmental protection to link nature and societies and they are thus some of the most comprehensive and cost-efficient options in the quest for a more sustainable future. The project wants to raise awareness, create knowledge, and enhance skills linked to NBS and their implementation for tackling climate change and achieving sustainability, with the crucial objective of integrating NBS in primary and secondary education.

These projects are chosen as examples of sustainability in education for two main reasons. Firstly, they all link back to the three pillars of sustainability already discussed: society, nature, and economics. This connection, however, is not unidimensional – i.e. where one project approaches one pillar. Indeed, through their main topic of concern, the projects address sustainability in and outside education, highlighting the continuous interactions among society, the environment, and economic consideration, an approach that lies at the core of sustainability thinking. By discussing the ethics of animal testing, linking economic development with climate mitigation, or proposing all-encompassing solutions to societal problems based on nature and ecosystem services, these projects demonstrate the degree to which sustainability is a transdisciplinary and interlinked matter. For instance, even though bioeconomy and NBS are not part of any traditional subject addressed by formal education, their various applications make them ideal examples for teachers. Teachers, then, can use these two themes to include the analysis of holistic systems that combine social aspects with STEM in their classrooms, facilitating the understanding of how science relates to everyday life.

Secondly, the projects combine, in different ways, three fundamental methods deemed useful for effectively addressing sustainability concerns in schools by focussing on teachers. These methods, which will be scrutinized in depth in the following discussion, are: providing teachers with best practices to tackle complex topics in class through learning scenarios, offering professional development possibilities with MOOCs, and sparking a multiplier effect with teachers' competitions.

[4] The NBS project is initiated and funded by the European Commission Directorate-General for Research and Innovation and coordinated by PPMI, in collaboration with European Schoolnet (EUN). PPMI (www.ppmi.lt/en) is a leading European research and policy analysis centre, aiming to help public sector and civil society leaders from around the world, presenting evidence in a way that is simple, clear and ready to use.

5.1. Using learning scenarios to integrate sustainability topics in educations

Let us begin by examining the first method proposed, the learning scenario. A learning scenario (LS) is a structured description of educational activities to be carried out in the classroom that are connected to a specific topic. It covers objectives, pedagogical methodologies, duration, and target age, and it includes, alongside the mentioned areas, curriculum integration, aims and outcomes of the lesson, relevant educational trends, and 21st century skills. Learning scenarios have been implemented in all the case studies, but it is the 3Rs and the NBS projects that place a specific focus on them. As stated, a learning scenario fosters the use of innovative pedagogical trends such as project-based learning, peer learning, and student-centred learning in traditional classrooms. In the case of 3Rs, project-based learning was applied by having students work in groups on a research project on animal use in society and alternatives to animal testing; and they experienced inquiry-based education by investigating the views of their peers on animal testing. At the same time, a learning scenario promotes relevant 21st century skills such as creativity, information literacy, critical thinking, collaboration, and communication. For example, in the NBS project (Gras-Velázquez et al, 2020), students developed ICT skills by constructing their NBS tools, such as CO2 sensors. Whereas, in 3Rs, students explored their creativity through roleplay activities such as asking for funding for research into non-animal alternatives. Additionally, students increased their information literacy by reviewing examples of bad science reporting and how the media covers animal testing (Bilgin et al, 2020). Its ability to introduce innovative pedagogies and support system thinking, digital, and communication skills alone make learning scenarios an efficient vehicle for sustainability.

However, other characteristics strengthen the role of learning scenarios in the classroom. Learning scenarios are created by teachers for teachers to guide their peers in the development of insightful lessons on the topic of choice, supplying concrete pedagogical materials organized conveniently and intuitively, with clear-cut guidelines on how to use them. During both the NBS and the 3Rs projects, teachers designed their learning scenarios with a process of co-creation supported and coordinated by EUN. Through face-to-face workshops and continuous feedback – along the lines of the Living Lab concept (Hagy & Morrison, 2017) –, teachers were able to interact, exchange ideas, share knowledge, and work together for the realizations of meaningful learning scenarios. This meant that teachers from different disciplines engaged and reflected together on how education practices should evolve to respond to societal and scientific concerns, such as ethics and climate change. A co-creation process is then necessary for the development of transdisciplinary and creative lessons, crucial for the integration of sustainability insights in classrooms. It follows that a learning scenario thus supports sustainability in education *ex-ante,* through its building blocks and its design.

Following their creation, learning scenarios undergo a dual testing procedure to validate the educational value of the materials created. In the two projects, teachers tested the different learning scenarios in their classrooms and then reflected on the implementations to further refine and improve them. Subsequently, teachers from a different country tested the scenarios with their students to verify their adaptability to different teaching contexts. From the testing phases of both projects emerged a clear appreciation of the learning scenarios from both students and teachers. The latter especially praised the high-quality resources and the versatility of the scenarios, which allowed for seamlessly adaptation of the learning scenarios according to students' ages, or subject knowledge. Teacher feedback reported that through the NBS project, students discovered the potential of Nature-based solutions as concrete answers to urban sustainability challenges, limiting the impact of climate change and fostering biodiversity. In turns, this spurred pupils' engagement with their surroundings, not only at the school, but also at home and in their communities. On top of that, teachers underlined how approaching NBS in class resonated among students in terms of creativity, critical thinking, and motivation to learn. As for the 3Rs project, the percentage of students feeling comfortable finding resources on non-animal alternatives in scientific studies doubled after the implementation of the learning scenarios. Generally, they considered themselves more literate on the topic, which further stimulated a passion for science. Teachers participating in the project overwhelmingly agreed that these learning scenarios improved their ability to present animal testing and welfare in class, and how this ability enhanced students' motivation in learning the curriculum. From these results we can deduce that learning scenarios are beneficial tools for sustainability in education. They are complementary and non-competitive with national curricula, supporting the inclusion of complex sustainability topics in a wide variety of subjects – the learning scenarios in the NBS projects involved physics, biology, chemistry, environmental science, geology, design and technology, economics, arts, and English. They increased student engagement with traditional subjects while also opened perspectives on new topics, developing overall sustainability literacy among the student and teaching bodies. In summary, learning scenarios are an optimal way to introduce multifaceted and interdisciplinary matters in a classroom, as they come with the right tools, and they prove able to boost theoretical understanding and practical action.

5.2. Using professional development to integrate sustainability in education

We have already stressed how sustainability is a context-rich, interdisciplinary and, ultimately, complex topic. Learning scenarios lend themselves to the preparation of efficient, well-structured lesson plans, but to tackle issues of sustainable development, teachers might need to reinforce their preliminary knowledge on them. One of the ways in which teachers can improve their professional development is through Massive Open Online Courses (MOOCs). Teachers often find that their capacity to develop professionally is hindered by

conflicting time schedules, lack of incentives, and monetary considerations (Ainley & Carstens, 2018). MOOCs respond to these challenges by offering teachers the opportunity to get high-quality focussed professional training that is flexible and allows them to build upon their skills to develop in their careers and provide their students with quality teaching materials and methods. At EUN, although mainly targeted for teachers but open to the public at large, MOOCs are hosted at the European Schoolnet Academy, which already offers 69 courses and has reached almost 120,000 enrolments. The Academy is a platform where teachers learn about multiple types of innovations in schools and classrooms, while it helps teachers develop and enhance their practice. EUN MOOCs follow a collaborative approach and include peer assessment between teachers to stimulate reflection and discussion. In these courses, teachers can reflect on their practice, share experiences and resources, learn from peers, and build a professional community. Both the BLOOM and 3Rs projects included a MOOC.

The BLOOM "Boosting Bioeconomy Knowledge in Schools" MOOC[5] focussed on bioeconomy and its applications in teaching. It aimed at training educators in teaching bioeconomy as part of their STEM lessons by providing them with an introduction into the field and its applications in class. At the core of the MOOC was the BLOOM School Box, a collection of lesson plans co-created by twenty BLOOM pilot teachers, illustrating how it is possible to introduce bioeconomy in different STEM subjects. Throughout the course, participants learnt what bioeconomy means for societies and day-to-day lives, why it is relevant to integrate it in education, and how to use its concepts to contextualize STEM teaching. The final goal was to empower teachers by providing them the tools to showcase their students the importance of integrated STEM subjects for developing solutions to current and future environmental, economic, and social issues. This MOOC was live between the 3rd of March 2019 – 10th April 2019, for 5.5 weeks and had over 800 participants reaching almost 10,000 students.

In the 3Rs MOOC[6], on the other hand, the course explained the importance of the three Rs and the alternatives that exist to animal testing. The MOOC addressed the various ways teachers could approach this complex ethical topic in their classrooms. It tackled three main areas: animal welfare and science literacy, human-based science opens, and critical thinking. The goals were to shed light on the role of animals in society and raise awareness on new scientific methods and professions that do not require the use of animals for testing. At the same time, the online course encouraged participants to create their own relevant learning activities. To achieve these objectives, the MOOC showcased the six learning scenarios of the project and helped teachers integrate the three Rs in their daily teaching. Upon finishing either of the courses, teachers highlighted their increased knowledge on the theory and practice of the three Rs and bioeconomy, as well as an improved ability to explain

[5] https://www.europeanschoolnetacademy.eu/courses/course-v1:BLOOM+BoostBioec+2019/about
[6] https://www.europeanschoolnetacademy.eu/courses/course-v1:3Rs+AnimalsInScience+2020/about

these topics in the classroom, and an appreciation of being able to access carefully selected materials that helped them in their professional development. The 3Rs MOOC had almost 700 active participants, reaching over 8,000 students.

To have a positive impact on their students and form active and engaged young citizens, teachers must be allowed to learn and educate themselves continuously. Massive online open courses offer convenient access to professionalization for educators. These courses are a flexible tool for teachers to work on their skills, update their knowledge of current topics, and further examine new and innovative pedagogies. For this reason, they are optimal in introducing their participants with complex and multi-disciplinary concepts. MOOCs demonstrate that these concepts are relevant, can link to different subjects, and can be addressed in classrooms when using the appropriate instruments and methodologies. Participants in MOOCs get acquainted with these instruments by looking at real cases of implementation, the learning scenarios, that are successful in both delivering knowledge and engaging the students proactively. By showcasing best practices, the MOOCs of the projects analysed above showed teachers that meaningful examination of sustainability is not only doable in classes, but also beneficial to both the teaching and the student bodies. Simply put, the courses showed that sustainability education works, in real schools, with real teachers and for real students. Demonstrations like are extremely relevant in supporting the claim that sustainability should be addressed more and more in classrooms across Europe and provide experiential evidence of its feasibility. And, as the results of the MOOCs highlight, the benefits of these courses are tangible and widely recognized among education stakeholders and reach large number of teachers and through them students.

5.3. Using competitions to encourage sustainability topic integrations in education

The two methods analysed focused principally on classroom implementation and teachers professionalization. There is another tool, however, that has the potential to mainstream the integration of complex topics in formal education: teachers' competitions. Competitions call for teachers, and their classrooms, from across Europe to present their best learning scenarios, or activities on a given topic. By pushing teachers to engage in the design of appealing and effective materials, competitions could activate a sort of multiplier effect for sustainability in education. Teachers will be able to present the classroom activities they have elaborated starting from an online course – or their own initiative – to a broader audience in a competitive environment. This move can support the spread of these activities, bringing them to the attention of a higher number of teachers and schools, but also external stakeholders. Competitions magnify the beneficial effects of learning scenarios and MOOCs for the understanding and integration of sustainability concepts in education, be that only due to the result-oriented nature of this tool, which triggers teachers' motivation and commitment to the betterment of their materials. Among the three projects examined, BLOOM is the only one to include not one, but two competitions. The first, *Teach bioeconomy!*, was organized to raise

awareness on the educational gains offered by teaching with bioeconomy, and it was open to STEM teachers who participated in the BLOOM MOOC. The competition served to recognize the efforts of those teachers who, inspired by the MOOC, had created innovative learning scenarios covering the use of bioeconomy in class. As a bonus, it resulted in an increased number of educational resources on bioeconomy available to educational professionals worldwide, therefore enriching the BLOOM School Box. *Teach bioeconomy!* was also the testing ground for the main interdisciplinary school competition linked to BLOOM, *Stories of Implementation*, which engaged teachers and their students from Europe and beyond. Once again, the objective was to raise awareness on bioeconomy among the public by inspiring teachers to use the BLOOM teaching resources to create new learning materials. This approach, based on using existing resources to create new, diverse ones that further strengthen the extent to which a topic is understood, discussed and accepted, in education and society, clearly shows the multiplier effect of competitions. In BLOOM, both competitions aimed, firstly, at triggering interest in teachers for upscaling the use of bioeconomy in classrooms. Secondly, they highlighted how bioeconomy enhances students' – i.e. young citizens – interest in STEM subjects and innovative practices. Finally, the competitions highlighted and acknowledged the efforts of teachers using the BLOOM School box. Competitions, therefore, offer an instrument to spur teachers' engagement with complex topics through the elaboration and refinement of learning activities while mainstreaming these topics by presenting relevant resources to an ever-great number of educators and schools.

5.4. Combining the different methods

Competitions, as well as the other methods outlined in this section, can be used as a standalone approach. Indeed, learning scenarios, MOOCs and competitions are complete tools *per se*, and they are independent of each other in their application. Nevertheless, they work best when implemented together, as the three projects demonstrate. Learning scenarios are useful tools for teachers that need guidelines and insights on how to best implement a complex topic in class. At the same time, precisely because the themes addressed are often so new and multifaceted, teachers might need training on the subject before being ready to implement it in class. Participating in MOOCs can help understand complex topics, which in turn supports the design of new learning scenarios. MOOCs allow for both gaining new knowledge and enhancing professional skills. They help educators acquire new ideas and possibilities in their educational toolbox, and they empower teachers to innovative teaching techniques through tested real-life examples, the learning scenarios. The combination of learning scenarios with a MOOC informed the 3Rs project.

What is the role of competitions then? They can motivate teachers to improve what they have created after careful participation in a MOOC. Indeed, they can instigate the design of better activities on the one hand and, on the other, they allow teachers to share their scenarios with a more extensive pool of teachers, who can

then be inspired by the stories of implementations of these scenarios and develop their own. As suggested above, the BLOOM project is a working example of how the three methods build upon each other. With the BLOOM School Box, the project created a collection of bioeconomy-related teaching resources that educators can use at their advantage to raise student interest in socio-ecological challenges and solutions. The core of the School Box, five high-quality learning scenarios co-created by a selected number of teachers, lay the foundations for the BLOOM MOOC as well. The MOOC used these learning scenarios as best practice for participants to understand how to integrate bioeconomy in class and to inspire them to generate new activities stemming from own interest and creativity. Finally, competitions serve as point of convergence to bring together and mainstream these innovative materials, while again, sparking the production of more relevant scenarios and activities among more and more teachers. Combining learning scenarios, massive online open courses, and competitions, especially those that end with the winning learning scenarios or stories of implementation published in resources repositories like the one in Scientix[7], creates what could be described as a self-reproducing and ever-growing cycle of ideas, tools, and best practices for the integration of complex topics in formal education and in the broader society. As we have shown, these examples clearly show the potential flowing from these tools for the enhancement of education for sustainability, and of sustainability in education. At the same time, they explain how to unleash this potential according to existing structures in the school system, in ways that are both edge-cutting and result-oriented.

Conclusions: sustainability and education? It should be done, it can be done

Sustainability and education are two core values for resilience and positive developments in a 21st century characterized by social, economic, and environmental uncertainties. This paper has highlighted and exemplified how the two mutually feed and reinforce each other. Education can increase environmental literacy and support positive socio-environmental relations. Sustainability, on the

[7] Scientix, the community for science education in Europe, promotes and supports a Europe-wide collaboration among STEM (science, technology, engineering, and maths) teachers, education researchers, policymakers, and other STEM education professionals. Scientix has a portal where the teaching materials created through different projects on STEM education are included. An example is the Scientix MOOC "STEM Is Everywhere!" organized in 2018 which aimed to connect STEM classes with "real life" and help teachers integrate real-world problems into their STEM lessons and practices. During the course, participants had the chance to develop their own lesson plans. More than 2000 participants followed the MOOC and over 800 completed it. Of them, 274 submitted their learning scenario for consideration to be published in the Scientix resources repository. In the end, 36 were selected based on their topics and quality and they were made available for everyone in the Scientix resources repository. See http://www.scientix.eu/news/news-all/news-detail?articleId=867715.

other hand, with its transdisciplinary nature, can bring into classrooms comprehensive approaches, system thinking, and weave together different subjects in a shared narrative. The two of them combined have the potential to form active, informed, and responsible youth. Innovative and student-centred pedagogical trends that foster critical thinking and inquire, promote interdisciplinary opportunities, and encourage civic engagement, can be used to reinforce the dialogue between sustainability and education. Nevertheless, this is currently feasible mainly when sustainability is embedded in existing curricula rather than through changes to national educational plans, which is a slow and convoluted process. We are not arguing that national educational plans should not tackle these issues and embrace these changes. We are, however, highlighting how small changes to integrate more sustainability topics within already existing curricula can enhance the learning environments already in place. The three case studies serve precisely as models of what can be achieved within the existing framework. They use a combination of three methodologies – learning scenarios, MOOCS, and competitions – that can provide teachers with the knowledge, skills, willingness and, most prominently, peer community and support to confront complex sustainability topics in class. This approach achieves the triple objective of delivering socio-ecological themes and solutions to teachers, students, and the wider society, starting with the provision of excellent materials and ending with the creation of new methods and activities. The overview of reasons and methods offered in this paper attests to the positive outcomes of engaging with sustainability in classrooms. When teachers are trained, innovative pedagogies used, students engaged and there is a willingness to take the challenge, then no topic is too complex to address in the classroom. Sustainability is one relevant example, but the same concept could be applied for the future implementation of other challenging yet enriching topics.

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