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Coastal risks and resilience learning

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ABSTRACT

The hazards that particularly affect local coastal communities require education that is conducive to the development within planetary boundaries. The paper analyses the features of education for resilience and sustainability based on good practice and the principles stipulated in strategic documents on sustainable development issued by international organizations and professional associations. In developing the curricula for strengthening resilience, focus should be placed on deeper learning about local knowledge, on stimulating local sustainability, systems thinking, integrating teaching about the environment and responsible citizenship into all school subjects. To achieve the objectives proposed it is necessary to enhance whole-institution approach and bridge the divide between the subjects in humanities and STEM areas by providing courses which afford insights into connections between various disciplines required for perceiving local and global issues and the solutions thereto, and to implement citizen science. Resilience thinking should be embedded in planning and strategic environmental assessment procedures for a wide range of themes and activities affecting coastal area environment and its communities.

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1 Introduction

Threats to the coasts, climate crisis, COVID-19 pandemic and the threats of impending ones, the destruction of wildlife and world's ecosystems (Johnson et at., 2020), biodiversity loss, pollution, poverty, inequality, armed conflicts, earthquakes (Čolja Hršak, Runko Luttenberger, 2021), floods, and other global challenges, mandate the education that is conducive to the development within planetary boundaries. The learner should become both a critical thinker and a resilient citizen (Lambrechts, 2021).

Given holistic approach of the topic, the author applied qualitative research based on observations, authors' previous research and experiences, the reports on current research, and official documents on the subject. With the focus being primarily on coastal risks, this paper provides an overview of basic concepts of resilience and argues how striving for optimization and efficiency weakens resilience. It presents resilience principles and the characteristics of education for and learning the resilience, considering in particular systems thinking, interdisciplinarity as well as the science, technology, engineering and mathematics (STEM) learning from elementary schooling to academic levels, as well as the role of citizen science. The paper emphasizes the importance of integrating resilience thinking in implementing the strategic environmental assessment procedures preceding he adoption of plans, programmes, policies and strategies, providing an overview of activities and themes that are strongly related to coastal areas.

2 Coastal risks and their challenges

Disaster histories have to a great part shaped coastal communities which have for that reason developed substantial knowledge about surviving them. In present days those experiences are unfortunately insufficient considering the speed of population growth, increasing mobility, as well as infrastructure and technological developments (Dippel and Rafliana, 2021).

There are seven essential principles of ocean literacy (NOAA, 2020) to be born in mind in considering not only coastal resilience, but the resilience in wider sense: (1) Earth has one big ocean with many features, (2) The ocean and life in the ocean shape the features of the Earth, (3) The ocean is a major influence on weather and climate, (4) The ocean makes Earth habitable, (5) The ocean supports a great diversity of life and ecosystems, (6) The ocean and humans are inextricably linked, and (7) The ocean is largely unexplored. Humans are highly dependent on the oceans, its resources and capacity, while the ocean poses major risks for coastal communities, that being sublimed in the sixth principle.

Humans however, through various activities, exert enormous pressures on the oceans and the seas on which they depend and thus increase the threats on themselves. Those activities take place both on land and at the sea. Land-based activities involve greenhouse gas emissions from fossil fuels burning used for transportation, electric power, heating, fuel, industrial processes, mining, natural gas and oil production, agriculture, and waste management. Agriculture, besides being the source of carbon emissions, is also the source of nutrients which cause eutrophication. Industry is the source of various pollutants ending in the seas and oceans. Insufficiently treated municipal wastewaters are a significant source of nutrients and pollutants, as are also the stormwaters. Land use changes, that is, modifications on land such as paving/deforestation and coastal structures either diminish normal sediment transport or exacerbate erosion and flash floods. Land is also a major source of marine litter.

Human expansion into the ocean involves marine aquaculture, deep hydrocarbons, deep-sea minerals, desalinization, marine genetic resources, world ocean database, shipping, submarine cables, cruise tourism, offshore windfarms, marine protected areas and extended continental shelf (Blasiak et al, 2021). Blue Economy itself exerts significant pressures on oceans and the seas, resulting in greenhouse gas production, pollution, exhausting live resources, in underwater noise, and introduction of allochthonous species.

The increasing greenhouse gases emissions cause ocean acidification, the heat they produce may change seawater temperature, salinity, oxygen content, sea level, while accumulated energy may result in storm surges, hurricanes, as well as in changing of the upwelling processes and current flows. Hazard threats that in a disproportionate manner affect many local coastal communities are thus numerous, making the resilience an aspect of particular importance for them.

3 Resilience of social-ecological systems

Resilience is the capacity of the system to absorb disturbance, undergo change and still retain its basic structure and function. In common usage however, resilience is often meant to be the ability to bounce back after some disturbance or shock, with reference being made for instance to a resilient child or resilient community, a concept of indisputable importance in short term. Engineering resilience on its part is a measure of stability of the system. It describes how quickly certain system (e.g. mechanical) is able to return to equilibrium after disturbance.

In this paper the author focuses on the first of the three definitions above, also described as ecological resilience, see Holling (1973), which is attributive to social-ecological systems, such as coastal ones for instance. It considers thresholds that will be dealt with later in the text, as opposed to other two perceptions which imply bouncing. Since resilience considers the interplay between disturbance and reorganisation, it represents not only the ability to withstand, or adapt to, hardships but also to transform into something stronger (Krasny, Lundholm, Plummer, 2010).

Resilient social-ecological systems have the ability to change as the world changes and still maintain their functionality. A good example for illustrating resilience is a person carrying full cup of water on board the ship in rough seas, where the challenge is to maintain balance on a pitching floor by finding handholds, footholds, and flexing the knees, by absorbing disturbance. In ecological systems for instance, surprise events can be storms, pest outbreaks, floods, draughts, etc. Ecological and social systems undergoing changes must therefore be managed to enhance their resilience, and not only to supply certain specific service or product (Walker and Salt, 2006).

Resilience thinking is unfortunately hardly encountered in present-day academic and management institutions, partly because in studying social-ecological phenomena (linked to people and nature) very often only the disciplinary theories are used (Schlüter et al., 2022). Resilience thinking is systems thinking so the role of education is precisely achieving such competences and „anticipatory thinking“ (Lambrechts, 2020). According to Meadows (2008) we cannot impose our will on a system but should listen to what the system tells us and discover how its properties and values can work together to bring forth something much better than would ever be produced by our will alone.

One of the essential aspects of in understanding resilience concerns thresholds. Thresholds are crossing points. Crossing them may alter the future of systems on which we depend, although we often become aware of the thresholds only after they have been crossed once the system starts to behave in a different manner. The system may be illustrated as a ball in a basin, fig. 1, where the ball is the state of the social-ecological system, the basin in which it is moving is the set of states, and dotted line is a threshold. It is not just the position of the ball in relation to the threshold that is important. If changing conditions cause the basin accommodating the ball to change its shape and get smaller, resilience declines, and the poten-

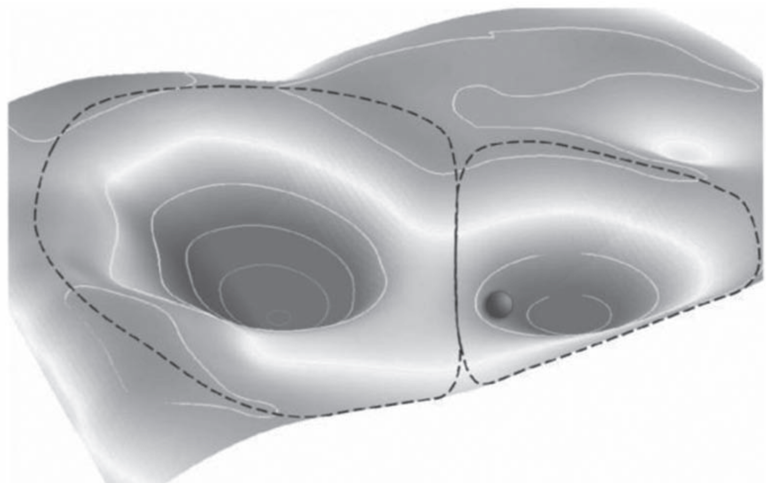

Figure 1 State of the system and the thresholds (from Walker et al, 2004).

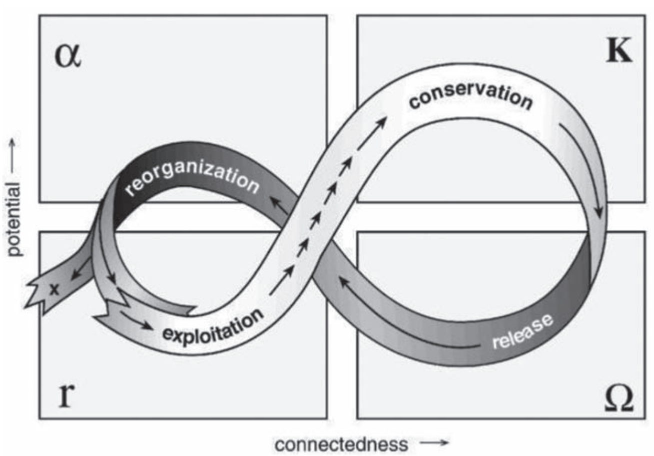

Figure 2 Adaptive cycle (Gunderson and Holling, 2002)

tial of the system to cross into a different basin of attraction becomes easier. Ever smaller disturbance may then push the system over the threshold. Consequently, system's resilience can be measured by its distance from the thresholds. Sustainability is knowing if and where the thresholds exist and having the capacity to manage the system in relation to thresholds (Walker and Salt, 2006).

Apart from the model of multiple regimes separated by thresholds illustrated above, another important aspect of resilience thinking are adaptive cycles, fig. 2. Adaptive cycle shows the behaviour of social-ecological systems over time which goes through growth (r-phase) and conservation (K-phase), followed by release (Ω-phase) and reorganisation (α-phase). The growth and conservation phases constitute the fore loop in which there is a slow accumulation of capital and potential. For instance, sticking with bad ideas for long periods because innovation is too challenging is the so-called danger of late K-phase (Walker and Salt, 2006). Very often the transition to new practices is obstructed by the very existence of physical, societal, and organizational infrastructures developed around a particular concept. Examples may be found in various sectors, such as for instance transport. Reliance on road transport may for instance be an obstacle to embracing rail transport or short-sea shipping (Runko Luttenberger, 2011). Energy sector centred on a particular fossil fuel or outdated waste management concept are good examples as well. Going back to adaptive cycle, the release and reorganisation phases are referred to as the back loop. They are characterized by uncertainty, novelty, and experimentation, with the loss of all forms of capital. It is also the time of great potential for destructive or creative change of the system.

The system progresses through adaptive cycles at different scales, whereby the very linkages across scales are the determinant factor for system's behaviour at a particular scale. Panarchy is the hierarchy of linked adaptive cycles, see figure 3.

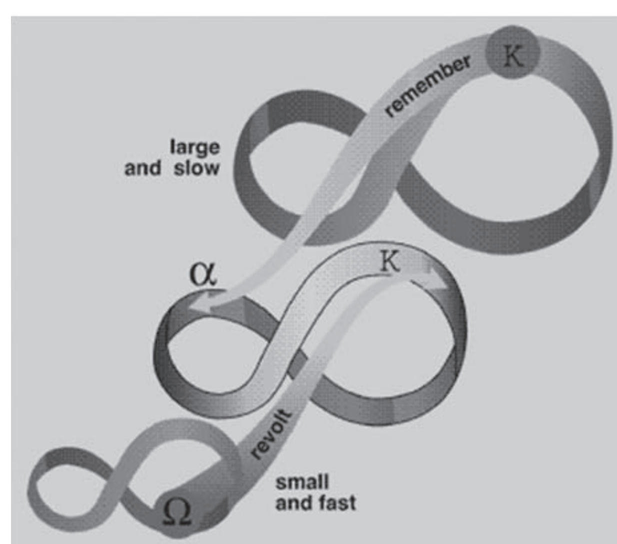

Figure 3 Panarchy (Gunderson and Holling, 2002).

Table 1 Resilience principles

Maintain diversity and redundancies	Diversity may be biological, landscape, social, and economic and it is a major source of future options and a capacity of the system to respond to change and disturbance in different ways. It is opposite to the trend of homogenizing the world. Some of the biggest environmental problems are the result of past efforts to dampen and control ecological variability. Redundancy provides insurance, allowing components to compensate for the loss or failure of others. Top-down structures with no redundancy may be efficient in the short term, but fail when circumstances in which they were developed change.
Manage connectivity	Systems that are well connected can overcome and recover from disturbances more quickly. On the other hand, overconnected systems are susceptible to shocks that are rapidly transmitted through the system. Resilient world should involve modularity.
Manage slow variables and feedbacks	It is crucial to focus on variables associated with thresholds and avoid shifting into undesirable regime or shifting out of it if we are already in it. Feedbacks allow detecting thresholds before they are crossed. Globalization for instance leads to delayed feedbacks that used to be tighter. Namely, developed world receives weak feedback about the impacts of their consuming the products from the developing world.
Foster complex adaptive systems thinking	Social-ecological systems are based on a complex and unpredictable web of connections and interdependencies. Mere complexity can be illustrated by contrasting "the cogworld" where everything is made of interconnected cogs, being complicated but systematic and predictable, and the "the bugworld" that is both complex and adaptive, in which it is impossible to predict emergent behaviour by understanding separately its component subgroups.
Encourage learning	Emphasis should be placed on learning, experimentation, locally developed rules and on embracing change. Currently we strive to get better in the decreasing range of activities. Instead of assisting the change and experimentation, current system subsidizes not making changes.
Broaden participation	Resilience depends on the capacity of people in the system to respond together and effectively. That requires trust, strong social networks and leadership.
Promote polycentric governance systems	Well-connected governance structures can swiftly deal with change and disturbance.

Source: Authors based on input by Biggs et al., 2015 and Walker and Salt, 2006.

Management may thus have an influence on the shape of the basin, system's position within the basin and should also consider where the system lies in the adoptive cycle, what is happening at the scales above and below, the linkages with these scales, and where the system is heading to. However, prevailing management models assume that changes are incremental and linear, often ignoring the changes at higher and lower scales, and they endeavour to optimize the system and hold it there so that it renders maximum sustained benefit. Such an efficiency, applied to a particular aspect of interest, leads to elimination of redundancies and resilience loss. To achieve sustainability, there is a need to strike a balance between efficiency and resilience. According to Snick (2011), two legs are necessary to progress in a pluralist and evolving society. One foot sets out the direction, while the other reacts to changes in the environment, shifts the centre of gravity, adjusts the direction, and restores balance. As explained previously, optimal state of a dynamic system does not exist because the systems are undergoing permanent change and shift, thus maintaining their resilience. Therefore, instead of constantly striving to increase the efficiency and control over change and to optimize the systems, they should be managed according to resilience principles. Another important issue in systems management is inappropriate response to slow changes because they are either not noticed or the opinion prevails that not much can be done about them. Slow variables are for instance the size of human population and climate change.

Table 1 lists resilience principles (Biggs et al., 2015) which the author merged with resilience attributes (Walker and Salt, 2006). Particular value in a resilient world should be ascribed to ecosystem services. All the unpriced ecosystem services should be included in development proposals and assessments. Those are for instance pollination, water purification, nutrient cycling, natural beaches as coastal protection, etc. Such services are unfortunately only recognized and appreciated when they are lost.

4 Resilience learning and training

The anticipation of future losses may particularly impact children and youth growing up with „doom and gloom" narratives (Cunsolo and Ellis, 2018). Both the post-truth context and the disruptive effects of global crises such as COVID-19 (Kratofil, Debeljak, Vidović, 2020) force us to rethink possible futures of education (Runko Luttenberger, 1998). Characteristics of education for achieving social-ecological resilience and sustainable development involve the relevance to local context, contribution to the common good, skills and competencies for sustainability, intersectoral cooperation, and cultivating hope for a better future (Leicht et al, 2018).

The empowerment and resilience are essential in coping with future challenges. Empowerment enables the learner to become a critical thinker, while resilience enables him/her to cope with adversity, uncertainty, and frustration. Combining both perspectives, along with framing competences with the capabilities approach, provides necessary conditions to lead flourishing lives in the future. Presently the goal of education is to provide the individual with the „right" (instrumental) skills in order to be able to function in an economic setting, the job. The social goal is also combined into a focus on economic efficiency, whereby culture and other factors shift to the background or are positioned in economic efficiency thinking, leading to separation between knowledge and skills and reducing education from being a broad learning process, to a narrow and instrumental acquisition process of several skills, selected on the basis of their usefulness in a certain economic context (Lambrechts, 2020).

Other obstacles encountered are democratic deficit in the sense that technological development is seen as a process over which citizens no longer have any control, the digital divide, the gap between specialists and citizens, and polarisation between "believers" in technological discoveries and 'sceptics'. Also, by focusing on this micro level, scientists and technologists lose sight of the impact of their creations on the macro level (Snick, 2011). Technology itself can contribute both positively and negatively to the resilience of social-ecological systems (Smith and Stirling, 2008). Besides that, school's curriculum is predominantly single-subject and discipline-led, whereby having no authority by the school's pedagogical based management team over the everyday running of the school buildings and grounds leaves little room for the school to implement sustainable development changes and "live what they learn" (Mathie, 2019), or whole-institution approach.

Upon acquiring basic numerical and literacy skills, the learners must become familiar with innovative technologies, i.e. solid computational and digital skills, complemented by anthropological, geographical and economic knowledge to make sense of the changing world and learners' place in it. Educational tools obviously need to be adjusted to different needs, so trying to identify the "best" teaching materials depends on context because what works in some does not work in other contexts (COVIDEA 2020).

Education must contribute to solutions for social problems and teach technical skills so that citizens are able to make well-informed choices when participating in society. Education must therefore slow down on the path of economic efficiency thinking, but integrate critical thinking into social context (Lambrechts, 2020). It should provide systems thinking competency, meaning the abilities to recognize and understand relationships, analyse complex systems, think of how systems are embedded within different domains and different scales, and deal with uncertainty (UNESCO, 2017). Learners should develop the skills, competences and knowledge not only to be part of the workforce but also to be able to lead happy and productive lives in a sustainable environment (COVIDEA, 2020). Education should ensure that learners become resilient to shocks caused by global risks and flexible to adjust to changing circumstances through critical thinking, adaptability, self-awareness, reflective learning and collaboration (Lambrechts, 2020). Adaptability here means the capacity of actors in a social-ecological system to influence the system's trajectory relative to a threshold and the positions of thresholds (Walker and Salt, 2006). As the occurrence of new disruption, its form, and consequences are hardly predictable, it is insufficient to organize learning based on fixed mental models and the formulation of rigid learning outcomes. What the learner must be prepared for is to cope with uncertainty, deal with adversity, and be resilient during disruptive times. In other words, education must prepare citizens to be adaptive in a changing society (Lambrechts, 2020). As even a very complex systems can be understood by identifying not more than three to five key interacting components that organize all the rest (Holling 2001), the learner must acquire the capability to recognize those essential components.

As an example, in finding its way to utilise its human resources available as efficiently as possible, the University of Malta entry regulations as from the eighties require students to pass an examination in Systems of Knowledge (Heywood and Serracino Inglott, 1987) at intermediate matriculation level. Although Systems of Knowledge has raised a lot of controversy especially because it is obligatory for entry to university, it has acted as a vehicle for a systematic discussion of environmental issues in which young people are interested. Students have come across issues concerning global ecosystems, world human population, environment and society, natural resources, and threats to the environment.

Another approach encountered in practice is the whole-institution approach to education for sustainability and resilience, which is not only about teaching sustainable development and adding new content to courses and training. Schools and universities should see themselves as places of learning and experience for sustainable development. Whole institution approach is focused on the development of the educational facility as a whole and considers not only the role of the early childhood educators or primary teachers but also school leaders, community or state leaders, etc. Learning for sustainability (LfS) practiced in Scotland enables learners, educators, schools and their wider communities to build a socially-just, sustainable and equitable society. LfS integrates global citizenship, sustainable development education, outdoor learning and children's rights to create coherent, rewarding and transformative learning experiences (Education Scotland, 2016).

Education programmes have traditionally focused on schoolchildren, whilst adults have constantly been ignored (Leal Filho, 1994). Education must however have the potential to improve the quality and relevance of educational experiences and the agency of ordinary citizens (children and adults), managers of local urban municipalities and rural councils, and politicians elected in their geopolitical constituencies (Leicht et al., 2018). It must also be pointed out here that although formal education plays an important role, the major forces of environmental education are media, governments, international agencies, NGOs, foreign investors and other external influences (Leal Filho, 2018).

5 Importance of STEM learning and training

Starting with the planetary level, nine processes that regulate the stability and resilience of the Earth system have been identified (Rockström, 2009) and their quantitative planetary boundaries proposed within which humanity can continue to develop and thrive for generations to come. Crossing these boundaries increases the risk of generating large-scale abrupt or irreversible environmental changes. The planetary boundaries involve stratospheric ozone depletion, biodiversity loss and extinction, chemical pollution and the release of novel entities, climate change, ocean acidification, freshwater consumption and global hydrological cycle, land system change, nitrogen and phosphorus flows to the biosphere, as well as ocean and atmospheric aerosol loading. Safe operating space for four boundaries, possibly five (Persson, 2022) has been crossed.

Besides the awareness about global challenges, focusing at local level is crucial for achieving sustainability and resilience of the community. Such issues involve primarily costal zones, water supply, wastewater, solid waste, transport distances to work and for provision, biodiversity, tourism, clearing of natural cover for development and farming purposes, etc. The times of crises revive in the community the question of self-sufficiency, reliable public transport, infrastructure ownership and maintenance, local food production, local artisan, manufacturing and repairing skills, minimising waste at the source rather than "at the end of the pipe", proximity principles, and practising local circular economy. All these concepts and their implementation require the acquisition of relevant knowledge.

Cities concentrate people and infrastructure (water supply, sewers, roads, landfills, power plants) and they are now particularly susceptible to heat islands, sea level rise, and extreme weather. Flooding causes heavy metal and bacterial contamination of drinking water. Envisioning cities from a social-ecological-technological perspective raises governance questions, such as the type of institutions and knowledge needed and how interactions among social-political-cultural-economic and biophysical domains are mediated through infrastructure (Hamsted et al, 2021).

Thus, the knowledge, skills, and an understanding of science, technology, engineering, and mathematical phenomena contribute to developing citizen foundations to understand aforementioned local and global problems and support actions in society that address these challenges in a meaningful and knowledge-based way. Therefore, the relevance of scientific literacy in young children, or the need to learn and undertake science in a wide sense (Bascopé and Reiss, 2021). STEM and particularly engineering sits at the intersection between the society and scientific knowledge (Pahnke et al., 2019), making engineers critical in facilitating and leading to sustainable development. For instance, engineering challenges identified by the National Academy for Engineering (NAE, 2008) intersect with UN Sustainable Development Goals (United Nations, 2015), those being personalized learning, renewable energy, virtual reality, better medicines, health informatics, urban infrastructure, secure cyberspace, clean water access, energy from fusion, present nuclear terror, managing nitrogen cycle, developing carbon sequestration methods, and engineering tools for scientific discovery (Wilson, 2019).

The author points out that present concept of maritime education and training for instance already holds a number of basic features necessary for resilience learning. It is a part of STEM, but it also integrates various other disciplines necessary for learning systems thinking and acquiring the knowledge and skills on how to live from, preserve and survive at the oceans and the seas.

Engineering educators have an important task in the sense of advancing a major shift in mindset from controlling nature to participating with nature and doing so in such a way that synergistically improves both human life and environment. STEM for sustainability approach should promote advocacy for both the workforce development, a traditional argument of why STEM education matters, and for developing students' critical thinking and sustainability mindsets, habits of using scientific evidence to justify sustainable practices, and understanding the value of STEM education for society as a whole, integrating STEM fields with social and emotional learning and civic engagement.

A workforce provided with STEM competences is a strong backbone that can withstand pressures because the skills of critical thinking problem solving, and innovation have become deeply ingrained. The International Labour Organization Women in STEM for Workforce Readiness and Development programme has developed the STEM in technical and vocational education and training (TVET) learning design framework (ILO, 2021). STEM competences that support TVET have four major domains. Besides disciplinal and transdisciplinary STEM, those are thinking skills, multiliteracies, and socio-emotional intelligence. Thinking skills involve creative/inventive thinking, critical thinking, systems thinking, problem solving, transdisciplinary thinking, decision-making, computational thinking, and ethical thinking. Multiliteracies refer to numeracy, civic literacy, digital literacy, cultural literacy, and organizational literacy. Socio-emotional intelligence entails empathy, agency, resilience, service orientation, project management, and glocal mindset.

6 The role of citizen science

There is no single definition of citizen science but rather a series of definitions that reveal the dynamics of this research approach which is continually evolving and implies new collaborative activities and shared objectives between the main stakeholder groups. Broadly, citizen science is scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions, foregrounding the role of the professional scientist. In principle, almost everyone has the opportunity to become a citizen scientist and to contribute to a scientific discipline or topic of interest. To turn true potential of citizen science into reality, there is a need to overcome the challenges of literacy in general and scientific literacy in particular, especially the access to technology. Also, in line with inclusion and the „leaving no one behind" principles of the United Nation's 2030 Agenda for Sustainable Development, scientists are slowly realising the importance of understanding how people interact with their local environments. Citizen science contributes to education for sustainable development and is its beneficiary (Skarlatidou and Haklay, 2021). In citizen science, a broad network of people collaborates. Participants provide experimental data and facilities for researchers, raise new questions, and co-create a new scientific culture. While they add value, volunteers acquire new learning and skills and gain a deeper understanding of the scientific work in appealing ways. As a result of this open, networked, and transdisciplinary scenario, science-society-policy interactions are improved, leading in turn to a more democratic research based on evidence and informed decision-making. The formats of citizen science may be various, ranging from research driven/socially driven, online/offline amateur/professional, formal/informal, one-day/permanent, to local/global. Its impacts are scientific, inspirational, educational, social, economic, environmental, and political (Socientize, 2014).

Education has very important role in implementing citizen science. It is therefore necessary to update educational programmes to promote and to recognise new forms of community engagement and digital skills in the curriculum. At the level of planning, educational plan on key aspects of citizen science that encompasses all phases of the life-long learning process, from early childhood to continuing adult education should be provided, with plans adapted to the different cultural settings found across Europe. The programmes should also provide educational strategies for citizen science actors and address, among others scientific procedures, technical issues, community management, sociological aspects or learning methodologies, as well as specific training for policy makers on citizen science methodologies. Schools are considered primary targets for the introduction and promotion of citizen science. Collaboration with teachers can give citizen science a boost and increase educational and media repercussion. Early collaboration between teachers and researchers during the development of collaboration activities is essential for success in adapting participative research activities of students to the national curricula and the specific school contexts.

7 Resilience and strategic environmental assessment in coastal areas

Resilience thinking provides a systematic way of perceiving the complexity, uncertainty, and interrelatedness of the systems and processes, and the new ways of dealing with planning and ex-ante procedures such as strategic environmental assessment (hereinafter: SEA). SEA is the formalized, systematic, and comprehensive process of evaluating the environmental impacts of a policy, plan, or program and its alternatives, preparing a written report on the findings of the evaluation and using the findings in publicly accountable decision-making (Therivel et al., 1992).

SEA is a tool for predicting the consequences of planned development, whereby considering the threats is of particular importance regarding plans, programmes, policies, and strategies related to coastal areas. Resilience thinking is the way to encourage people to develop their own systems suiting their understanding of their environment (Slootweg and Jones, 2011). Resilience thinking should thus be integrated in SEA procedures preceding the adoption of plans and strategies related to a wide range of themes/activities related to the sea, the coasts, and land, as they all ultimately affect coastal areas. Non-exhaustive list includes tourism, nautical tourism, fisheries, aquaculture, hydrocarbons exploration and exploitation, blue economy activities in general, the exploitation of mineral resources, particularly those abundant in coastal areas and the islands, such as limestone, marl, sand and other ingredients used for building materials and in construction, other industry, marine and other modes of transport, energy, agriculture, forestry, waste management, water management, and telecommunications. Resilience aspect is also an imperative in SEA procedures related to town and country planning or land use, marine spatial planning, carbon reduction strategies, adaptation to climate, and national development strategies.

8 Conclusion

In author's opinion, in developing school curriculum for strengthening resilience, focus should be placed on deeper learning about local knowledge, on stimulating local sustainability, systems thinking, integrating teaching about the environment and responsible citizenship into all school subjects. To achieve the objectives proposed it is necessary to enhance whole-institution approach and bridge the divide between the subjects in humanities and STEM areas by providing courses which afford insights into connections between various disciplines required for perceiving local and global issues and the solutions thereto. Environmental education should be infused into all subjects of the curriculum.

For solving local challenges, inquiry-based learning, outdoor exploration and place-based learning should be practised, with part of programmes being specific to a particular space. From early age the skills and arts that may benefit the community should be taught. Contact with nature in school is beneficial for children health and for holistic understanding of natural cycles, and in that sense the school should promote outdoor sports appropriate to a particular local geography, be it the sea, river, snow. For instance, children living in coastal communities should be taught sailing skills as well as marine ecosystems protection during their elementary schooling.

The author urges that education should target both children and adults in preparing them to cope with systems resilience. Building the capacities of educators and trainers as well as journalists in matters of resilience is equally important.

In coastal areas in particular, resilience thinking should be embedded in strategic environmental assessment procedures that precede the adoption of plans, programmes, policies and strategies affecting such areas, the emphasis being placed on applying nature-based solutions.

Authors' contribution: Conceptualization, L.R.L:, Methodology, N.M.; Research on general resilience aspects, STEM education and learning, citizen science, L.R.L., Research on ocean-related aspects of resilience, N.M.; Data collecting, L.R.L., N.M.; Coordination, L.R.L.; Writing, L.R.L.; Supervision, N.M.

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