Cos4Cloud
Co-designing Citizen Observatories Services for the European Open Science Cloud

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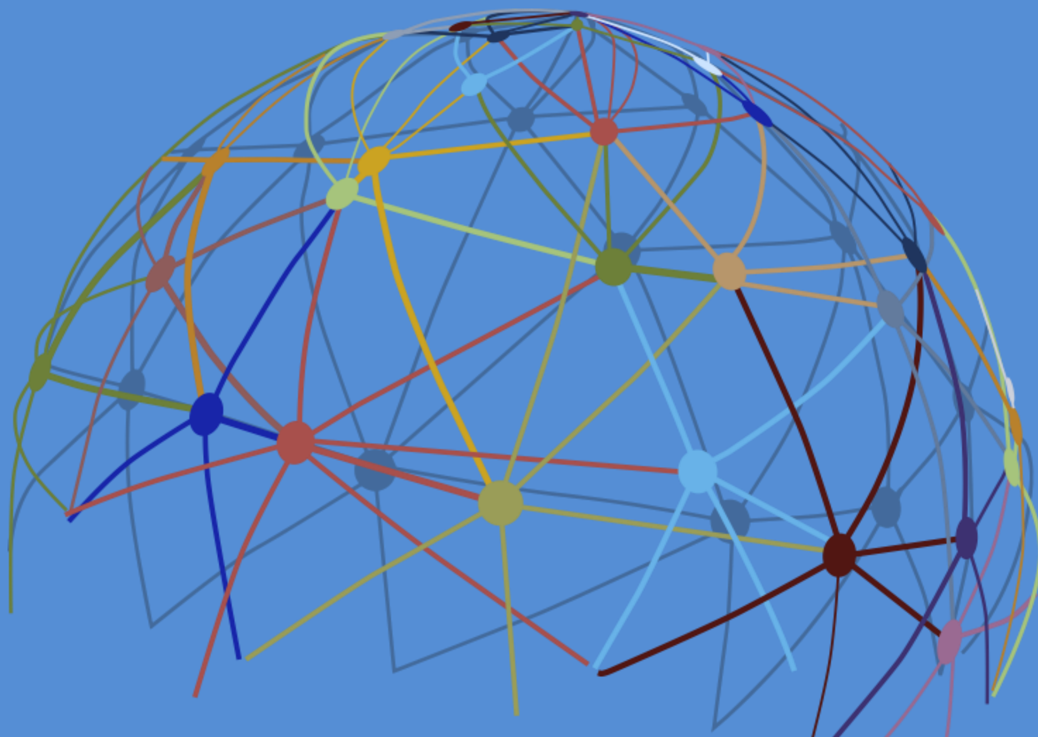

CITIZEN SCIENCE & ENVIRONMENTAL EDUCATION FOR SUSTAINABILITY

ONLINE
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Module 4

CITIZEN SCIENCE AND SCHOOL CURRICULA
IN THE CONTEXT OF ENVIRONMENTAL EDUCATION/ EDUCATION FOR SUSTAINABLE DEVELOPMENT

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In this Module...

The fourth module of the Training Course examines the relationship between Citizen Science (CS) and education, focussing particularly on the possibilities of collaboration with Environmental Education (EE) and Education for Sustainable Development (ESD). First the points where CS converges with EE/ESD are analysed as well as their common characteristics. This is followed by a description of possible ways of integrating CS into school curricula, highlighting the learning and other benefits derived from such a perspective. The conditions that define an effective and meaningful integration of CS into school curricula are also discussed. Finally, the positive effects of integrating CS into education and of connecting it with EE/ESD in school practice are shown .The module closes with a reference to examples of CS programmes that have been implemented in schools and a case study of a CS educational programme based on the Pl@ntnet Citizen Observatory

All the above are approached in Module 1 as answers to the following **questions**:

- ✓ Where does Citizen Science converge with Environmental Education for Sustainability?
- ✓ What are the common characteristics of Environmental Education for Sustainability and Citizen Science?
- ✓ In what ways can Citizen Science be integrated into EE/ESD actions and programmes?
- ✓ What are the learning benefits from integrating Citizen Science into school curricula?
- ✓ What are the conditions for an effective and meaningful integration of Citizen Science into school practices?
- ✓ What are the co-benefits for CS from its integration into school curricula?
- ✓ Are there examples of CS programmes implemented in schools?

Expected Learning Outcomes – Goals

Upon completion of Module 4 you should be able to:

- ✓ recognize the convergence points of CS with EE/ESD
- ✓ distinguish how different dimensions of CS are connected to EE/ESD goals and approaches
- ✓ understand different ways of integrating CS into schools
- ✓ state the learning benefits derived from integrating CS into school curricula
- ✓ understand what the conditions are for a substantial and meaningful integration of CS into school curricula
- ✓ know about cases of CS activities/programmes implemented in schools involving the school community
- ✓ explain the positive impact on the field of CS itself from its integration into school curricula

Keywords

- Citizen Science
- Environmental Education for Sustainability
- Educating Citizens
- School curricula
- Ways of integrating CS into schools
- Learning benefits

4. Citizen Science and school curricula in the context of Environmental Education/Education for Sustainable Development

4.1 Where do Citizen Science and Environmental Education for Sustainability converge?

Today's **environmental problems** are complicated social issues characterized by high levels of complexity and ambiguity and correspondingly low levels of sense of security and control. This is due to the fact that the reality of their nature, the factors that cause them and the available solutions may all change over time (what applies today may not necessarily apply tomorrow), just as the perspectives through which they are perceived may vary according to the context, situation or individuals involved.

This **inherent "difficulty" of addressing and managing environmental problems** requires action at more levels and in more ways. As seen in a previous module, **Citizen Science** (CS) recognizes the serious challenges posed by the complexity of today's environmental problems and the need for **actively engaging the general public** in every environmental protection effort, with CS itself serving as a tool for **knowledge** and **participation in decision-making** for environmental management, at both international and local levels. Through CS programmes and initiatives volunteer/amateur scientists, in addition to contributing to the strengthening of **science** and environmental **research**, also enhance **environmental governance** and feed into **environmental policy**. This is achieved on the one hand by the **environmental literacy** they develop and on the other through **their bonding more with a place** by experiencing it first-hand.

Certainly, CS is not alone in striving to address the multiple challenges posed by today's environmental issues. **Environmental Education** (EE) is another field of practice with similar goals. In fact, from the initial steps of its establishment (Stapp et al., 1969, Hungerford, Peyton, & Wilke, 1980, UNESCO-UNEP, 1976; UNESCO, 1978) two essential foci of the definition of CS have been (Short, 2009): (a) sound, research-based (individual or collective), educational methodologies **engaging** learners as **active** participants in learning processes, and, (b) the development of **environmentally literate and active citizens, capable of thinking critically** about environmental issues, and becoming actively involved in different environmental issues, to work toward improvement of environmental conditions and their quality of life.

Thus the concept of the **active and responsible citizen** becomes a key feature of EE and a basic tool for its future development as Education for Sustainable Development. According to Jensen & Schnack (1997) cultivating **action competence** should be the main focus of EE. Similarly, Breiting & Sorensen (1999) underline the importance of this approach, pointing out that it refers to a free action, where direction is not given beforehand and which is based on scientific knowledge and critical thinking, leading to the democratic participation of citizens in solving environmental issues.

In the same line of thought Chawla & Cushing (2007) argue that, ever since the Tbilisi Declaration, the ultimate objective of EE has been people's active involvement in working toward the resolution of environmental problems and all other objectives, (*awareness, knowledge, skills, concern for the environment*) are ingredients needed to achieve this goal. Short, too, (2009) emphasizes that although ''participation'' in environmental protection is clearly among EE's goals and one of its inherent characteristics, it is the development of ''*independent and thinking citizens, equipped with the necessary knowledge, attitudes and skills for long-term responsible behaviour*'' which is the main educational pursuit (Short, 2009, page 11).

Education for Sustainable Development, which followed on from EE in the early 1990's, corroborates a similar perspective. With a renewed approach, Education for Sustainable Development (ESD) sets in parallel with the environmental problems also the challenge of **sustainability,** as a vision and at the same time a new understanding of a way to manage these issues. Here again, the main focus is the development of active citizen participation through an environment of **transformative pedagogy**, that is '*action-oriented, supports self-directed learning, participation and collaboration, problem-orientation, inter-and transdisciplinarity as well as the linking of formal and informal learning (*UNESCO, 2019, page. 7) Specifically, it considers that the complex and pressing issues of ecological sustainability and social and political stability can be addressed through the **development of skills in authentic learning experiences**, which engage the learners in issues that concern and challenge them (UNESCO, 2017). For this purpose skills are required that will turn them into **active and responsible citizens**, who are interested in/concerned about everything going on around them and are ready to undertake initiatives and actions to bring about change.

In line with this UNESCO has, in recent years, been promoting also another approach which complements that of ESD's: **Global Citizenship Education** (GCED) (UNESCO, 2019). Both ''educations'' are based on three learning dimensions: (a) cognitive, (b) social-emotional, and (c) behavioral (UNESCO, 2017). More specifically, the aim is for citizens to acquire experiential and empirical knowledge of their environment, so that in addition to raised literacy, through participating in social learning processes they can be empowered and take action.

To sum up, whether related to the environment or sustainability the current issues of natural resource conservation, and protection of biological capital and environmental quality that are of concern to today's societies, pose complicated problems that are characterized by high levels of complexity uncertainty and unpredictability. A typical example is biodiversity loss (Dillon, Stevenson & Wals, 2016). In order for individuals to become agents of change and better address the ambiguity and insecurity inherent in these issues, **environmental learning** is a central priority, either in the context of formal/school education or through non-formal and informal educational programmes. With this type (pedagogical) of interventions experiential knowledge can be developed that will, on the one hand, help bring people into closer contact with the environment, to become more familiar with it and develop a sense of belonging, and on the other hand to understand the various issues in depth and develop a responsible attitude towards them, through participation and assertion (Leicht, Heiss & Byun, 2018).

Image 1: The 17 Sustainable Development goals

In 2015, as a result of a three-year process that followed the 2021 World Conference on Sustainable Development, Rio +20, the 2023 Agenda for Sustainable Development was adopted so that the UN member states could use it as a base upon which to formulate their political agenda for the next 15 years. Sustainable Development was once again at the forefront of global discussions, and the 17 Sustainable Development Goals (SDGs) were placed in the spotlight. These goals address major and critical challenges for the survival of humanity and seek to pave the way towards sustainability, peace, prosperity and equality.

The vision reflected by the 17 Goals was connected with education right from the start. Education itself was recognized as one of the goals (Goal 4: Quality Education). At the same time, however, penetrating the goals horizontally, a series of indicators are identified which connect with and are based on education, highlighting it as a key means to achieving them. Thus education is not just another goal among the 17. Rather it is considered the key factor contributing to the promotion and stimulation of the vision to take concerted action regarding issues of vital importance for mankind (UNESCO, 2017).

Education for Sustainable Development (ESD) has been promoted ever since 1992 by UNESCO, the United Nations specialized agency for education, and it is UNESCO itself that continued and renewed the theme of Environmental Education (EE). Having been the driving force of the Decade for Sustainable Development 2005-2014, ESD is today the educational approach supporting the 2030 Agenda and its 17 Goals, after being upgraded and renewed through the Global Action Programme - GAP on ESD. This programme was recognized in 2014 as the step of the Decade. At the same time in recent years, UNESCO has also been promoting the Global Citizenship Education – GCED approach, which it considers as complementing ESD (UNESCO, 2019).

Thus ESD, supported also by the GCED, is a fundamental component of the 2030 Agenda and is considered as a base for quality education in the context of lifelong learning. (Leicht, Heiss & Byun, 2018). Specifically, through Goal 4.7, the ESD approach is recognized as a priority together with the adoption of sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and the appreciation of cultural diversity (UNESCO, 2019).

Following this path ever since, ESD has been shaped into a multi-faceted educational approach that is brimming with challenges. More specifically, according to UNESCO (2017, page. 7):

“ESD consists of holistic and transformational education that addresses learning content and outcomes, pedagogy and the learning environment. In addition to including and prioritizing content on climate change, poverty and sustainable consumption in the curriculum, ESD also creates interactive, learner-centred teaching and learning settings. In essence, ESD requires a shift from teaching to learning. This takes the form of an action-oriented transformative pedagogy, characterized by elements such as self-directed learning, participation and collaboration, problem-orientation, and inter and transdisciplinarity, as well as the linking of formal and informal learning. Such pedagogical approaches are essential for the development of competencies needed for promoting sustainable development” (UNESCO, 2019, page 7).

This description of ESD is characteristic of the extent of the changes and reorientation required across the length and breadth of education, at all levels and in all forms – typical, non-typical and informal. This is a particularly ambitious approach (Wals, Mochizuki & Leicht, 2017), through which however it appears abundantly clear that the complex and pressing sustainability issues regarding ecological sustainability and social and political stability can only be addressed if education can responsibly support the development of skills in authentic learning experiences, that will engage learners in issues that regard them and that are related to today’s challenges (UNESCO, 2017). These are skills that will essentially empower learners to become active and responsible citizens who are interested in everything going on around them and are ready to undertake initiatives and actions to bring about change.

Coming back to the present, we see that the critical/serious conservation issues of today’s societies are characterized by high levels of complexity and unpredictability, since the situation is constantly changing. A typical example is biodiversity loss (Dillon, Stevenson & Wals, 2016). In order to become agents of change and better address the ambiguities, complexities and insecurity that these constantly growing issues cause, its central aim is learning, stemming either from school education or non-formal and informal education, and to experiential knowledge that will help bring people into closer contact with the environment and to get to know it better so as to develop, on the one hand, a sense of belonging, and on the other hand to understand the various issues in depth and develop an active and responsible attitude towards them, through participation and assertion (Leicht, Heiss & Byun, 2018).

Image 2: Citizens as agents of change in the challenge and vision of sustainability

4.2 What are the common characteristics of Environmental Education for Sustainability and Citizen Science?

By closely reading UNESCO's (2019) definition of Education for Sustainable Development (ESD,) as a continuation and extension of Environmental Education (EE) centred on the concept of Sustainability, it can be seen that ESD has many things in common with Citizen Science (CS). The two approaches are not only compatible with each other, but also complementary.

As elaborated also in the previous subsection, the vision of EE and ESD lies in the cultivation of active and responsible citizens, who are interested in, and understand, the complex issues that concern the world around them and undertake initiatives and actions to bring about changes in them to work toward sustainability. Both versions, EE and ESD, therefore, basically concern **educating citizens**.

The same applies to CS. Both the **citizen** as a concept and **education** as a process are intrinsic to CS. CS Participants are educated as both citizens and scientists while at the same time they are encouraged to participate democratically in society and their scientific way of thinking is developed.

More specifically, a key element of EE and of ESD is the shift **from teaching to learning**. CS involves a **new type of engagement with science**, which breaks the barriers of traditional science that is characterized by its distinct roles and the monopolistic production of knowledge by professional scientists. This new engagement with science opens up **new ways to learn**, through a variety of experiences that are developed at a non-formal and informal learning level.

An important principle both in EE and in ESD is **the idea of self-directed learning**. Another core dimension of EE is that citizens participate in all activities entirely on a **voluntary basis**. They choose to take part driven by internal motivations, whether these stem from an interest in science and research or from their reflection and desire to find solutions to the problems around them.

Also important, both in EE and in ESD is **the concept of participation**, which is of course a core element and key objective also of CS. More specifically, participation of ordinary citizens is promoted both in the scientific processes and in discussion and decision-making on public issues. On the other hand, the participation of research scientists is also promoted in relevant discussions and in decision-making as part of the democratic processes.

A key feature characterizing both EE and ESD is that both approaches are clearly **action-oriented** and **focused on real-world problems**. Accordingly, CS is based on, and promotes, citizens' active involvement in various aspects of scientific research through democratic and collaborative processes, supporting their action toward solving real problems of the world around them, through democratic and collaborative processes.

Image 3: Researching the world around us to solve real problems

Finally, both EE and ESD are not confined to formal education but are considered **lifelong learning processes** that can apply to all levels of education, and all contexts, formal, non-formal and informal, of learning. Similarly, CS, either as a non-formal type of learning, incorporated into the school setting, or as a purely informal form of learning, outside schools, exists as a piece of the puzzle of learning experiences that complement a continuous learning process.

Summing up, it is noted that **the compatibility between the two fields does not eliminate their differences nor unique characteristics.** Through their synergy each field can develop individually with a renewed perspective and dynamic. A perspective, through which CS will be perceived, for example, as a mechanism for empowering and transforming science and the community (Dillon, Stevenson & Wals, 2016). As pointed out, in particular by Dunkley (2017), when an EE/ESD lens is applied in order to study CS then **the perspective offers a *social, political and emotional* understanding rather than a uni-dimensional scientific understanding of the role of CS.** So the conjunction then of CS with EE/ESD and the interconnections that can be formed between the two fields has been seen as a major opportunity.

4.3. In what ways can Citizen Science be integrated into EE/ESD actions and programmes?

Both EE and ESD have been proposed as educational processes and practices, which attempt to bring about **changes**: to the **environment** and **society**, **people** and **education** itself (Sauvé, 1994, 2002 · Daskolia, 2005). All three of these interrelated perspectives are based on, and promoted through, a new pedagogy, whose logic is not limited to merely renewing the current curriculum and enriching it with sustainability concepts and issues, but instead extends to a holistic revision of the curricula and teaching method by adopting interactive and student-centred teaching approaches, that are based on, and which promote, **inquiry-based learning** and **collaboration**.

And it could not have been otherwise, since **sustainability issues** (such as climate change, biodiversity loss, food security, etc.), present multidimensional, and to a large extent, chaotic challenges, as they belong to the category of what are characterized as ''**wicked issues''**, namely issues that are complex and unclear in nature and are consequently hard to address (Gibson & Fox, 2013).

Simple Problem

- Easy to solve.
- A clear problem with a
- clear solution.

- *Predictable*
- *Straightforward*
- *Obvious*

Complex Problem

- Resists solving.
- The problem and the solution
- are not clear but can
- be understood with time.

- *Many elements, although the elements themselves are familiar*
- *Hidden root causes*
- *Non-linear*
- *Inter-operating parts effect each other*

Wicked Problem

- Resists defining
- Problem and solution not understood, and keep shifting when we try to define them

- *Ambiguous, chaotic*
- *Many shareholders, with conflicting perspectives*
- *Many elements, many hidden and some hitherto unknown*
- *Strong social aspect*
- *Involves changes in belief, behaviour and/or identity*
- *No right/wrong solution*
- *Non-quantifiable*
- *No precedent*

Simple, Complex and Wicked Problems..
(Source: Gibson & Fox, 2013)

The great diversity and interdependence of environmental and social systems inevitably leads to the need to reorient the ways of considering these issues since, for example, knowledge related to local issues may conflict with knowledge regarding similar issues in a wider context. Therefore, the traditional teaching approach is not suitable when addressing problems of this kind. A different way of thinking is required and, at the level of school learning, **a redefinition of the educational process** (Dillon, 2016).

On the other hand, Citizen Science (CS) is recognized as a developing tool for increasing scientific knowledge and research skills (Bonney et al., 2009· National Research Council, 2009). It is an **exploratory and empowering process**, that aligns with the personal learning interests of **adult citizens** or their social concerns in relation to local or global issues (Crall et al., 2013· Wals et al., 2014· Jordan et al., 2016). Nevertheless, **its connection with formal education has been little approached and exploited**, despite the fact that school curricula offer many opportunities for students to actively take part in, and benefit from, CS programmes and actions. The question is: *in what ways* can we best integrate CS into (formal) education, so that everyone involved can derive the maximum benefit from it.

As seen in the previous subsections, **EE/ESD practice in schools provides a suitable and compatible framework for activating and forming creative synergies with CS**. Learning experiences with reference to EE/ESD can be designed pedagogically to engage students (and other members of the school and local community) in activities and programmes so that they can identify, explore and examine local environmental and sustainability issues. Investing in such actions has a double benefit: not only is the educational practice enriched but the opportunities of ensuring a better environment and better quality of life for all are multiplied.

According to the typology of Dillon, Stevenson & Wals (2016), the priorities of most CS programmes and initiatives are either science-driven (starting from a scientific logic) or policy-driven (born from a necessity to document new or more appropriate polices). In comparison, there are far fewer CS initiatives and programmes aimed at bringing about real changes in the environment, society and people's daily lives (transition-driven). Nevertheless, the synergy between CS and EE/ESD can pave the way towards this, namely by promoting **actions aimed at effectively improving the situation**, through the transformation of the scientific research processes or through changes in the ways citizens engage with local sustainability issues. Therefore, by imbuing CT with the **transformative perspective of EE/ESD,** CS can move away from the instrumental character it displays and evolve on the basis of a more emancipatory practice compared to its current state. A description of the various types of CS according to Dillon, Stevenson & Wals' typology (2016) is given in the Text Box below.

Citizen Science Approaches

based on Dillon, Stevenson & Wals' (2016) typology

In the field defined as CS one can distinguish several varieties of programmes that adopt and support different approaches. If one looks closely at these approaches they can understand issues related both to the motivations that lead scientists and citizens to participate in these initiatives as well as the benefits derived from such collaborations. According to Dillon, Stevenson & Wals (2016) the different types of CS programmes form a continuum, at one end of which one can distinguish more instrumental approaches to CS that are fully-led by scientists, whereas at the other end are more emancipatory approaches in which citizens take the initiative.

Science-driven citizen science programmes: *For these programmes the agenda is set fully by the scientists. They determine the tasks (which often involves monitoring and collecting data) and the citizen volunteers collect and share the data using prescribed protocols. It is the scientists who analyse the data and interpret the results and who present and publish them. The results can be shared with the citizen volunteers.*

Policy-driven citizen science programmes: *These CS programmes seek citizen participation based on the idea that public participation in science can support specific environmental protection policies and measures. Here too the scientists play a key-role in defining the issues at stake and determining what research needs to be done but there is also some flexibility regarding the ways in which citizens' ideas can be incorporated and utilized.*

Transition-driven citizen science programmes: *This is a relatively new approach, that places even greater emphasis on the active ''citizenship'' of the participating citizens (civic science). It is the citizens themselves that have the initiative and responsibility to determine the questions to be addressed, collect the data and build new knowledge. It is a form of CS that is not driven, but rather supported, by motivations and people that are not linked purely with science or policy-making. Scientists, citizens and all the stakeholders participate in a joint learning process focussed on addressing complex sustainability issues.*

4.4 What are the learning benefits from integrating Citizen Science into school curricula

As seen in Module 1, **Citizen Science** (CS) promotes **a new type of engagement for citizens in science and research.** Its key characteristic is that it endeavours to reposition science within, in relation to, and in interaction with society, by strengthening its democratisation and supporting citizen participation in decision-making processes. It forms, therefore, an emerging 'paradigm' of scientific practice, which is based on, and promotes, **collaboration** between citizens and scientists.

On the other hand, **integrating CS into the educational process** offers a variety of learning opportunities, turning CS respectively into an emerging new 'paradigm of **educational practice**. Specifically CS that focusses on questions and issues of environmental management and protection can be utilized in the context of EE/ESD, providing a framework for, and enriching, environmental learning towards sustainability.

More specifically, including CS in the learning process significantly benefits both schools and students. First of all, it increases the **school's openness towards science** since the pupils participate in collaborative research processes focussed on real problems in their local environment. Secondly, it acts as an **empowerment mechanism for the school community** as a whole, not only by engaging it in scientific practices and developing new knowledge but also through its undertaking of initiatives and participation in dialogue on global and local environmental issues and sustainability issues. (Bonney et al, 2014). At a purely cognitive level, participating in CS programmes that are connected with and concerned with the environment and environmental problems cultivates students' **scientific** and **environmental** literacy. At the same time it also nurtures their **''ecological literacy''**, i.e. the development of a new way of thinking and acting, which forms the basis for decision-making regarding critical environmental problems concerning present-day societies at both global and local level (Jordan, Ballard & Phillips, 2012· Jordan et al, 2011).

In general, through CS programmes, students are educated at multiple levels, both as **scientists** and as **citizens** developing the abilities and skills (cognitive, social, emotional and behavioural) typical of a responsible and active citizen, and of a ''scientist'' with social awareness and reflection. Voluntarily participating in solving real environmental issues strengthens their **sense of solidarity** and **empathy**, together with their **curiosity** and **interest in science and life**. All these characteristics give CS a special dynamic that differentiates it from the regular programmes of non-formal and informal learning in the school community (Jordan, Ballard & Phillips, 2012).

Research on the subject shows that students' engagement in CS programmes can change their **way of thinking about the concept of participation** in community actions, thus strengthening **active citizenship**. Specifically, Ballard, Dixon & Harris (2017) who studied CS programmes, followed by youth participants and run in parallel and in combination, both inside and outside of school, note that when these programmes are connected with specific processes within the ambit of the community, such as: a) *rigorous data collection*, b) *disseminating scientific findings to an external audience* and c) *investigating complex social-ecological systems*, then they can not only foster youth participation in current conservation actions, but also build their capacity for future conservation actions.

Aspects of CS	What students learn from it	Related pedagogy
based on the scientific methodology	*• Working with research hypotheses and experiment design* *• Gathering Data* *• Extracting conclusions from observations and/or data* *• Criticize and discuss*	*• Evidence-based pedagogy* *• Learning through research* *• Theoretical learning*
in the project structure	*• Managing a project and its resources (e.g. time, money, actors)*	*• Project-based education*
community-based, involving various actors (individuals, agencies)	*• Interacting, connecting and coordinating with various actors* *• Benefiting from the experience of others* *• Practising inclusivity, patience and other key social skills from intergenerational learning*	*• Community-based learning*
engagement-centred	*• Get into action* *• Find motivation and self-confidence*	*• Action-oriented pedagogy* *• Hands-on learning*
''real-world'' implications and applicability	*• Using theoretical knowledge in reality* *• Solving concrete-case problems*	*• Authentic situation pedagogy* *• Learning-by-doing* *• Challenge-based education*
based on sharing culture	*• Practising openness and sharing culture*	
		(DITOS consortium, 2019, page 2)

Table 1: Aspects of citizen science

To sum up, CS can serve as an important **pedagogical tool** when integrated with EE/ESD. Depending on their type and thematic focus CS programmes can bring together a wide range of **aspects of learning** (see Table 1), providing a comprehensive educational framework in which different approaches are combined and utilized (DITOS consortium, 2019). With this combination of collaborative, student-centred and exploratory approaches CS can contribute to the creation of **holistic learning experiences**, which go to the core and beyond of the dominant, mainly knowledge-based approaches to sustainability issues.

Finally, the learning benefits derived from implementing CS programmes in schools are not confined only to individuals, in fact they go beyond them, stretching also to the **community**. Individuals have the opportunity to develop skills related to critical thinking, engagement in lifelong learning processes, action aimed at adapting to the new circumstances and support of the social-ecological systems in more sustainable and resilient ways (Stevenson et al., 2013). All the aforementioned, however, also reflect directly on the community as well, since they have resulted in the development of a ''social capital'' which is needed in efforts towards seeking collective solutions to today's environmental problems and improving community well-being (Jordan, Ballard & Phillips, 2012).

Image 4: Looking more closely at already familiar environments

4.5 What are the conditions for an effective and meaningful integration of Citizen Science into school curricula?

Following on from what has been discussed so far, it is believed that CS can function as a trigger also for a review of, and change in, the way in which **learning is promoted through the curricula**. One is prompted to think differently now about education itself and the school curriculum.

International experience from CS programmes connected with school education shows that the majority of them occur as individual, one-off events with no follow-up (DITOS consortium, 2019). Research however has shown that fragmentary actions, that have no duration and iterability, do not help students to achieve basic social and scientific goals (DITOS consortium, 2019**) – Consequently it is important that CS be integrated systematically into the EE/ESD framework,** as this multiplies the possibilities of deeper and more meaningful recognition of the learning objectives a**nd of** achieving changes towards sustainability.

Liu & Kobernus (2017) argue that particular attention should be given to the fact that CS programmes should be tailor-designed to the participants, i.e. match both their **interests** and **skills**. This encourages enthusiasm and enjoyment, which are two of the main drivers of, and crucial to the success of, CS programmes.

> *'The strength of CS programmes lies in the curiosity and joy of the volunteers in learning and observing things that they had not observed in environments they already knew''.*
>
> (Liu & Kobernus, 2017, page. 161)

Another point that requires attention is, according to Jenkins (2011) that the integration of CS into educational practice should seek to build **connections between the everyday life of students and science.** This kind of thing is particularly important since the research notes that students' experiences of science are to a great extent negative, also due to the fact that science, as taught in schools, is not connected to their daily lives. CS lends itself to the development of a **'communication bridge' between science and education** and the cultivation of a scientific literacy through the democratization of science (Gray, Nicosia & Jordan, 2012).

Moreover, by introducing science into the classroom and engaging students and teachers in CS practices, **epistemology and scientific research methods become open and accessible** and the nature of science itself becomes the subject of discussions regarding the curriculum. This of course means that scientists, for their part, must relinquish full control over the scientific research and offer their tools for use in the classroom. (Gray, Nicosia & Jordan, 2012). It also means that teachers must broaden their perspectives, making room for new, perhaps less certain, but at the same time more "innovative" practices, breaking away from the more usual and established logic of science experiments (Grandy & Duschl, 2008). Lastly, teachers need to ''communicate'' science to their students instead of merely transferring already acquired knowledge (Shah & Martinez, 2016). This means that both they themselves and the wider school community should be ready to accept open and unstructured student-centred practices.

Ultimately, a holistic approach to these practices must involve also the **engagement of the school and the community**. Interactive and student-centred processes, through which different forms of learning are developed, are best promoted in the context of whole-school approaches as in the case of 'eco-schools' or 'green' schools and, even more, so forest (sustainability) schools (Dillon, 2016).

In closing, to ensure the quality and effectiveness of the processes when integrating CS into school curricula through EE/ESD the following criteria should be taken into account and an attempt made to adhere to them: (DITOS consortium, 2019, page. 4):

- *Ensuring time for conducting these types of programmes in schools*
- *Training teachers to plan and implement these programmes*
- *Moving away from ''right-wrong'' types of assessment*
- *Developing assessment tools for skills and cultivating curiosity and reflection*
- *Supporting local actors to develop pedagogical content and programmes in collaboration with teachers*
- *Encouraging partnerships between the local and school community.*

4.6 What are the co-benefits for CS from its integration into school curricula?

The previous subsection referred to the learning benefits derived from integrating CS into school curricula through EE/ESD. Extending the discussion, consideration will be made as to what extent this collaboration between CS and EE/ESD **works to the advantage of CS itself**, by developing it both as a field and as a practice.

According to research by Hecker et al (2018), CS programmes and initiatives have been predominantly pursued within the realms of the **natural sciences**, while initiatives linked to **social sciences** and **humanities** are much rarer (Heiss & Matthes, 2017). Likewise, the predominant orientation of most CS programmes to date appears to be ‘’scientific only’’.

The first element that has a renewing effect and also to the benefit of CS, is that through its collaboration with EE/ESD efforts are strengthened to reexamine this orientation and to open up CS towards an **interdisciplinary focus and methodology**, that is not limited only to the perspective and tradition of the natural sciences but extends also to the social sciences and humanities. This dimension arises as a condition for the **multifaceted and global approach to environmental problems,** with the contribution of different sciences (Tauginienė et al., 2020).

A second element relates to the **public**, towards whom CS has traditionally been directed to date, and to the **context of the learning processes** that it promotes. **Adults** are the main target group of most CS programmers where the activities take place mainly in non-formal and informal learning environments. There are comparatively far fewer cases of CS being implemented in school education. In this sense, integrating and promoting CS through EE/ESD actions in **schools** and in **other types of formal education broadens the scope of CS to a new and dynamic audience**. The pursuit of common goals is thus strengthened across the length and breadth of education, as part of a **lifelong learning process**. In addition, it addresses a special, uniquely important audience, which through engagement in education can develop the appropriate knowledge, values and skills, thus constituting an important investment for the future.

4.7 Are there examples of CS programmes implemented in schools?

As already mentioned, in recent years the importance of CS has already started to be recognized as an empowerment mechanism for the school community with significant learning benefits both for the students themselves and the school community as a whole (Bonney et al, 2014). Consequently a large number of CS programmes have already made their way into schools and are being followed by students of all ages and levels, from preschool to university. Some CS programmes have been included in the school curriculum and students participate ''officially'' in them. In the higher levels in particular students are motivated by their desire to participate, thus enriching their formal educational curriculum (Dunkley, 2016). Programmes implemented in schools vary as regards the degree and method of their involvement with research, with many of them contributing data that are officially used in many scientific studies (Dunkley, 2016).

Some examples of CS programmes implemented in schools are given below:

- ✓ **Seeds in Space**

(https://schoolgardening.rhs.org.uk/news/Newsresults/National/2015/May/rocket-science)

The programme is based in the United Kingdom and involves an observational exercise comparing whether, and how, seeds grow in space as opposed to on school grounds. Astronaut Tim Peak launched this project to coincide with his space mission. It is a collaborative project between the Royal Horticulture Society, the UK Space agency and a large number of schools in the United Kingdom (Dunkley, 2016).

- ✓ **ENVIRAD-Radiolab project**

This project was initiated by the Radioactivity Laboratory of the Physics Department at the University of Naples, which collaborated with secondary school students to take radioactivity measurements, focussing on the risks associated with radioactivity. More specifically, the project, based on a survey, was carried out in 49 schools, involving about 1000 pupils. The students were directly involved in radon long-term measurements, being responsible for the data collection. In some cases they were also responsible for measurements performed in sites other than the schools, in order to promote the awareness of this issue among other citizens. The main aim of the project was the achievement of scientific results that were immediately utilizable by the scientific community and useful for the students themselves. This approach was a way to back up the connection between science and society and to improve the students' awareness of the multiple connections and interactions between scientists on an issue (Ellenburg et al 2019).

- ✓ **GLOBE Program** (www.globe.gov)

In 1994 the American government announced the launch of the Global Learning and Observations to Benefit the Environment (GLOBE) Program, as an effort by different agencies to involve students and citizens from around the world in collecting data about the environment and the Earth as an ecosystem. In this programme, students and citizens collect data about the environment following the guidelines of a series of well-designed protocols and they upload it on the Internet (Balzano, Miele & Serpico, 2016)

- ✓ **FutureForest**

In this programme CS was used as an educational tool in the context of formal education. Participating students were involved in a DNA barcoding programme. By using DNA barcoding students can perform genetic identification of species. 276 high school students from Germany took part in this programme as part of an education module on biodiversity (Schneiderhan-Opel & Bogner 2020).

Shah & Martinez (2016) also list a number of examples of CS programmes which are appropriate and are ongoing or which can be implemented, after integration into school curricula, according to the level of education, and which are given in the Table below (pg. 91).

Image 5: Seed development in the 'Seeds in Space' project

Examples of CS projects appropriate for school-age students		
Education level	**Title**	**Description**
Elementary school	Journey North www.learner.org/jnorth/	Students investigate global wildlife migration and seasonal change.
	FeederWatch www.birds.cornell.edu/pfw/	Students set up bird feeders and observe when the birds are feeding. Data collection on the type and number of birds.
	Bee Hunt www.discoverlife.org/bee/index.html	Students inventory pollinators at a selected site using photographs to identity insects and plants.
Middle school	Encyclopedia of Life www.eol.org/	Students take wildlife photos, comment, research and write about the species on Earth.
	Galaxy Zoo www.galaxyzoo.org/	Students examine images of space and classify them according to their shape, allowing scientists to understand galaxy formation while students gain exposure to astronomy research.
	S'Cool http://scool.larc.nasa.gov/	Students observe clouds at particular times focusing on type, height, cover and thickness.
	World Water Monitoring Day www.worldwatermonitoringday.org/	Students use test kits to monitor the health of local water bodies by measuring pH, dissolved oxygen, temperature and turbidity.
High school	FoldIt http://fold.it/portal/	Students become familiar with synthesis and breakdown of proteins including how structure affects function.
	Nature's Notebook, USA Phenology Network www.usanpn.org/home	Students observe and identify specific plants and animals in a region to determine the effects of global climate change on vegetation and wildlife.

Table 2: Examples of citizen-science projects appropriate for school-age students

To sum up…

CS converges with EE/EES, since they both seek to cultivate the idea of the active and responsible citizen and put them at the centre of their practice. There are many points connecting the two fields and many common principles and approaches that make CS and EE/ESD compatible and complementary to each other. These include the central role of learning, basic concepts such as participation and that of active citizenship, orientation towards action and real-world problems. Integrating CS into school curricula is challenging, however EE/ESD appears to be a suitable and compatible framework for activating and forming creative synergies with CS. Integrating CS into formal education generates many benefits, both at the learning level and at the general level of educational practice, making CS an emerging 'paradigm' of educational practice. However, in order for its integration to be effective and meaningful, a series of 'conditions' must be taken into account that will help ensure that the benefit is mutual. Although the prospects for creative collaborations in this direction are still open, specific cases from international programmes already indicate considerable interest and an active presence.

ANNEX 1
Module 4

Research: Participation of schools in CS research

Based on their research conducted with secondary school teachers and students as part of a CS project entitled, **'Helsinki Urban Rat Project'** (HURP; https://www.helsinki.fi/en/projects/urban-rats) Aivelo & Huovelin (2020), drew the following conclusions in relation to implementation of CS programmes in schools:

'The results of our research show that CS can be a valuable part of formal education as regards incorporating authentic research practices into every day classroom practices. In addition, the participation of students and teachers in research that is coordinated by external partners (such as academic researchers and scientists) is perceived as more important than research work done at school and only for the school. Especially in cases where data collection is performed outside the school, even if this is in a neighbouring environment, the motivations for participation are highly important.

Our research sheds light on some critical points that need to be taken into account as regards participation in CS programmes to guarantee their success:

Firstly, teachers' goals and those of the students must be headed in the same direction as those of the researchers conducting the programme. It would be good if the CS programme could be embedded into the curriculum and provide ready-made 'material' for teachers to draw on.

Secondly, teachers should not be passive participants in the programme. It is important that they interact with, and share in, the experiences of the students and the results of their work. It is vital to discuss in class the goals, problems and ultimately the experiences pupils had during the programme. While some students may gain significant learning experiences through their participation alone, the opportunity for reflection in class about the programme, can provide them with many more learning opportunities.

Thirdly, data analysis can also provide further learning opportunities. A co-designed CS programme can be even more rewarding from an educational perspective. Nevertheless, there are no hard and fast rules on how much time a teacher should devote to education, nor on the level of engagement of a pupil''.

(Aivelo & Huovelin, 2020, page 336)

ANNEX 2
Module 4

Case study:

"The secret Life of city"

Two national education programmes based on the Pl@ntNet platform

The aim of the following case was to highlight a new form of EE and ESD projects based on participatory science and artificial intelligence technologies based on the Pl@ntNet Citizen Observatory. The project was implemented in two central European countries: Slovakia and the Czech Republic

The project

The project was implemented in two non-governmental, non-profit organizations

- Zivica, Slovakia (http://www.zivica.sk)
- Tereza, Czech Republic (http://www.terezanet.cz//cz)

In both these countries, botany at school is taught mainly inside the classroom or in the playground. To promote learning about botany through more direct interaction with nature, the abovementioned organisations sought a new method based on direct student-nature contact. The project focused on important plant species that can be observed within or close to cities, to emphasize the fact that plant biodiversity exists and is important both in cities and in remote natural areas.

In the methodology followed students and teachers became researchers, combining their forces in order to inform the wider community about the variety of plants in their city, town or village. There was a range of activities, of varying degrees of complexity, so as to spark the creativity of the students.

Aim: The main aim of the project was to raise public awareness of the surrounding environment and to emphasize the importance of biodiversity in cities as an important element of sustainability.

Duration: The project's duration was two years to give the participants ample time to cultivate their skills.

Description

Both organisations sent invitations to 350 schools in each country, while simultaneously using the European Eco-schools network ('Eco-schools', http://www.eco-ecole.org). The schools concerned were Primary and Secondary schools attended by students aged 9 to 15.

The invitation included:

A) Project description (goals, expected benefits for the students and student-, teacher and school commitments)

B) Description of teacher and student training courses

C) Description of the equipment schools would receive (4 tablets per school per year and a one- or two-year commitment request

50 schools were selected from each country. The combined total of schools was 100, which were operating in large cities (e.g. Bratislava, 432,000 inhabitants) and towns (e.g. Vojcice, 2,200 inhabitants).

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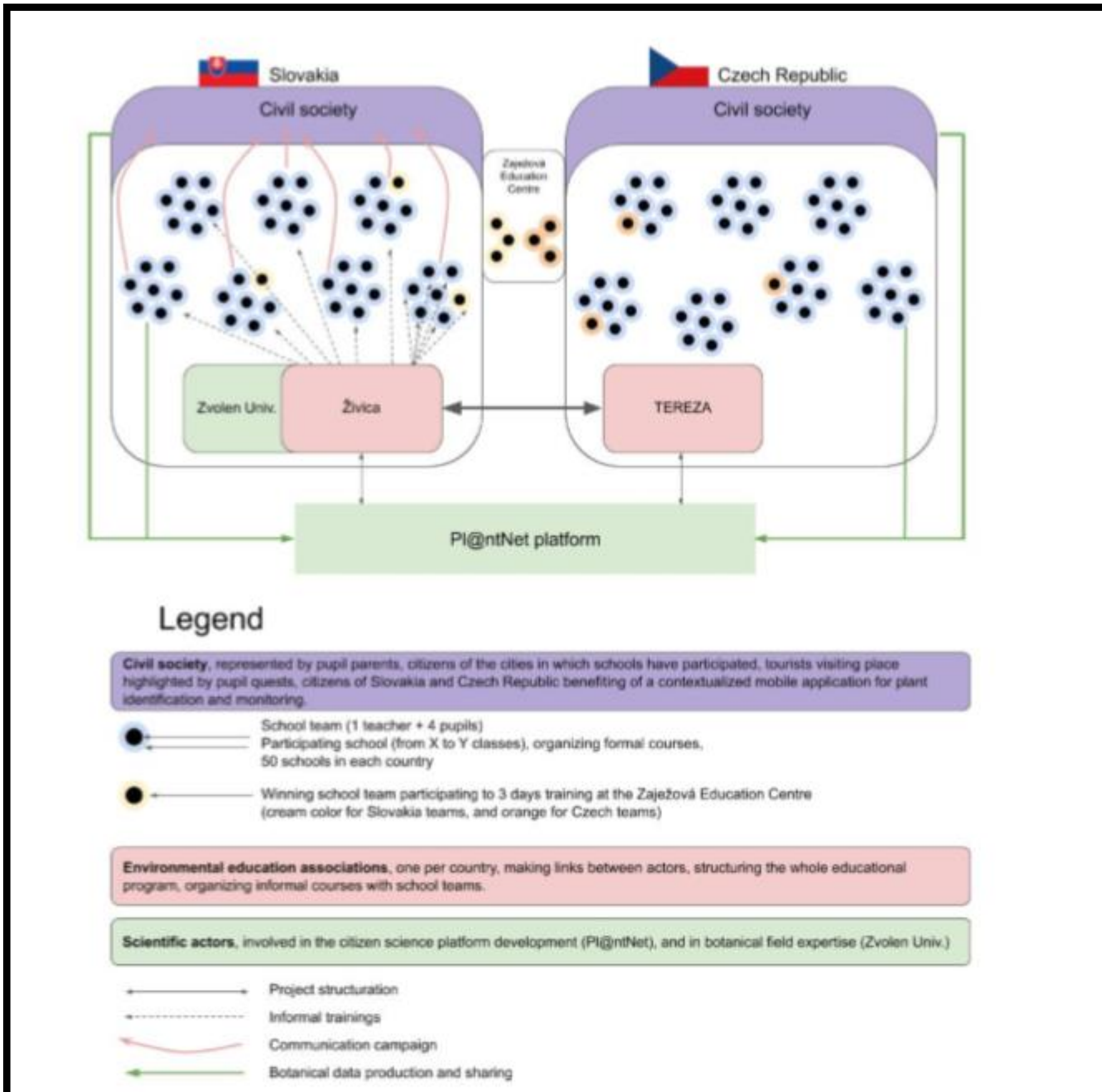

Figure 1 : Diagram view of the design of the two education programs.

Figure 1: The implementation design of the two educational programmes as a diagram

Teacher training

The project included a training programme for 50 teachers in each country. Training was conducted through 3-day seminars attended by groups of 25 teachers. Various methods of activation were used during the training program. The goals were for the teachers to experiment with the use of Pl@ntNet and to enhance their knowledge of urban biodiversity and its protection.

The University of Zvolen also took part in the training programme, communicating to the teachers its knowledge and experience in biodiversity and ensuring correct use of the Pl@ntNet platform.

Training of schools

A team was formed in each school comprising one reference teacher (who had been trained) and 4 selected students. A training seminar was organised for these teams in each country. 7 teams participated in each seminar. The teams were divided according to geographical location.

The goal was to promote the discovery of urban biodiversity. The training was aimed at familiarising the students with the Pl@ntNet platform so that they could collect observations from 5 plant species and identify the plants with the aid of the Pl@ntNet image recognition algorithm.

The students also had access to 4 tablets and to books to help them confirm their observations. At the end of the programme every team presented their observations to all participants in the form of poster. This would also train them in communication and prepare them for the next step of the programme. Through this training, the students:

a) discovered part of the urban flora

b) learnt to use the application

c) learnt to collaborate

d) were trained in methods of recording and communicating knowledge.

Transfer of knowledge within schools

The role of the trained students was twofold: On the one hand they would make the Pl@ntNet application known to the other students and on the other they would help to record a large number of correctly identified plant observations via Pl@ntNet. The Pl@ntNet app is free and available online for iPhones or Android, so it could be easily used by all students.

The target set for each school was, as an initial step, to record and share 50 observations in the first month. Observations: a) were not to be too easy to make, b) had to present as many species as possible that did not have a large presence on Pl@ntNet and c) had to present, if possible, rare and endemic plant species. Every school had a user account on Pl@ntNet so it was easy to trace all observations made.

Communicating the programme to the general public

In addition to dissemination within the school itself the school, groups conducted public awareness campaigns. Each school's information campaign differed according to the desired format and means available:

- leaflets
- stands with games based on observations
- actions with the general public
- journal articles
- radio broadcasts

- press releases
- T-shirt creation

The awareness campaigns were very often supported by local tourist agents/authorities with a view to informing also the tourists and getting them to participate in the actions.

Rewards and incentives for teams:

The 3 best teams from each country that had most successfully promoted the biodiversity of their city/town/village were rewarded with a 3-day educational visit to Zajezova Education Centre (http://www.centrumzajezova.sk/), to benefit from another interesting learning experience.

Strategy for continuing the project into the 2nd year

For the transition from the 1st to the 2nd year there was an assessment stage. At the end of the 1st year, in order to remain in the project, the schools had to submit a report. In the report they recorded their best observations, as well as the method used for communicating with the public. The quality of the report was the criterion for the evaluation of the schools and also for their continuation in the project. Otherwise new groups would be selected based on the same criteria and in the same way as at the start of the project.

The second year followed the same logic as the first but with the addition of one more goal:, an adventure/exploration to discover important monuments in the city. The exploration was based on a questionnaire that allowed students to perform a search in their city/town/village in order to discover its natural, historical and cultural heritage. The questionnaires for the exploration were structured in such a way that the participants had to reply to one question before being able to proceed to the next. These explorations took the form of a story inviting the participants to 'travel' and learn about their environment. The questions also included plant identification using Pl@ntNet.

At the end, participants arrived at some point of their city where ''treasure'' had been placed. Some routes had been designed to be followed on foot and others by bicycle.

These explorations were not only for students but for the general public too. They were also promoted by local tourist offices through posters or local websites.

Results

All those involved benefitted significantly and profited from having participated in the project:

- The research organisations gained greater geographical coverage as regards European flora
- The NGOs acquired a free, simple and useful tool for the observation, identification and recording of local flora
- The teachers, schools and students themselves gained access to, and learnt about a new way of using materials, tools and methods, as well as being trained in new activities

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