UNIVERSITY OF NOVA GORICA
SCHOOL OF ENGINEERING AND MANAGEMENT

STRENGTHENING ENERGY AND CLIMATE LITERACY WITH MICROLEARNING AND OPEN EDUCATIONAL RESOURCES

MASTER'S THESIS

Mojca Drevenšek

Mentor: Prof. dr. Tanja Urbančič

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TITLE

Strengthening Energy and Climate Literacy with Microlearning and Open Educational Resources

ABSTRACT

This master's thesis is motivated by the desire to actively engage Slovenian youth in co-creating our energy and climate future. The background is the growing interest in effective energy transition at the national, EU and global levels, and we specifically focus on the role of education in achieving this goal. The main problem we address is the need for improvement of energy- and climate-related non-formal youth education to increase their interest in the topic, and motivate their engagement in public discussions and the policy-making processes. To tackle this problem, we use the existing En-ROADS energy and climate interactive simulation tool and the accompanying online training series and complement it with new learning materials and learning activities, developed in our educational project. Our approach focuses on open education practices and the co-creation of open educational resources (OER), supported by microlearning via social media (Instagram). We develop a novel approach to address the problem by involving youth in a non-formal open educational process where they are invited to co-create the content and format of learning materials, decide on the technologies used, and affect the implementational process of the key learning activities. The main contributions of the thesis are the developed OERs, which can be adapted, reused or remixed by other stakeholders in the field of energy and climate education, and the recommendations for educators both in the field of energy and climate topics as well as in other fields, related to education for sustainable development. The main methodological finding of the thesis focuses on the importance of flexibility and adaptation of learning materials and activities according to the expressed interests and expectations of young learners. Their feedback needs to be carefully gathered and integrated into the implementation of the project.

KEYWORDS

energy literacy, climate literacy, open education, OER (open educational resources), microlearning, online learning, systems thinking

NASLOV

Krepitev energetske in podnebne pismenosti z mikroučenjem in odprtimi izobraževalnimi viri

IZVLEČEK

Magistrsko delo motivira želja po aktivnem vključevanju slovenske mladine v soustvarjanje naše energetske in podnebne prihodnosti. Ozadje za to je vse večje zanimanje za učinkovit energetski prehod na nacionalni, evropski in svetovni ravni, pri čemer se posebej osredotočamo na vlogo izobraževanja pri njegovem uresničevanju. Glavni problem, ki ga obravnavamo, je potreba po izboljšanju neformalnega energetsko-podnebnega izobraževanja mladih, da bi povečali njihovo zanimanje za to temo in spodbudili njihovo sodelovanje v javnih razpravah in procesih oblikovanja politik. Za rešitev tega problema smo uporabili obstoječe interaktivno energetsko-podnebno simulacijsko orodje En-ROADS ter spremljajočo serijo spletnih usposabljanj ter ju dopolnili in nadgradili z novimi učnimi gradivi in učnimi dejavnostmi, razvitimi v našem izobraževalnem projektu. Naš pristop je osredotočen na prakse odprtega izobraževanja in soustvarjanje odprtih izobraževalnih virov (OIV), podprtih z mikroučenjem prek družbenih medijev (Instagram). Razvili smo nov pristop k reševanju problema z vključevanjem mladih v neformalen odprt izobraževalni proces, kjer so povabljeni k soustvarjanju vsebin in formatov učnih gradiv, izboru tehnologij in načinu izvajanja učnih aktivnosti. Glavni prispevki magistrskega dela so razviti OIV, ki jih drugi deležniki v energetsko-podnebnem izobraževanju lahko ponovno uporabijo in po želji prilagodijo svojim potrebam. Oblikovali smo tudi priporočila izobraževalcem z energetsko-podnebnega področja in z drugih vsebinskih področij, povezanih z izobraževanjem za trajnostni razvoj. Osrednje metodološko spoznanje dela se osredotoča na pomen fleksibilnosti in prilagajanja učnih gradiv in aktivnosti izraženim interesom in pričakovanjem učeče mladine. Njihove povratne informacije je treba skrbno zbrati in vključiti v izvajanje projekta.

KLJUČNE BESEDE

energetska pismenost, podnebna pismenost, odprto izobraževanje, odprti izobraževalni viri (OIV), mikroučenje, spletno učenje, sistemsko razmišljanje

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1 INTRODUCTION

Our planet today faces many energy and climate issues (Roser, 2020; Alkaher, 2020; World Energy Outlook, 2021; Barbier, 2022; Bristow et al., 2022; World Energy Council, 2022; NASA, 2023; Helbling et al., 2023). The most critical among them are the following:

- Most of global energy production is still based on fossil fuels which produce greenhouse gas emissions and cause climate change.
- Hundreds of millions of people lack access to energy in general or to clean energy in specific.
- Climate change has caused increased heat, drought, and insect outbreaks and the warming climate has also caused a decline in water supplies, reduced agricultural yields, triggered heat-related health impacts in cities and forced people to migrate from their homes.

No universal and ultimate solution exists to solve the energy and climate crisis our society faces. Energy and climate-related issues have their roots deep in the strategic geopolitics of countries and continents (Bordoff and O'Sullivan, 2022). Therefore, political, economic as well as socio-cultural, technological and educational solutions are needed. Although educated citizens are not able to solve the energy and climate issues themselves entirely, it is important to address these issues by increasing awareness and understanding. This can lead to promoting and adopting sustainable practices that can help mitigate these problems. It lessens the lack of awareness and knowledge among citizens about the importance of the energy-climate transition and its impact on society, the economy and other critical aspects, and strengthens active citizenship which may contribute to a more informed and relevant dialogue between citizens and decision-makers (Alkaher, 2020; Rousell and Cutter-Mackenzie-Knowles, 2020; Barbier, 2022; Energy Literacy project, 2022a; Travers, 2023).

As Antje Danielson, MIT Energy Initiative's director of education claims in her interview (Travers, 2023), transitioning the entire global energy system from high carbon emissions to low or zero emissions is a global, huge and urgent problem. Besides the lack of understanding, there is an abundance of competing issues that

people in many countries are dealing with every day, e.g. poverty, personal health, unemployment, inflation, pandemics, housing, wars etc.

Therefore, educational initiatives are welcome that highlight the relationship between energy supply, climate change, and socio-economical issues like health, financial damage and quality of life in general. One of the ways to better address the energy, climate and related challenges of the future of our planet is through educational approaches that give the learners the knowledge and skills, as well as the courage to *be ready to act* and to share with their fellow citizens what they know and what they do. Namely, energy and climate change education require not only a *commitment to teach and learn* but a *commitment to act*. Research has shown that knowledge alone is insufficient for societies to change behaviour (Alkaher, 2020; Energy Literacy project, 2022a; Vaughter, 2016).

Thus, educational policymakers must move beyond education systems that simply transmit knowledge to ones that promote engagement in systemic change. A policy brief, created as an outcome of the project *Education for Sustainable Development* (Vaughter, 2016), focuses on the recommendation that in developing curriculums and learning outcomes related to climate change literacy, not just knowledge but *action competence* needs to be emphasized. Additionally, the recommendations focus on creating a learning environment in which students can practise action competence in responding to climate change.

Vaughter (2016) emphasizes that education policies must be more ambitious if they wish to modify the behaviour of citizens. He claims that formal education can teach youth the skills for responding to climate change but the challenge now is to shape non-formal climate change education. Non-formal energy and climate education, by bridging the cognitive domain with affective, behavioural and action-oriented characteristics, can empower citizens to make appropriate decisions regarding their energy use and the impacts they make on the climate. In this way, energy and climate literacy become essential tools to sensitize citizens to create and promote sustainable energy consumption habits (Martins et al., 2020) and to support *people-centred transitions* (World Energy Outlook, 2021), where younger and older citizens act as an *energy transition accelerator* (Travers, 2023) and are given a ‘voice’ and a ‘hand’ in redressing climate change (Rousell and Cutter-Mackenzie-Knowles, 2020).

In the context of these educational challenges, this **thesis aims to develop and implement a non-formal educational project in Slovenia, that will:**

- **raise awareness** about the importance of energy and climate issues and their connectedness with other issues like the economy, mobility, society, environment etc.,
- **stimulate public discussion** among the representatives of the young generation and other key stakeholders of the energy transition, and
- **encourage knowledge-based and fact-oriented youth activism** for an effective energy transition.

The focus on non-formal education was chosen since the processes of accepting and updating official energy and climate policies are in progress and it is important to act quickly. Although having formal education involved can importantly increase outreach and positive influence, and this is in our view something to be done in the future, it may take longer to prepare everything needed in the framework of formal education and to reach the point of sufficiently representative examples. We see this non-formal educational project as a pilot that can later be evaluated and adapted for more formal educational settings.

Our non-formal approach encompassed developing, implementing and evaluating an educational project for strengthening the energy and climate literacy of Slovenian youth, based on an existing, freely available and globally recognized energy and climate online simulation tool, namely the En-ROADS (Rooney-Varga et al., 2019; Nuccitelli, 2020). By strengthening their energy and climate literacy with complementary new learning materials and learning activities, we want to empower youth to actively engage in the energy transition.

We mention the specifics of the situation among Slovenian youth in section 4.1.3, and these specifics were taken into account when deciding on the educational approach. However, due to the open nature of the learning materials as well as the open process of planning and implementing the learning activities, the project's results, if appropriately adapted, can be used also in other educational projects with similar or other topical contexts as well as in geographically different environments. Before that,

the specifics of youth in that particular situation will have to be investigated and taken into consideration when deciding about the implementation in their context.

The project was implemented under the umbrella of the ENLITE Society for strengthening energy literacy, a Slovenian non-profit and non-governmental organisation, registered in 2015 and working in the public interest in the field of energy. The author of this thesis is the President of ENLITE and is in charge of the planning, implementation and evaluation of Society's key activities.

Due to the project's complexity, a broader team and technical infrastructure, including communications channels and project administration were needed and provided by the ENLITE Society. While the author of this master's thesis was the project's conceptual and strategic leader and main coordinator of all project activities, some other members of the ENLITE development and expert teams[1] have also been involved in the planning and/or implementation of the learning materials and learning activities, as presented in section 6, where their specific roles are fully described (see Table 11 for details). All other contributions of this thesis as well as the thesis itself have been conceptualized and implemented by the author.

In section 2 of the thesis, we explain the importance of energy and climate literacy and their societal benefits. In section 3, we present the suggested approach and methodology, focusing on our target group of learners, the systems thinking perspective, the open approach towards education and the creation of learning materials, supported by microlearning via social media.

In sections 4, 5 and 6 we present the **key steps in our project's evolution**:

- Firstly, section 4 explores the **development phase**, defining the strategic, pedagogical and technological aspects.
- Secondly, section 5 presents the **project implementation** through three main phases, namely the initial implementation phase, the feedback-gathering phase and the adapted implementation phase.

[1] All team members are listed here: https://www.en-lite.si/ekipa

- Thirdly, section 6 presents the **project results**: (1) the implemented learning materials, (2) methodological findings, (3) topical contributions, applicable to other energy and climate projects, (4) recommendations for OE practitioners and OER developers in energy and climate, as well as in other fields of education for sustainable development, and (5) a plan of possible project future developments.

Section 7 describes the **conclusions**, focusing on what was done and achieved, with what significance and what could be done in the future.

2 THE IMPORTANCE OF ENERGY AND CLIMATE LITERACY

In this thesis, we will follow the definitions of energy and climate literacy as given below. These are directly connected to our suggested approach and methodology, as presented in section 3.

2.1 Definitions

In its *Framework for Energy Education*, the U. S. Department of Energy (2017) defines *energy literacy* as an understanding of the nature and role of energy in the world and daily lives accompanied by the ability to apply this understanding to answer questions and solve problems. An energy-literate person can trace energy flows and think in terms of energy systems, knows how much energy they use, for what purpose, and where the energy comes from, can assess the credibility of information about energy, can communicate about energy and energy use in meaningful ways, and is able to make informed energy use decisions based on an understanding of impacts and consequences.

Closely related to energy literacy is *climate literacy* (U.S. Global Change Research Program, 2009), which encompasses the essential educational principles of climate science, supported by fundamental concepts analogous to those underlying science literacy benchmarks. Climate science literacy is an understanding of our influence on climate and climate's influence on us and society at large. A climate-literate person understands the essential principles of Earth's climate system, knows how to assess scientifically verified information about climate, communicates about climate and climate change in a meaningful way, and is able to make informed and responsible decisions about actions that may affect the climate.

2.2 Societal benefits of energy and climate literacy

Decisions that affect the Earth's climate must be made with an understanding of the complex interconnections among the physical and biological components of the Earth's system and with the understanding of the consequences of such decisions on social, economic, and cultural systems (U.S. Global Change Research Program, 2009;

Martins et al. 2020; Alkaher, 2020; Barbier, 2022; Travers, 2023; United Nations, n.d.).

By being energy and climate literate, citizens can help reduce vulnerability to the impacts of insecure energy supply and climate change by integrating their knowledge into their everyday life decisions and practices, similar to the concept of environmental citizenship (Drevensek, 2006). A better understanding of energy and climate issues by individual citizens and communities can bring benefits to the micro, meso, and macro societal level.

At the **micro** level, individuals who are energy and climate literate can make informed decisions about their energy use and consumption. They can reduce their carbon footprint by using energy-efficient appliances, reducing their use of fossil fuels, and choosing renewable energy sources. This can result in cost savings for the individual and a reduction in greenhouse gas emissions.

At the **meso** level, communities and organizations that are energy and climate literate can implement policies and practices that promote sustainable energy use and reduce greenhouse gas emissions. This can include initiatives such as community renewable energy projects, green building standards, and public transportation systems (Newcomers, 2021). These actions can improve the health and well-being of community members by reducing air pollution and promoting active transportation.

At the **macro** level, societies that are energy and climate literate can implement policies and practices that promote sustainable energy use and reduce greenhouse gas emissions on a larger scale. This can include initiatives such as transitioning to low-carbon energy sources, implementing carbon pricing mechanisms, and promoting sustainable land use practices. These actions can help mitigate the impacts of climate change, improve public health, and promote economic development.

In general, **energy and climate literacy** can:

- lead to more informed decisions,
- help individuals and organizations save money,
- lead to sustainable energy use,
- reduce environmental risks and negative impacts,
- promote economic development and
- improve the security of a nation.

Without a basic understanding of energy, energy sources, generation, use, and conservation strategies, individuals and communities cannot make informed decisions on topics ranging from smart energy use at home and sustainable consumer choices to their engagement and public participation in national and international energy policy-making processes. Current national and global issues such as the energy supply and climate change highlight the need for more and better energy education (Atkin and Rose, 2019) to improve this understanding.

3 SUGGESTED APPROACH AND METHODOLOGY

3.1 Target audience: youth

Shifting the energy sector toward a sustainable state requires an urgent systemic change where all societal, public and private stakeholders need to synergise their efforts for a successful transition. Youth are an **especially important stakeholder in the energy and climate transition** for at least two reasons:

- Firstly, they are **the future leaders and decision-makers** of our society (Kalossaka et al., 2022; EYEN, 2022; Stockemer and Sundström, 2022; Stockemer and Sundström, 2023).

- Secondly, **today's decisions related to energy supply and climate change will affect the next generations** in the following decades (Grounded, 2020).

Education can encourage young people to change their attitudes and behaviour towards energy use and climate change. It also helps them to develop critical thinking (Vincent-Lancrin et al., 2019) and make informed decisions in different dimensions of their lives, e.g. related to their studying or employment, financial and housing issues, health, mobility etc. (U.S. Global Change Research Program, 2009; U.S. Department of Energy, 2017; Rousell and Cutter-Mackenzie-Knowles, 2020; World Energy Outlook, 2021; Cannas et al., 2022). By being energy and climate literate, young people can help spread their knowledge, attitudes, skills and behaviour among their peers, family members and other communities they interact with.

As Kalossaka and coauthors (2022) claim, and this is indirectly supported also by Student Energy's *Youth Impact Framework* and its *Policy Brief* (Student Energy, 2023a and 2023b), currently, youth has a huge potential to play an active role in the energy transition and related policy-making processes. They have the power in their hands to be the best-equipped generation to drive this change. However, this requires complementary skills, connections, confidence and knowledge necessary to accelerate the energy transition.

The European Youth Energy Network (EYEN, 2022; European Youth Forum, 2023) has the mission to reshape youth engagement, streamline the voice of young people and create a space for them to act: 'The ongoing shift in our energy paradigm, where conventional procedures and solutions are no longer enough to face the current challenges, dictates the need for a transgenerational consensus on the future of the energy sector /…/ The inclusion of youth in the decision-making processes is crucial to ensure ownership of the implemented solutions /.../ It is vital to define a framework which will enable a broader and more diverse group of young people to impact the energy sector, by bringing youth closer to key public and private stakeholders to co-design the future of our energy system.' (EYEN, 2022, p. 4).

As one of the key pillars for active youth engagement in the energy transition, EYEN (2022) defines *Knowledge Transfer and Education*, by suggesting the following five **proposals related to youth engagement**:

- Energy transition workshops for high school students,
- Green skills for educators,
- Compel universities to provide SDGs (Sustainable Development Goals) and ET (Energy Transition) courses,
- Youth NEETs (Not in Employment, Education or Training) just transition training,
- One-stop-shop for youth engagement.

3.2 The systems thinking perspective in energy and climate education

Among the key required complementary knowledge and skills for youth to successfully accelerate the energy transition are the understanding of the complex interconnections between the physical and biological components of the Earth system, and the social, economic, and cultural decisions. By understanding these complex systems and their interconnections, young individuals can make and promote informed decisions about energy use and climate change mitigation.

As Rooney-Varga and coauthors (2019) claim, educational opportunities are needed that take a *high-level, holistic view* of the climate-energy system while also enabling the exploration of particular aspects or perspectives on it. The *system thinking perspective* can enable the high-level, holistic view while the more particular exploration of specific aspects or perspectives needs to be covered in another way, e.g. with a microlearning approach (as discussed in section 3.4).

System thinking is a broad and multi-disciplinary approach to complex problem-solving with many benefits confirmed in the educational domain (Fisher, 2007; Groff, 2013; Fischer et al. 2015). Many different definitions of systems thinking can be found throughout the systems community, and efforts have been made by researchers to propose a definition of systems thinking for use in a variety of disciplines. Arnold and Wade (2015) have focussed on developing a definition with particular emphasis on the development and assessment of systems thinking educational efforts. They define systems thinking as a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviours, and devising modifications to them in order to produce desired effects. These skills work together as a system. As they emphasize, systems thinking is widely believed to be critical in handling the complexity facing the world in the coming decades; however, it still resides in the educational margins. Many of the challenges we face as a society require complex solutions that are sustainable, cross disciplinary boundaries and take into account multiple perspectives, which stimulates *critical thinking* (Heinberg, 2018; School of Education Online, 2020; Hoffmann et al., 2022; Birt, 2023; Scherer, n. d.). The connection between critical thinking and systems thinking is further explored from the perspective of *critical literacy* as a condition for systems thinking in practice (Reynolds, 2011).

For educational and awareness-raising purposes of the systems thinking perspective, interactive online tools have been shown effective, e.g. the Climate Action Simulation which combines an interactive computer model, En-ROADS, with a role-play in which participants make decisions about energy and climate policy, and at the same time learn about the dynamics of the climate and energy systems. As Rooney-Varga and coauthors claim (2020), this enables people to learn for themselves about climate change and the energy transition needed to mitigate it. In doing so, it creates an

immersive, social learning experience that is not proscriptive, but instead creates a risk- and cost-free environment in which participants learn and generate innovative, systemic solutions, through the experience of systemic change.

Similarly but in the context of nature reconnection, Ives et al. (2018) adopt a *social-ecological systems perspective* and draw upon the emerging and innovative concept of leverage points as the places in complex systems to intervene to generate change. They explore examples of how actions to reconnect people with nature can help transform society towards sustainability and define **different types of nature connections**:

- material (consumption of goods/materials from nature),
- experiential (direct interaction with natural environments, e.g. parks, forests),
- cognitive (knowledge or awareness of the environment and attitudes/values towards nature),
- emotional (feelings of attachment to or empathy towards nature) and
- philosophical (perspective of world view on what nature is, why it matters, and how humans ought to interact with it),

which can all be **applied to the educational and awareness-raising practices related to strengthening energy and climate literacy**.

Also, in the context of climate change, Bristow and coauthors (2022) explore both the cognitive and emotional foundations of nature (re)connection. They focus on mindfulness as a mode of awareness with particular qualities, and compassion, a motivational quality constitutive of flourishing societies. They do not claim that current practices and policy approaches to energy and climate change are wrong and the interventions outlined in their work are not offered as an alternative solution. Their aim is rather to activate more integrated approaches that link systems change with behavioural, cultural, and psychological considerations, as this can lead to the most lasting impact.

3.3 Open education and OER

A lot of communication and collaboration is needed both between the learners as well as in their relation to the experts, policy-makers and other key stakeholders of the energy transition. This relates also to Rooney-Varga and coauthors' (2019) claim about the urgency of a high-level, holistic view of the climate-energy system, and the importance of sharing information and learning about the dynamics of this system by simulating decisions in many different areas, e.g. energy supply; transport; buildings and industry; population and economic growth; land, food and industry emissions; and carbon removal.

Regarding these challenges, there are many benefits that *open education* (OE) and *open educational resources* (OER) can bring into play. When discussing the attributes of *open pedagogy* as a model for implementing OE practices and creating OER, Hegarty (2015) emphasizes the principles of openness that can contribute to the effectiveness of the systems thinking perspective in strengthening energy and climate literacy. Among these **principles of openness** are:

- collaboration and sharing of information;
- connected communication about learning and teaching; and
- collectivity to grow knowledge and resources.

These principles of openness are the main reasons why we decided to plan and implement our educational project based on the principles of OE and OER. Namely, the foundations of open education and OER emphasize the value of education as a public good which is accessible to everyone (Bregar et al., 2020). In general, open education is understood as a philosophy about the way people should produce, share, and build on knowledge.

Proponents of open education believe everyone in the world should have access to high-quality educational experiences and resources, and they work to eliminate barriers to this goal (Luo et al., 2019; Grimaldi et al. 2019, Opensource.com, n.d.), while other researchers focus more generally of the attributes and benefits of open pedagogy and OER (Hegarty, 2015; Inamorato dos Santos and et al., 2017; UNESCO,

2019), on the development of OE and/or OER policies (Miao et al., 2019; Mengual-Andres and Payà, 2019; Atenas et al., 2020) and specifically on the benefits of open science and the sharing of scientific advancements (UNESCO, n. d.; Sanjana, 2021; Drevenšek and Tajnšek, 2023).

For achieving the main aims of this thesis, which relate to raising awareness about the importance of energy and climate issues and their connectedness with other issues like the economy, mobility, society, environment etc., stimulating public discussion and encouraging youth activism for an effective energy transition, it is important to understand that different *dimensions of openness* exist and need to be taken into consideration when planning OE activities and creating OER.

Woert et al. (2015) emphasize how *connecting various forms of openness* adds to the value proposition. They claim that in addition to open education, open access, open source software and open innovation, the open movement has also developed other *varieties of openness*. Although many types of 'openness' exist, they are all based on the same basic principles. The connection of various 'open' areas can provide considerable added value, enabling innovation, improvement of quality, expansion of knowledge domains and development of new insights.

One practical example of presenting different dimensions of open teaching practices is offered by García-Holgado et al. (2020) as part of the OpenGame project where 24 real-life open teaching practices are explored that respond to eight main challenges educators face today and that can be tackled through open approaches. Based on this, an *Open Education Competences Framework* is proposed, connecting challenges, practices and needed competencies.

Several benefits of OE and OER are discussed in the literature (e.g. Grimaldi et al., 2019; Mengual-Andres and Payà, 2018; Luo et al., 2019; UNESCO, n.d.), and some of them can be transferred to the challenge of supporting the systems thinking perspective in strengthening energy and climate literacy. One of the possibilities for discussing the benefits of OE and OER for strengthening systems thinking is to focus on the benefit of providing learners with access to a wider range of educational resources from different disciplines and to encourage collaboration through the reuse and remix of OER among social sciences, natural sciences and engineering students or

experts. In this way, the transfer of knowledge and collaboration among learners and/or experts from different fields is encouraged which helps them develop higher-order thinking skills to understand and address complex, interdisciplinary, real-world problems. But this is only one aspect of the benefits which is highly important but not sufficient.

It needs to be taken into consideration that in tackling complex issues and supporting systems thinking, a high-level perspective can be seen as only one side of the coin which needs to be complemented by a *micro-level exploration*. As Rooney-Varga and coauthors claim (2019), educational opportunities are needed to also enable the more micro-level exploration of particular aspects of the topics at hand. In our opinion, the microlearning approach is a suitable solution to approach this other side of the coin.

3.4 Microlearning via social media to design and promote OER

While there is no universal definition of microlearning, several authors offer functional definitions that are relevant to the aims of this thesis. As put by Alqurashi (2017), microlearning refers to a learning strategy designed using a series of short learning content and short activities that makes a mini course. It is also called bite-sized learning because it utilizes small, well-planned, meaningful bite-sized chunks of units or activities (Bregar et al., 2020).

From the **advantages of microlearning** (Giurgiu, 2017; Bregar et al., 2020, Lee et al., 2021; Taylor and Hung, 2022), the following two are the most important in our case:

- **It reduces cognitive load** by eliminating content that is not necessary for achieving the learning objectives.
- **It encourages independent learning** by offering the learners to follow their preferred learning dynamics.

Besides the advantages, there are also **disadvantages of the microlearning approach**, among them is **lack of depth**. Because microlearning is designed to be brief and concise, it may not always provide enough depth on a particular topic (Corbeil et al. (ed.), 2021).

This presents a huge challenge for the specifics of our educational project that needs to reconcile between the need for high-level, holistic, systems thinking view and the particular, bite-sized aspects, delivered by the microlearning approach.

In the context of the aims of this thesis, the microlearning approach is especially important taking into consideration the target audience – youth, as it addresses their style of learning and might significantly increase their motivation for learning. The applicability of the microlearning concept is supported by studies showing the benefits of offering knowledge divided into smaller chunks or shorter learning units (Bradbury, 2016; Taylor and Hung, 2022; Lee et al., 2021).

Alqurashi (2017) discusses content, pedagogy and technology as the **main three elements of creating an effective microlearning environment**:

- The first element in creating a microlearning environment is **content**. It is necessary to identify areas in the curriculum appropriate for the microlearning approach. To choose appropriate content for microlearning, we have to consider at least the following questions:

    - What do I want my learners to know and understand to move forward?
    - What is worth my learners' time?
    - What are the most common mistakes learners make that affect their learning about energy and climate topics? What are the most common myths related to these topics?
    - What topics can be broken down into small pieces?
    - What are the 3 or 4 most important things I want my learners to learn?

- Once the content is identified, it is essential to think about the **pedagogical aspects** and the instructional design model (discussed in section 4.2) where the microlearning elements will be embedded.

- From the third, **technological perspective** it is important to think about the appropriate choice of technology to support the learning process. The potential of social media needs to be taken into consideration, especially if the target audience is youth, as in our educational project. Namely, the rise of social media has changed people's information-seeking and consuming behaviours, which gears their preference toward single, discrete topics that are presented in short duration to meet their moment of learning need (Rothkrantz, 2016; Trowbridge et al., 2017). Additionally, the reports and research on millennium generations, ranging from elementary school students to university students show that youth prefers learning from YouTube videos over traditional textbooks or even TV videos (Taylor and Hung, 2022; Bradbury, 2016).

4 DEVELOPING AN OPEN EDUCATIONAL PROJECT

Based on the suggested approach and methodology, presented in section 3, we decided to develop and implement an educational project, targeting youth (related to the findings from section 3.1) and integrating *systems thinking* (section 3.2), *open education and OER* (section 3.3) and *microlearning* (section 3.4) methodological approaches.

In the following sections, the open approach to our educational project planning, implementation and future ambitions is presented. First, the **project development phase** is described (section 4), taking into consideration the key aspects of educational projects, namely the strategic, pedagogical and technological aspects. Based on these, the key **three implementational phases of the project** are presented in section 5, namely:

- **the initial implementation phase**,
- **the learners' feedback-gathering phase**,
- **the adapted implementation phase**.

This is followed by describing project results, methodological findings, topical contributions, recommendations, and the project's future development (section 6).

4.1 Strategic aspects

To appropriately plan our open educational project from the content perspective, we have taken into consideration the following **strategic inputs**:

- the **status and challenges of energy and climate goals on the EU level**,
- the **energy supply situation and future challenges in Slovenia**,
- the **energy literacy level in Slovenia**, especially among young adults.

We briefly describe the key strategic inputs that have impacted the planning of our educational project.

4.1.1 European and climate goals at the EU level

We have researched the current energy and climate issues facing the EU in general, and Slovenia in specific (Roser, 2020). The EU has set ambitious goals to combat climate change (European Commission, n. d.; Fit For 55, n. d.). Under the European climate law, EU countries must cut greenhouse gas emissions by at least 55 % by 2030 and their goal is to make the EU climate-neutral by 2050. The European Council underlined that the transition to climate neutrality brings significant opportunities for economic growth, markets and jobs, technological development, and more. The European Commission has been asked to take forward work on the European Green Deal. Deriving from the European Green Deal, the Fit for 55 package is a set of proposals to revise and update EU legislation and to put in place new initiatives to ensure that EU policies are in line with the climate goals agreed by the Council and the European Parliament. The name *Fit for 55* refers to the EU's target of reducing net greenhouse gas emissions by at least 55 % by 2030.

The climate neutrality goal is closely linked to the future of the energy supply for Europe. Namely, the Fit for 55 package includes several measures that will impact the future of the EU energy supply. For example, the Council has agreed on higher targets for renewables and energy efficiency. Energy production and use account for 75 % of the EU's emissions, and the more ambitious targets will be a significant contribution towards meeting the EU's overall goal of reducing net greenhouse gas emissions by at least 55 % by 2030 compared to the 1990 levels.

The Council agreed to set a binding EU-level target of 40 % of energy from renewable sources in the overall energy mix by 2030, up from the current target of at least 32 %. Member states will need to increase their national contributions set in their integrated national energy and climate plans (NECPs), to be updated in 2023 and 2024, to collectively achieve the new target.

Based on these findings, the following are some of the **key topics affecting the strategic aspects of our educational project**:

- EU climate goals and the concept of climate neutrality,
- the connection between climate goals and energy supply goals,
- energy sources (renewables, low-carbon energy sources) and energy efficiency in households, industry, public sector,
- the regulatory setting, national energy and climate plans, and the role of citizens to collectively achieve the targets.

4.1.2 Energy supply situation and future challenges in Slovenia

According to the International Atomic Energy Agency (IAEA, 2022), Slovenia imported half of its primary energy demand and all of its oil and natural gas in 2020. The country's energy supply consisted of around 29 % oil, 25 % nuclear, 16 % coal, 11 % natural gas, 11 % combustible renewables and waste, 6 % hydro and 2 % other renewables (solar and wind). Energy dependency as of 2020 stood at 44.5 %.

The World Energy Council (WEC) assesses a country's energy sector according to three key dimensions: energy security, energy equity, and environmental sustainability (World Energy Council, 2022). The latest WEC Energy Trilemma Index for 2022 has ranked Slovenia as 9th globally with an overall grade slightly improved compared to Trilemma Index Report 2021 (EZS, 2022).

Here are **Slovenia's ratings for each dimension**:

- the first dimension - energy security: 69.8 out of 100 points (Canada remains in first place with 76.9 points),
- the second dimension - energy equity: 94.7 points (Luxembourg is in first place with 100 points),
- the third dimension - environmental sustainability: 76 points (Switzerland remains in first place with 87.5 points).

Slovenia remains a strong Energy Trilemma performer, positioned among the top 25 % of countries in two dimensions. In particular, Slovenia's energy equity index rose

by 11 points compared to the year 2021 due to the implementation of measures to protect the most vulnerable consumers that have been affected by rising energy prices in several EU Member States, including Slovenia. There is still room for improvement in the sustainability dimension of the Trilemma index, although there has been steady growth in this area over the past 20 years due to declining emissions from the energy sector, decreasing CO_2 intensity and air pollution.

The Slovenian results in the energy trilemma, related to energy security, energy equity, and environmental sustainability, and their connection to the outlook for future energy supply in Slovenia, present the strategic input for the content focus of our open educational project, the learning materials and learning activities, with a special content focus being developed related to our primary target group, the youth.

Additionally, the issues related to the updating of the NECP (the Integrated National Energy and Climate Plan) are taken into consideration. NECP is a ten-year integrated document mandated by the EU to each of its member states in order for the EU to meet its overall climate targets, and it is one of Slovenia's key steps towards a climate-neutral Slovenia and EU by 2050 (Vlada RS, 2020; Vlada RS, 2023). A broad public consultation has been implemented during the preparations of the updated NECP in 2022 and 2023 (Institut "Jožef Stefan", 2023). The key suggestions from the public consultation, related to energy and climate education and awareness raising, contributed also by the author of this thesis in the name of the ENLITE Society, are indirectly integrated into the design of the educational project.

4.1.3 Energy literacy in Slovenia among young adults

As part of the Erasmus+ project called EL-practice (Energy Literacy practice), a survey was conducted in six European partner countries, including Slovenia (Energy Literacy project, 2022a and 2022b). It has shown that general awareness about energy sustainability among young Slovenian adults, aged 29 to 39, is high. The survey authors emphasize that young adults have a very good understanding of issues related to energy, understand the consequences of their actions and are conscious of ways they should evolve their daily energy habits. This stems partially from their upbringing and partially from media and other information consumed daily through various channels.

They are aware of the ways they can improve their sustainable behaviours, but as the authors conclude, more can be done, providing awareness, ideas, and solutions to some of the missing pieces in their daily lives and sustainable energy choices. (Energy Literacy Project, 2022b).

For example, as the results of the abovementioned survey show, young people are not particularly involved in following the global energy-related discussion and researching literature, and they are not interested in being familiarized with EU directives and policies. Therefore, it is important to bring these topics closer to them and provide them with relevant and understandable information.

The **main knowledge gaps of young Slovenian adults**, as identified by the EL-practice project (Energy Literacy Project, 2022a and 2022b) and other studies (Care4Climate, 2021) are the following:

- Lack of knowledge **about EU and national directives, policies and strategies** that are influencing our lives as energy consumers;
- Lack of **interest and awareness about global discussions and trends** regarding energy production and consumption;
- Lack of **knowledge about national incentives** for energy-efficient renovations;
- Lack of **practical knowledge about how to calculate return on investment as well as financial and energy savings** that can be achieved by energy-efficient investments.

We have integrated these findings as strategic inputs for the content and structure of our educational project.

4.2 Pedagogical aspects

Pedagogical aspects are of crucial importance for the educational project design. The theoretical framework for defining these aspects is provided by the *instructional design theory* (Bregar et al., 2020) and it helps us develop today's educational programmes for different contexts so that the learning goals are achieved (Boarta, 2021).

4.2.1 Educational needs analysis

One of the key inputs for the instructional design model is the *educational needs analysis*. According to the *Dick and Carey model* (Bregar et al., 2020), we have **performed the educational needs analysis in the following three steps**:

- Step 1: Defining the objectives of the educational project
- Step 2: Analysis of content and activities
- Step 3: Learners' analysis

Each of the steps is briefly described below.

Step 1: Defining the objectives of the educational project

In general, the objective of our educational project is to **increase the knowledge and interest** of youth related to energy, climate and related topics. Based on this knowledge and interest, they will be **better equipped to take part in co-creating decisions** related to our energy and climate future.

Specifically, the project aims to **encourage and enable representatives of youth to confidently and knowledgeably take part in public discussions** with the experts, policymakers and decision-makers focussing on our future energy supply. The project is designed in a non-formal educational setting.

Step 2: Analysis of content and activities

The key topics which need to be covered in the educational project, are related to the *essential principles and fundamental concepts of energy literacy*, presented in section 2, and to the strategic aspects of the project, presented in section 4.1. An **interdisciplinary approach to teaching and learning about energy**, climate and related topics is taken **which will equip the learners with data and knowledge to**:

- be able to trace energy flows and think in terms of energy systems;
- know how much energy they use, for what purpose, and where the energy comes from;

- be able to assess the credibility of information about energy, climate and related topics;
- communicate about energy and energy use in meaningful ways; and
- make informed energy use decisions based on an understanding of impacts and consequences.

There are some good examples of specific activities in Slovenia related to strengthening energy literacy. For example, at the city level, Novo mesto has implemented a programme of consultation, education and communication activities to increase energy literacy, related to the successful implementation of energy efficiency and low-carbon energy measures. Additionally, several initiatives to strengthen energy literacy in Slovenia have been organised through events and non-formal educational projects. However, the need to enhance energy literacy has been recognised especially by professionals from different fields, decision-makers, young people, teachers and professors, and the media. The desire to improve energy literacy is perceived also at the universities among natural and social sciences students (Energy Literacy Project, 2022a). We integrate these findings into the design of our project by focusing on non-formal education and awareness raising among youth by closing the identified knowledge gaps. Simultaneously we also develop the potential future ambition to bring our learning materials and learning activities closer to formal education.

Step 3: Learners' analysis

The **primary target group** of the educational project are **young adults, aged 18 to 35 years**, who are either:

- **representatives of Slovenian youth organisations or movements**, active in the fields of energy, environment, climate change or connected topics, or whose mission is to empower youth in general;
- **undergraduate or postgraduate students** of natural science, technical/engineering or social sciences and humanities, interested in energy and climate topics;
- **individuals (young citizens)**, generally interested in energy and climate topics.

The **secondary target group** are teachers, professors, and mentors, as well as policymakers and decision-makers in the fields of energy and climate issues.

As our project is based on *open* educational principles, all other interested citizens are welcome to join the learning activities and make use of the learning materials.

We analysed the following **features of our primary target group of learners** and identified them as follows:

- **age**: from 18 to 35 years;
- **educational background**: students at least on the undergraduate level or higher;
- **geographical background**: from all over Slovenia but mainly from the central and north-eastern regions;
- **previous knowledge** about energy and climate topics: medium to high;
- **interest** in the energy and climate topics: high;
- **organisational background**: most are active members of youth organisations or movements. These are either topically oriented towards energy, climate change, environment or sustainability issues or are covering horizontal youth-related topics, e.g. youth empowerment. Some learners are not active in activist organisations but are interested as students;
- **time, available for learning**: very limited, as they are all active in their organisations or at universities. Therefore, the energy literacy topics need to focus as precisely as possible on their existing or growing interests, needs and expectations;
- **digital literacy**, including their access to the internet, social media use etc.: high to extremely high, most are also active social media users.

4.2.2 The main aim of the educational project

The main aim of the educational project is to **enable stronger and more informed engagement of Slovenian youth** (as individuals and/or as representatives of active youth organisations and movements) **in the energy and climate-related decision-making processes**, supporting Slovenia's transition to a low-carbon economy and society.

Through the implementation of this educational project, **young adults in Slovenia will become informed, competent, confident and empowered stakeholders in the participatory processes** of designing realistic and responsible future energy and climate scenarios for Slovenia.

4.2.3 Project's instructional design

To develop the instructional design for an educational project, an instructional designer applies systematic methodology, which is rooted in instructional models and theories. It addresses the question of how to design the educational programme for different contexts so that the programme's learning objectives and specific learning goals are achieved (Bregar et al, 2020; Boarta, 2021).

The **instructional design** for our educational project **follows a process of**:

- **determining the instructional design model**,
- **choosing the main learning theories**, and
- **defining the key competencies and learning objectives**.

Instructional design model

The first step towards the instructional design application is made by choosing the *instructional design model*. The ***A***nalyse, ***D***esign, ***D***evelop, ***I***mplement, ***E***valuate - ***ADDIE*** model was chosen for our project as one of the most established and generic models for instructional design, linking inputs, processes and outputs. However, we have only used the ADDIE model as a basis, and have then integrated it with some of the key elements from the more flexible and adaptable AGILE (Align, Get set, Iterate

& Implement, Leverage, Evaluate) model. This is in line with the project's implementational aspects, presented in section 5, which allowed for rapid development of new content, and learners' selection of related technologies and applications. This enabled changes in the project's content, learning materials and learning activities, and the development of new capabilities in learners based on their expressed interests and expectations. Table 1 summarizes the key elements of the ADDIE and AGILE instructional design models and emphasises the specific features which made both of the models useful for our educational project (adapted from Bregar, 2020).

Table 1: Key features of the instructional design models for our project

ADDIE Model	**AGILE Model**
Analyse	Align
Design	Get set
Develop	Iterate & implement
Implement	Leverage
Evaluate	Evaluate
Focus on content: taking the existing En-ROADS simulation tool and its online training course as a starting point for the development of the open online course content and its microlearning support	**Learner-centred**: active engagement of learners through interactive workshop discussions, offering them the possibility to co-create content and impact the selection of format and technology
Linearity: progression in stages from initial youth workshops through online course and microlearning creation, implementation and evaluation	**Non-linearity**: flexible approach, allowing for ongoing project changing and upgrading

Despite the important elements of the AGILE model, allowing for flexibility and learners' collaboration in the co-creation of the educational project, we take the ADDIE model as a basis for explaining the different *dimensions of openness*, used in the educational project. The key dimensions are presented in Table 2.

Table 2: Key dimensions of openness, related to the ADDIE model

Stage in the ADDIE model	**The key activity in our educational project, related to this stage**	**Elements of openness, integrated into this activity**
Analyse	En-ROADS tool and training Youth energy and climate workshops	Through open discussions in the workshops, the interests of learners are identified and their ideas/suggestions gathered
Design	Design of online course and microlearning content	Co-creation of the topics for the video lectures and youth educational videos, and selection of formats/technology for the online course and the microlearning channel (together with youth representatives and a multidisciplinary experts group)
Develop	Co-creation of OER	Active engagement of youth in the implementation of educational videos by posing questions and sharing their energy and climate-related suggestions/solutions
Implement	Launch and promotion of the youth educational project	Youth collaboration in sharing of educational resources, and their motivation for reusing,

		revising and remixing the OER in their future activities
Evaluate	Youth energy and climate training	During a 3-day energy and climate training, opinions and suggestions of participants were gathered related to the implementation of the project and their future aspirations

Learning theories

Learning theories are the basis for designing educational projects (Bregar et al., 2020). They help us choose the most suitable learning methods and make decisions regarding the learning materials and learning activities.

Our open educational project is based on a **combination of three learning theories, which emphasize the following**:

- **theory of constructivism**, where learning is conceived as a social, collaborative process, stimulating communication of learners with their teacher and among themselves;
- **theory of community of inquiry** (CoI), which takes into consideration the cognitive and social/collaborative aspect of learning; and
- **heutagogy theory**, which emphasizes the importance of self-directed learning, independent from the teacher.

Table 3 summarizes the key features of each of the chosen three learning theories that are relevant to the educational project.

Table 3: Learning theories, applied to the educational project

Learning theory	**Key features of the theories, relevant to our educational project**
Constructivist theory	- learning is primarily a *social and collaborative process*, which stimulates communication between the learner and the teacher and also among learners, their colleagues and friends; - knowledge is also an *expression of values*, therefore it is necessary to be continuously critical of the knowledge provided; - among the most effective forms of pedagogical support is *group discussion.*
Theory of Community of Inquiry (CoI)	- the e-learning experience is based on the *interaction of the social, cognitive and teaching presence*; - effective e-learning requires the *existence of a community*.
Heutagogy theory	- *autonomous or self-directed learning* reduces the dependence of learners on the teacher; - the individual is *an important agent of learning* with control and responsibility for the learning process; - the *learners need to be digitally literate* to be able to achieve self-directed learning and consume the *benefits of social media*, such as connectivity with others by discovering and sharing information.

Key competencies and learning objectives

Based on the educational needs analysis, as described in section 4.2.1, we identify **two groups of the project's learning objectives**:

- the **general learning objectives**, related to the key competencies for sustainability education, and the
- the **specific learning objectives**, related to the energy and climate literacy abilities of citizens.

The **general learning objectives** are closely related to the *key competencies for sustainability education*, in line with UNESCO (2017). Our educational project, originating from the *Open Education for a Better World* global mentoring programme, which aims to foster the design and reuse of OER for SDGs (Urbančič et al., 2019), focuses primarily on SDGs number 7 (*Affordable and Clean Energy*) and number 13 (*Climate Action*). Therefore, the general learning objectives are mostly connected to these two goals. However, the *cross-cutting key competencies* for achieving all SDGs are taken into consideration first, because people must understand the complex world in which we live and be ready to collaborate (UNESCO, 2017). The following **key competencies** are important **for education on sustainable development**:

- systems thinking competency,
- anticipatory competency,
- normative competency,
- strategic competency,
- collaboration competency,
- critical thinking competency,
- self-awareness competency,
- integrated problem-solving competency.

Based on the pedagogical aspects of our educational project, presented in section 4.2 (the educational needs analysis, project aims and instructional design) we have selected **three key competencies** to be of crucial importance for the energy and climate educational project, as presented in Table 4.

Table 4: Key competencies to be obtained through the educational project

Key competency	**Brief description of what the learner is able to do based on this competency**	**How will this competency be developed/strengthened through our project's learning materials and activities?**
Systems thinking competency	recognize and understand relationships; analyse complex systems and how they are embedded within different domains and different scales; deal with uncertainty	Learning materials will provide insight into the interconnections between energy, climate, economy, mobility, forests, agriculture, socio-demographics etc. Learning activities will stimulate discussions about system aspects of energy and climate issues.
Collaboration competency	learn from others and respect their needs and actions (empathy); deal with conflicts in a group; facilitate participatory problem-solving	Learning activities will strengthen empathetic discussions. Through the learning activities, youth will be stimulated to explore the benefits of teamwork for the achievement of the SDGs (Drevensek and Urbancic, 2022) and collaborate both among themselves and with the experts and decision-makers, e.g. by asking questions, sharing suggestions etc.
Strategic competency	collectively develop and implement innovative actions at the local level, which can be used also at the EU or global level	Through the learning materials and learning activities, youth will be empowered to co-create future energy and climate policies not only in Slovenia but at the EU and global levels.

In line with the UNESCO (2017) guidance, there are general learning objectives described for each of the SDGs in the cognitive, socio-emotional and behavioural domains. Based on the educational needs analysis and the main aims of our educational project, as presented in sections 4.2.1 and 4.2.2, we have selected the **top three learning objectives** in each domain.

For the SDG7 on *Affordable and Clean Energy* (*Energy access to affordable, reliable, sustainable and clean energy for all*), we have selected the top three learning goals for each of the domains, as shown in Table 5.

Table 5: SDG7-related top three learning objectives, by their domains

Domain	**Top three learning objectives of our educational project**
Cognitive learning objectives	1. The learner **knows about the energy sources** and distinguishes between their **advantages and disadvantages**, as well as their meaningful **share in the energy mix** at the local, national and global energy-supply levels. 2. The learner understands **how energy and climate policies can influence** the future energy supply. 3. The learner knows about the **impacts of energy production** and understands how cleaner, low-carbon energy sources can help mitigate climate change.
Socio-emotional learning objectives	1. The learner assesses and **understands the need of other communities, countries or regions** related to affordable, reliable, low-carbon energy. 2. The learner **is able to collaborate with others** to transfer knowledge and share best practices. 3. The learner **develops a future energy-supply vision** for their country.
Behavioural learning objectives	1. The learner **analyses the impacts of large energy projects** (e.g. constructing a power plant) on different stakeholder groups. 2. The learner **influences energy and climate policies** based on facts and knowledge. 3. The learner **evaluates business models** of different future energy scenarios.

For SDG13 on *Climate Action* (*Take urgent action to combat climate change and its impact*), we have selected the following top three learning goals for each of the domains, as shown in Table 6.

Table 6: SDG13-related top three learning objectives, by their domains

Domain	**The top three learning objectives of our educational project**
Cognitive learning objectives	1. The learner **knows which human activities contribute most to climate change**. 2. The learner **knows about the main environmental, social and financial consequences of climate change** locally, nationally and globally. 3. The learner **knows about prevention, mitigation and adaptation strategies** at different levels (global to individual).
Socio-emotional learning objectives	1. The learner **can explain system dynamics** and how the environmental, social, economic and ethical impacts of climate change are interconnected. 2. The learner **encourages others to mitigate climate change**. 3. The learner **collaborates with others** to develop strategies to deal with climate change.
Behavioural learning objectives	1. The learner **anticipates and evaluates the impacts of climate change** on personal, community, local, national and global decisions. 2. The learner **promotes responsible and climate-protecting public policies.** 3. The learner **supports social, environmental and climate-friendly economic activities**.

Specific learning objectives

Related to the concepts of energy and climate literacy (U.S. Department of Energy, 2017; U.S. Global Change Research Program, 2009), presented in section 2, the specific learning objectives are linked to the **abilities of an energy and climate-literate person**, who:

- can trace energy flows and think in terms of energy systems,
- understands the essential principles of Earth's climate system,
- knows how much energy he or she uses, for what, and where the energy comes from,
- can assess the credibility of information about energy and climate,
- can communicate about energy, energy use, climate, and climate change in meaningful ways,
- makes informed energy and energy use decisions based on an understanding of impacts and consequences, as well as concerning actions that may affect climate,
- continues to learn about energy and climate throughout his or her life.

Based on these abilities, the following **key specific learning objectives** are defined for our educational project:

- **to understand the science and technology of energy supply** and its role on the local, national and global levels;
- **to identify and explain the key dynamics** driving the climate and energy system, and their connection to other relevant systems, e.g. transport, industry, forests and agriculture;
- **to be able to make informed individual and system-level decisions** about our energy and climate future.

4.3 Technological aspects

4.3.1 Importance of media and technologies

The selection of media and technologies can significantly transform the educational process. If used appropriately, they can improve the quality of education by allowing greater flexibility in the creation and use of learning materials and the implementation of learning activities.

As emphasized by Bregar et al. (2020), the media and technologies enable adaptation to different learning approaches and flexibility in time, space and content; encourage the development of more complex thought processes; allow interaction between learners despite spatial separation, greater autonomy in learning and authenticity of the learning experience.

According to Bregar et al. (2020), it is important to distinguish between media (as the means of communication) and technology (the physical means that make the media work).

4.3.2 Selection criteria

In selecting media and technologies for our educational project, we have taken into account the following **criteria**:

- **the purpose and the basic aim of the educational project and its learning objectives**,
- **the features of our learners**, especially their digital literacy skills,
- **the organisational and financial/cost aspects**.

Related to the pedagogical aspects of the educational project (presented in section 4.2), the **selection of media and related technologies was significantly impacted by**:

- **the educational needs analysis**, including the objectives of the project, which focus on increasing the knowledge and interest of youth and encouraging them to participate in public discussions; and **the learners' analysis**, which defined the key features of the primary target group of learners, incl. their high digital literacy skills; and
- **the project's instructional design**, focusing on learning theories, especially the *theory of community of inquiry* and *heutagogy*, with their emphasis on e-learning and the use of social media.

5 PROJECT IMPLEMENTATION

In this section, we first present how we *initially planned* the project (5.1), then we describe, how we have *stimulated and integrated learners' feedback* (5.2) and finally, how we have *adapted* the project based on the expressed needs, interests and expectations of youth as our primary learners (5.3).

5.1 Initial implementation phase

The initial implementation phase is directly based on the findings of the development phase, as presented in section 4. The strategic, pedagogical and technological aspects of the project (sections 4.1, 4.2 and 4.3) are the starting points for defining the initial project content for the planned learning materials and learning activities. In this way, the content and format of the educational project, which is a combination of online and offline learning materials and activities, are predefined but allow for a later adaptation, according to the expressed needs, interests and ambitions (feedback) of the participants.

Initially, the educational project focused on creating an **open online course on energy and climate transition**, supported with **microlearning materials** for enhancing learners' engagement and helping them effectively recognize their personal interests in the vast array of energy, climate and related topics.

As a starting point for creating these two educational resources, we focused on the reuse and remix of two existing, freely available learning materials: the En-ROADS interactive simulation tool (En-ROADS, n. d.) and the Mastering En-ROADS online training series (Mastering En-ROADS, n. d.).

Following the launch of the **Slovenian language translation of the En-ROADS simulation tool** in March 2022, we planned the **first interactive youth workshop** in June (in the Urban forest of Celje), and the second workshop in September 2022 (in the multimedia educational centre GEN Svet energije). The plan was to gain insight into the interests and expectations of youth through the workshop discussions and their use of a social annotation tool (Gao, 2013) that would allow them to co-create the open online course by suggesting or adding their topics of interest to best serve the needs

and expectations of interested Slovenian youth representatives. The **main content of the online course** was initially planned to consist of:

- 20- to 30-minute video lectures by Slovenian experts and
- microcontent, delivered via social media (Instagram) to support and promote the open online course, e.g. relevant statistics and infographics.

Table 7 gives the details about our **initial project plans**:

- **key input learning materials** (En-ROADS simulation tool and En-ROADS online training),
- **main learning activity** (youth workshops), and
- planned **core OER outputs** (open online course and a microlearning channel).

Table 7: Planned inputs, learning activity and outputs of the educational project

Element type and name	**Description of planned project activities**
Input learning material: EnROADS interactive simulation tool and online training	We translated the En-ROADS interactive simulation tool, created by MIT/Climate Interactive, into the Slovenian language and adapted the content where necessary regarding Slovenian specifics. The main descriptions of the En-ROADS content (graphs and sliders) are now available in Slovenian language but more detailed information is only available in English, as is the case with many other of the 20 language translations. Climate Interactive offers an 8-week free online training program to advance understanding of the En-ROADS simulation tool and its complementary learning experiences. The main aim of the online training is to equip individuals with the skills to lead climate events (workshops etc.) worldwide and become so-called *En-ROADS Climate Ambassadors*. We planned to reuse and remix parts of the content from this online training in our (Slovenian) online course by adapting the content structure according to the specific needs, interests and expectations of our learners.
Learning activity: Youth energy and climate workshops	To stimulate discussion with active Slovenian youth representatives, we implemented two interactive workshops by using the En-ROADS simulation tool. In this way, we gathered feedback from the participants about the topics of their interest and their willingness for future collaboration in the project. Their feedback has significantly impacted our project's next steps.

Output learning material 1: Open online educational course on energy and climate change	Based on the reuse and adaptation of the En-ROADS online training, we planned to create a topic-oriented online course based on pedagogical guidelines to strengthen the energy and climate literacy of Slovenian youth. The following main original educational resources were supposed to be created and integrated into the online course: 20- to 30-min. video lectures by Slovenian experts on topics, determined by youth; key statistical data for Slovenia and the EU (in line with the global data, integrated into the En-ROADS course modules); infographics, supporting key knowledge and used also in our microlearning channel on Instagram. For the course participants interested in more detailed information and with the ambition to lead future energy and climate workshops by using the En-ROADS simulation tool, we planned to integrate into the Slovenian course also parts of the En-ROADS online training. By completing both online courses, the learner would acquire the knowledge and skills, necessary for using the En-ROADS simulation tool and get in-depth insight into the Slovenian specifics of the energy, climate and related topics.
Output learning material 2: Energy and climate microlearning channel on social media	We planned to develop a microlearning channel on Instagram to encourage youth to learn about energy, climate and related topics. The educational posts offer micro units of knowledge, to be integrated also in our open online educational course (e.g. interesting parts of the video lectures by Slovenian experts, relevant statistical data and infographics). This microlearning channel would help promote the online course and engage the young audience to participate in it.

Figure 1 graphically summarizes the initial phase and its plans related to the learning materials and activities.

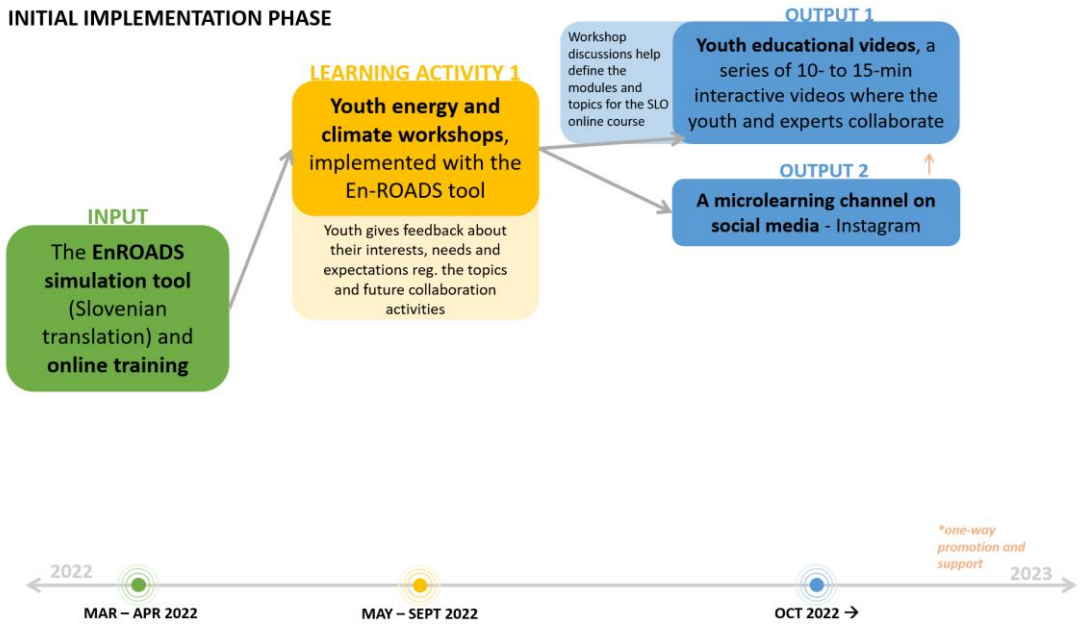


Figure 1: Initial implementation phase

5.2 Feedback-gathering phase

As mentioned, the implementation of the initial learning activities started in the spring of 2022. In March 2022, we launched the Slovenian language version of the En-ROADS simulation tool and in the middle of June, we implemented the first interactive energy and climate youth workshop. A group of 12 youth representatives from 5 Slovenian youth organisations and movements actively participated in the discussions, supported by the use of the En-ROADS simulation tool.

For the continuation of our project, it was crucial to get feedback from the learners related to the planned learning activities and the creation of learning materials. As part of the En-ROADS June workshop, we implemented **a guided discussion with the goal to identify the**:

- **youth motivations** to participate in the workshop,
- **topics** they would like to discuss and further evolve, and

- **possible ways of their future collaboration** in the educational project.

The key **findings from this discussion** can be summarised in two main groups, namely:

- the findings, **related to the content** of our educational project, and
- the findings, **related to the process** of our educational project, i.e. the co-creation process and future youth collaboration opportunities.

As regards the **content** of the educational project, youth representatives have expressed their interest in the following topics to be covered in the learning materials:

- price of energy and energy independence,
- sustainable mobility, focusing especially on electromobility,
- role of energy supply for the Slovenian industry,
- societal and environmental aspects of the energy transition.

As regards the **process** of the educational project, the workshop participants expressed their interest in a much more active role than merely co-creating and then participating in an online course. Related to the procedural aspects of their further collaboration they have expressed:

- reluctance towards using a social annotation tool for contributing content ideas for the online course;
- high interest in participating in live discussions, especially if these are part of public events, focusing on energy and climate topics;
- low interest in participating in the course without concrete future project collaboration opportunities;
- high interest in collaborating on energy and climate topics in future external events, e.g. by giving presentations and taking part in discussions at conferences, public discussions etc.;

- high interest in the co-creation of short youth-targeted video content, instead of co-creating a series of video lectures, given by experts.

The key findings from the open discussions with youth participants in the 1st workshop significantly impacted the future implementation of the educational project and led towards the adaptation of learning activities and learning materials, including the plans for the 2nd workshop, which took place in September 2022. There, five representatives from five organisations participated (two of them had already participated in the June workshop and others were new to the process). The primary purpose of this workshop was to equip its participants with the information and knowledge, needed for their attendance and active engagement at the EUSEW (European Sustainable Energy Week conference) in Brussels later in September. However, we used this opportunity to discuss with the youth the aspects of our educational project, based on the findings from the 1st workshop's discussion in June.

From the methodological perspective, the guided discussion in the 2nd workshop was implemented as a role-playing exercise, where youth participants were asked to have a short oral presentation from the viewpoint of their organisation's interest to engage in the energy and climate transition.

The goals of the discussion in the 2nd workshop were **to identify:**

- **additional topics of youth interest**, related to the energy and climate challenges,
- **specific interests of youth organisations** to engage in our educational project,
- **potential near-future events and other collaboration opportunities** for synergies with youth organisations.

The key findings after the guided discussion in the 2nd workshop can again be presented in two main groups, related to the content and process of the educational project. From the **content perspective**, the participants emphasized their interest in the topics, related to the EU energy and climate goals, technology development, and agricultural and forest aspects of climate change. From the **process perspective**, they expressed their interest to improve the representation of youth in energy- and climate-

related policy-making on the national and EU level. They shared information about the skills needed and their existing youth training opportunities where energy and climate topics could be applied. Table 8 describes learners' feedback from the 1st and 2nd workshops.

Table 8: Summary of learners' feedback

Feedback	**- from the 1st workshop**	**- from the 2nd workshop**
- related to the content	Topics of interest: energy price and energy independence, sustainable mobility, energy supply for industry, societal and environmental aspects.	Topics of interest: EU energy and climate goals, NECP (National Energy and Climate Plans), energy technology development, agricultural and forest aspects of climate change.
- related to the process	Active role in the educational project, participation in live discussions, collaboration in future events and co-creation of youth video content.	Improve youth representation in energy and climate policy-making, skills and training opportunities.

Based on the integration of learners' feedback, the initial concept of the core output, the open online course, needed to be significantly changed because the target audience suggested being a much more active participant in a diverse set of project activities, related to knowledge co-creation and knowledge transfer. The next section presents the main changes and adaptations, related to our educational project.

5.3 Adapted implementation phase

Based on the integration of learners' feedback (summarized in section 5.2), we have adapted (changed, eliminated, added or upgraded) specific elements of the educational project. Table 9 presents the key adaptations.

Table 9: Project adaptation, based on learners' feedback

Element type and name	**Description of the adapted project activities (in comparison to the initial plans, as presented in Table 8)**
Input learning material: En-ROADS interactive simulation tool and online training	No changes/adaptations to this element. Both the En-ROADS simulation tool and the online training remained the key input learning material for our educational project.
Learning activity 1: Youth energy and climate workshops	No changes/adaptations to this element.
Learning activity 2: Youth collaboration in external events	This activity was added to the educational project based on the learners' feedback, shared in the discussions with youth representatives where they expressed their interest in active collaboration in external events, e.g. by giving short presentations or taking part in public discussions. This has (in)directly impacted the content of the online course and other project outputs, as short videos from these events were integrated into the course.

Output 1: Youth educational videos	This new output is a direct consequence of discussions with youth representatives in the first two workshops where they have expressed what format of educational videos and what level of active content co-creation they are interested in. In each of the so far produced six youth educational videos, youth representatives ask questions or share their suggestions related to the topics covered. These videos are available on YouTube but are also the central ingredients of the online course modules. Therefore, the video lectures, given by experts, are no longer the key ingredients in our online course but rather a supporting learning resource.
Output 2: Microlearning channel on social media	The microlearning channel on Instagram has turned out to be a more centrally important digital learning material for young learners than first planned. It was initially planned to be mainly a supporting/promotional channel for the open online course but it turned out to be a more important learning material for the young learners than the online course itself. In July 2023, more than 470 followers reached @en_pismenost.

Output 3: Open online course on energy and climate	Major adaptations were made related to the key ingredients for the online course, where instead of a series of video lectures, given by experts, a series of more dynamic, youth educational videos was made where youth and experts interact. However, this learning resource has turned out to be of much lesser importance than planned in this phase of the educational project. Based on the learners' feedback, we realised that other educational aspects are much more relevant to them in this phase of the project than participating in and completing an online course. This is due to many reasons but among the key of them is the fact that our learners are all well-educated and highly active young adults who would like to take into action concrete activities related to the energy and climate future of Slovenia. Therefore, knowledge acquisition is only a prerequisite for their further activism in this field. Additionally, the learners have suggested publishing the course's video content on YouTube, where it can be accessed without registration. This has probably contributed to a lower number of online course participants in the Canvas Learning Management System, where free registration is needed. On the YouTube channel, more than 1.300 unique views of our video content have been recorded but only 14 participants have so far registered for the online course in Canvas. However, the learners have expressed their interest to participate in the online course in the future, if some additional project conditions are met, related to their role in planning and implementing certain project activities as energy and climate ambassadors. They have also suggested actively co-creating the course content if the topics are covered that are of high relevance to their youth organisations and movements or their research interests as students.

Output 4: Joint/partnering activities	This new/added output of our educational project is a consequence of the expressed ambitious role of learners who want to be engaged more actively than merely as co-creators of an online course. For example, youth representatives from one of the largest Slovenian youth organisations have suggested to co-organise a 3-day energy and climate youth training (implemented in February 2023), and other youth representatives suggested to co-create a series of podcasts about energy and climate (the activity started in June 2023). There are also other initiatives to be implemented in future, e.g. to co-organise a youth energy and climate forum in the autumn of 2023.

Figure 2 graphically summarizes the implementation phase and its adapted learning materials and activities, based on learners' feedback.

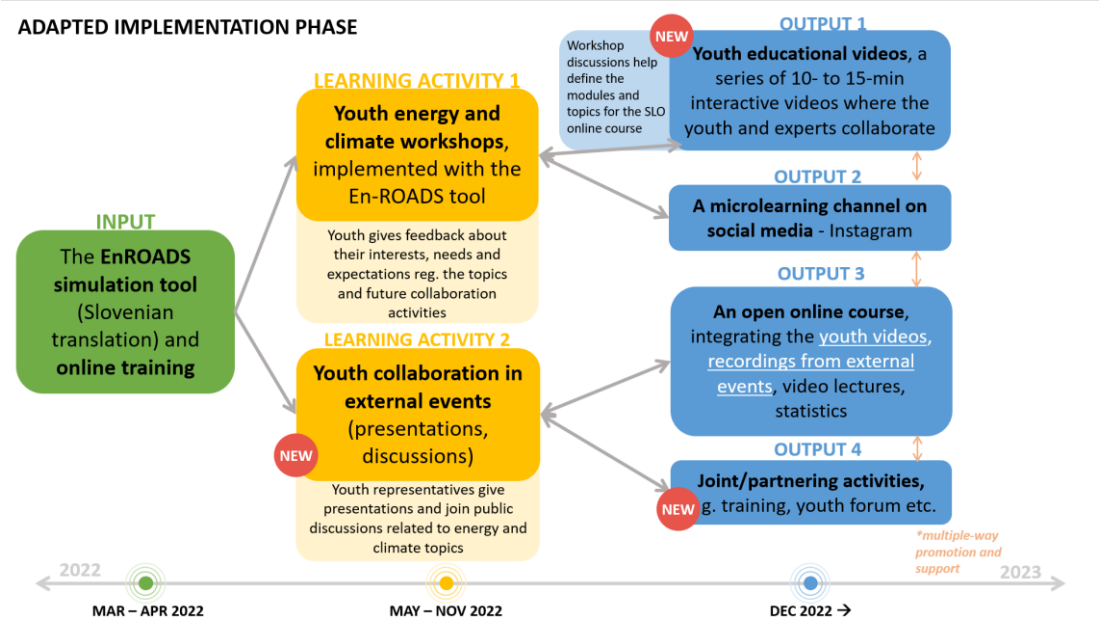


Figure 2: Adapted implementation phase

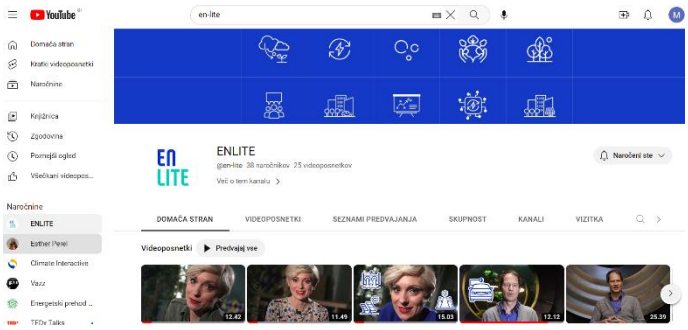
6 PROJECT RESULTS

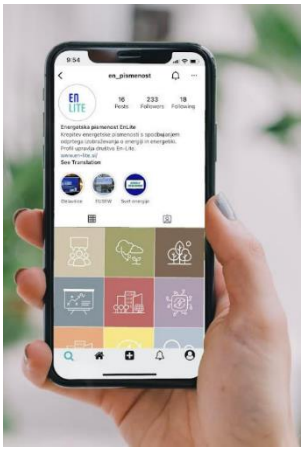
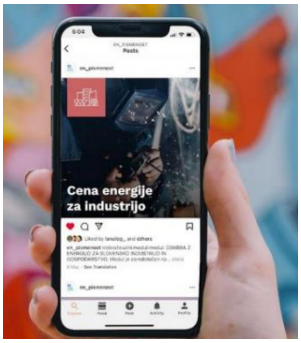
The implementation of the educational project has resulted in the following four groups of results: (1) a set of implemented learning materials, (2) three methodological findings, (3) three topical contributions, applicable to similar educational projects in the field of energy and climate change, (4) three general recommendations for OE practitioners and OER developers. We present these results in the following sections.

6.1 Implemented learning materials

Table 10 presents the learning materials implemented after the integration of learners' feedback, together with web links where they can be accessed.

Table 10: Key project's learning materials

Key project's learning materials	**A brief description of the learning material**
Interactive youth educational videos	A series of 6 youth educational videos have been produced and published on ENLITE Society's YouTube channel and integrated into the *Energy transition* online course in Canvas, covering topics defined by the youth learners.  ENLITE's YouTube channel: https://www.youtube.com/@en-lite Youth video no. 1: Energy for the Industry Youth video no. 2: Sustainable Mobility Youth video no. 3: Sustainable Mobility (part 2 – Electrical Mobility) Youth video no. 4: Energy, Society, and the Environment Youth video no. 5: Energy Sources Youth video no. 6: Energy Price and Energy Self-sufficiency

Microlearning channel on Instagram	@en_pismenost is our educational channel for microlearning about energy, climate change and related topics. The channel has more than 470 followers in July 2023, among them are the key Slovenian youth organisations and movements, high school and university students. The channel promotes our project's learning materials, e.g. the youth videos, the online course, interesting statistical data etc. We encourage our followers and partners to actively engage in content co-creation and offer interactive quizzes, which help us gain feedback and ideas for future content.   Instagram – open microlearning channel: @en_pismenost
Topical video lectures by experts	In the 10- to 30-min. video lectures, experts discuss in detail the topics, defined as interesting for the youth during their co-creation of the 10- to 15-min youth educational videos. However, the video lectures are recordings of the experts' presentations only, youth is not directly involved in this video material. Therefore, this resource is less *open* than interactive youth videos. ENLITE's YouTube channel: https://www.youtube.com/@en-lite Video lecture no. 1: Electromobility in Slovenia Video lectures no. 2, 3, 4, 5 and 6 will be published between July and October 2023.

Open online course	The open online course is titled *Energy transition* (in Slovenian: *Energetski prehod*) and is gradually upgraded and enriched as new learning materials are developed, e.g. new youth educational videos, infographics etc. The course integrates several new and existing (reused and remixed) OER, co-created in our open educational project or as part of other initiatives (e.g. the En-ROADS online training series and other educational and awareness-raising activities). It is licensed CC BY so the (info)graphics, slides from the expert's presentations, photos, text etc. can be reused, remixed, or redistributed, according to the specific needs of the users. Video resources from the En-ROADS online training and other sources are added to the specific topical modules. The course participants are invited to share their thoughts and give comments or suggest additional materials or future topics for the next modules. Website information about the online course content, its aims and the chosen technology/LMS: https://www.en-lite.si/spletni-tecaj Link to the online course in Canvas: https://canvas.instructure.com/enroll/KE8THP

As mentioned in the introduction to this thesis (section 1), the production of learning materials and the implementation of learning activities demanded the collaboration of a larger team with specific expertise and skills. Therefore, ENLITE Society's development and expert team members have been involved in different tasks, needed for the success of the project. However, the author of this thesis has been in charge of the key conceptual, strategic and coordination tasks, related to all project activities. Additionally, it is worth mentioning that all other sections of this thesis are conceptualised and written by the author herself and no other team members have collaborated in this part of the work. Table 11 shows their contribution to the planning and implementation of specific learning materials and learning activities.

Table 11: Contributions of other ENLITE team members

Project activity	**Role of the author of the thesis in this particular project activity**	**ENLITE members involved in the activity and a brief description of their specific roles**
Youth videos and Instagram posts	Idea design, structure and content creation (editing, writing) of learning materials	Garsia Kosinac: expert technical review of content, e.g. the scenarios for videos, content for Instagram educational posts.
Online course	Course idea concept and design, structure of content, creation and selection of key content elements (video, text, graphics) for modules, implementation support	Iva Tajnšek: creation and implementation of the introductory video for the course, course implementation and administration
Microlearning channel on Instagram	Microlearning channel concept, aligned with the online course; content structure, and content co-production (writing, editing of posts)	Lan Hostnik and Lina Jerina Ljubojević: co-creation of the concept, coordination with graphic designers, co-creation of content (writing, editing of posts)
Youth workshops	Workshop concept co-creation and implementation support for the indoor (energy and climate) part of the workshop	Mag. Robert Hostnik and Boštjan Hren: workshop concept co-creation and implementation of the outdoor (forest) part of the workshop, implemented in an urban forest Garsia Kosinac: workshop concept co-creation and implementation of the indoor part of the workshop

Live youth training	Training concept co-creation and implementation of Day 2 (the 'energy and climate expert part')	Martin Lenarčič, Nina Beja and Dominik Derenčin: training concept co-creation for Days 1 and 3 (the 'youth skills part') and implementation of the training
Youth educational videos	Concept co-creation, scenarios and content	Neža Prah Seničar: co-creation of concept, scenarios and content; production of videos and coordination with youth and expert speakers

6.2 Key methodological findings

The **key methodological findings**, identified through the implementation of our educational project, are presented below. They are **categorised into three interrelated groups**:

- findings related to the **dimensions of openness**,
- findings related to our **target group – youth**,
- findings related to the **content**.

In the following sections, we connect these methodological findings to the introductory theoretical assumptions, presented in section 2, and to the suggested approach and methodological aspects, presented in section 3. In this way, we try to interpret and embed the empirical, project-related findings within the theoretical, structural and methodological framework, designed to contribute to achieving the aims of this thesis. As we know from section 1, the aims are related to youth education and awareness raising, stimulation of public discussion and the encouragement of youth activism for an effective energy transition.

6.2.1 Findings, related to the dimensions of openness

Our open educational project has delivered important findings, related to the different dimensions of openness, as presented in section 3.3 of this thesis and connected to the concepts and frameworks, offered by Woert et al. (2015) and García-Holgado et al. (2020). This relates to **two initially planned aspects of our project**:

- the **creation of an open online course** as the key learning material and
- the **use of a social annotation tool** to co-create the course content together with the learners.

The open online course was initially planned in our educational project to have a central role as a learning material but already during the first steps of the project's implementation, the course turned out to be less important to our learners and served mainly to support other learning activities and learning materials, especially the co-creation of youth educational videos. Similarly, the learners have shown a high degree of reluctance to install and use a collaborative social annotation tool Hypothes.is[2] for the co-creation of the online course content, by reading, interpreting and commenting on the draft content of the course (McDaniel, 2021).

We planned to achieve the benefits of collaborative reading, related to fostering critical thinking about energy and climate topics, encouraging their active engagement in learning, and strengthening learners' confidence. However, it seemed that these were not the main motivational factors for our learners.

As described in section 5.2, during the first youth workshop, the learners clearly expressed that **instead of using the social annotation tool and co-creating an open online course, they are more interested in**:

- participating in live in-depth discussions during the workshops,
- having access to short, bite-sized chunks of energy and climate-related knowledge, delivered via social media, and

[2] https://web.hypothes.is/

- co-creating short youth educational videos, where they can have a visible role.

However, they have also clearly emphasized their **potential interest in co-creating, participating and completing a longer online course in the case at least one of the following two conditions is met**:

- (1) There are concrete future project activities associated with completing the online course (e.g. acquiring the status of an *Energy and Climate Ambassador* for those who complete the course and can then lead events and discussions); and/or

- (2) The completion of the course brings some 'certified value' for their research work at the university or in their youth organisations.

These methodological findings are integrated into the recommendations in section 6.4.

6.2.2 Findings, related to the specifics of the target group

We defined our project's primary target group of learners as the youth, aged 18 to 35. As emphasized in section 3.1, and related to EYEN (2022) and Kalossaka et al. (2022), we consider youth as future leaders and decision-makers of our society who have a huge potential to play an active role in the energy and climate transition.

This potentially active role of youth was strongly confirmed in our project. We have followed a highly open approach as to how they see their role in the energy and climate transition changing based on the impacts of our project's learning activities and materials. Additionally, we considered the approach, suggested by Ives et al. (2018) and Bristow et al. (2022), related to a social-ecological systems approach and the importance of nature reconnection, when discussing nature-related challenges like energy supply and climate change mitigation.

Two key findings, related to the target group dimension, emerged from the implementation of our project:

- **Firstly, knowledge-empowered youth wants to become active ambassadors and work in the energy and climate-related field**: Very soon

after the start of the first educational activities, it became clear that youth representatives wanted to acquire knowledge (e.g. via the educational workshops, microlearning via social media, and the open online course), to become empowered to lead discussions, raise awareness and get actively involved in the energy and climate transition. Two main stakeholder groups were identified by youth related to their potential future activation:

- **their peers and younger youth representatives**, i.e. youth in secondary schools, aged 15 - 18, with whom our target group of learners is most interested in implementing energy and climate awareness-raising activities, and

- **the decision-makers** in the fields of energy, environment, climate change, economy, health, forestry and agriculture, with whom our target group wants to connect to acquire policy-related information and then actively engage in decision-making.

- **Secondly, it matters to youth where open education takes place.** Besides the cognitive (knowledge and awareness-related) aspects, also experiential, emotional and even philosophical aspects of our energy and climate future are important to youth. The educational project started with a youth energy and climate workshop, of which the first, more social and networking-oriented part was implemented in a natural setting of an urban forest. It was not expected that this natural event setting would be so influential for the second, indoor-implemented and knowledge-oriented part of the event, led with the En-ROADS simulation tool. However, the participants expressed their highest gratitude for taking them through the forest first. We discovered how important the physical, natural environment is in which open discussion and open education take place. It helped us create an immersive, social learning experience by offering not only fact-based knowledge (the cognitive component) but also direct interaction with the natural environment, e.g. the trees, soil, water and clean fresh air (the experiential component). This facilitated the sharing of feelings of attachment among the young workshop participants and strengthened their empathy towards nature (the emotional

component). In this kind of workshop setting, they were able to openly discuss not only *facts and figures* but also their *world views* about the importance of nature and clean environment, and the fears and expectations, related to energy supply and climate change mitigation. These findings are partly integrated into the topical contributions of our project, as presented in section 6.3.3 (*The outdoor-indoor aspect*).

6.2.3 Findings, related to the re-usability of content

The learning materials, created as part of our open educational project, were planned to be offered to our learners to be reused, retained, revised, remixed, and redistributed (5R). They could make use of the OERs either as individuals (students, citizens) or as representatives of their youth organisations who are involved in different energy, climate and related activities. However, it turned out during the live open discussions there is quite low interest for this in this phase of the project. Much higher interest was expressed for bite-sized education about energy and climate issues, and reposting this content via social media - our Instagram microlearning channel @en_pismenost.

However, the learners have expressed interest in having these OERs available in their formal educational environments at the universities, presented and offered by their professors and mentors. This finding is integrated into the plans for future work in section 6.5.

6.3 Topical contributions to other energy and climate educational projects

Based on learners' feedback, the educational project has contributed to problem-solving in different ways that can be applied also to other projects and/or be reused and remixed by other OE practitioners, OER developers and other stakeholders, involved in energy and climate education and strengthening youth participation in energy and climate decision-making.

From the implemented learning materials and learning activities, we can extract **three main concrete topical contributions**, related to the:

- (1) **content** and (2) **microlearning/technology**: both of these two contributions refer to the implemented *learning materials* (see section 6.1 for details), namely the youth educational videos, the online course and the microlearning channel; and the

- (3) **place-related outdoor-indoor aspect** of the implemented *learning activity* – the youth workshops (see the second part of section 6.2.2 for details).

All three topical contributions **have the potential to be directly applied or adapted** (e.g. reused, retained, revised, remixed, and redistributed) in other youth educational and awareness-raising projects, planned and implemented by interested stakeholders in more or less similar topical contexts of energy, climate change and related issues.

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- **share**: copy and redistribute the material in any medium or format;

- **adapt**: remix, transform, and build upon the material for any purpose, even commercially.

However, sharing and adaptation can only be done **under the following terms**:

- **Attribution**: the reuser must give appropriate credit to ENLITE Society, provide a link to the license, and indicate if changes were made. This may be done in any reasonable manner, but not in any way that suggests the licensor endorses the reuser.

- **No additional restrictions**: the reuser may not apply legal terms or technological measures that legally restrict others from doing anything the license permits.

6.3.1 Contribution to the content aspect

This topical contribution of the project is related to the content structure of our youth educational videos and (more broadly) to the online educational course. These are two of our key learning materials, co-created with youth as OERs. Their content structure complements the existing En-ROADS online training (Mastering En-ROADS, n. d) as it adds layers of information and knowledge that are of relevance for stimulating energy and climate discussions on the national level. The content was defined by the expressed interests and expectations of our young learners. Of course, different content preferences might have been expressed by other groups of learners, depending on their age, educational background or other characteristics. Therefore this topical contribution is directly applicable only to youth educational projects.

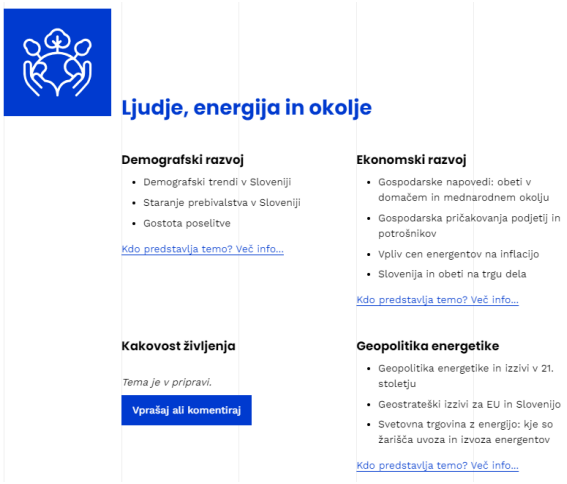
Table 12 presents the online course structure, encompassing eight content modules, and gives details about the specific content of those modules that have already been launched, focusing on its main ingredient: the youth educational videos.

Contribution's relevance and limitations: This contribution might be especially relevant for educational and other stakeholders, who are also using the En-ROADS simulation tool (En-ROADS, n. d.) to stimulate public discussion and collaborate with youth on energy and climate topics, and would like to offer some country- or region-specific information in addition to more globally-oriented learning resources like the En-ROADS online training (Mastering En-ROADS, n. d.).

Table 12: Project's online course curriculum

Module number and title	**Key topics, covered in this module** (screenshots with content details are in Slovenian language)
0. Introduction	About the course content About the interactive En-ROADS simulation tools Our supporters and partners

1. Energy supply for the industry	Youth educational video title: Energy for the industry Other topics: the role of industry and the importance of energy transition for the industry in Slovenia; challenges and opportunities of the energy transition – the industry's viewpoint; the energy intense industry's perspective on the energy transition 
2. Energy use	Youth educational video title: Sustainable mobility (part 1) and Electric mobility (part 2) Other topics: mobility; energy efficiency in the corporate sector; energy efficiency in households 

3. Energy, society and the environment	Youth educational video title: Energy, society, environment Other topics: demographic development, economic development, quality of life, geopolitics of energy 
4. Energy sources	Youth educational video title: Energy sources Other topics: energy powers society, Slovenia in the Energy Trilemma, fossil fuels, renewables, nuclear energy, hydro energy, biomass etc. 

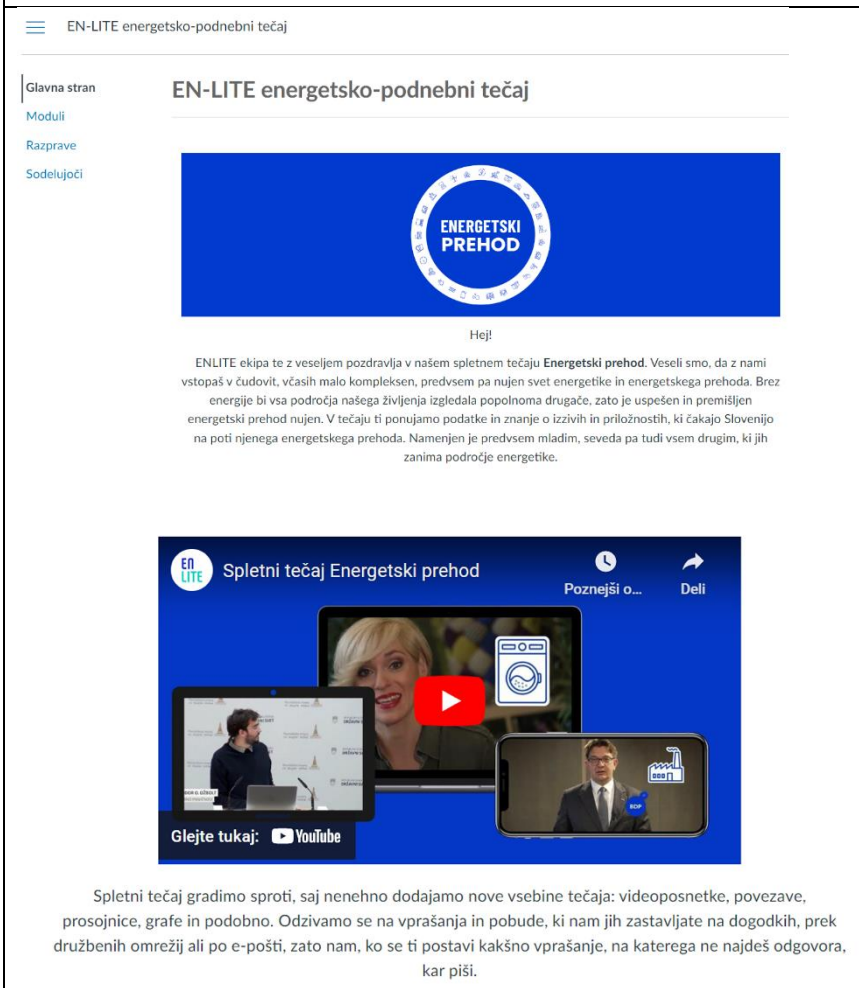
	Energija biomase • O biomasi (les za energetske potrebe) • Raba v Sloveniji • Stanje in trendi energetske izrabe biomase *Tema je v pripravi.* Vprašaj ali komentiraj **Obnovljivi viri energije** • Razpoložljivost OVE (energija sonca in vetra) v Sloveniji • Stanje in trendi rabe OVE • Priložnosti in ovire (prednosti in slabosti) *Tema je v pripravi.* Vprašaj ali komentiraj **Hidro energija** • Razpoložljivost hidro energije v Sloveniji • Stanje in trendi rabe hidro energije • Priložnosti in ovire (prednosti in slabosti) *Tema je v pripravi.* Vprašaj ali komentiraj **Jedrska energija** • Pomen jedrske energije v Sloveniji in EU • Jedrska energija in uresničevanje podnebnih ciljev • Priložnosti in izzivi prihodnje rabe jedrske energije Kdo predstavlja temo? Več info... **Novi brezogljični viri** • Fuzija: gorivo, tehnologija, varnost in vpliv na okolje; kje smo in kako naprej • Torijevi reaktorji: gorivo, tehnologija, prednosti in slabosti; prihodnji razvoj Kdo predstavlja temo? Več info...
5. Climate change: status and challenges	Youth educational video title: Energy, society, environment Other topics: dynamics of climate change, climate change impacts in Slovenia  **Stanje in izzivi podnebnih sprememb v Sloveniji** **Dinamika podnebnih sprememb** • Podnebne spremembe za nefizike – nekaj preprostih izračunov • Kaj prinašajo podnebne spremembe za Slovenijo? • Ukrepi za blažitev podnebnih sprememb: priložnosti in izzivi Kdo predstavlja temo? Več info... **Vplivi podnebnih sprememb** • Kako spremljamo podnebje? • Kako se že in se bo v prihodnje spreminjalo podnebje v Sloveniji? • Vplivi podnebnih sprememb na sektorje v Sloveniji Kdo predstavlja temo? Več info...

6. Energy system	Planned topics: Slovenian electric power transmission grid, grid stability 
7. Land use and emissions	Planned topics: forest management in Slovenia, greenhouse gas emissions in the agricultural sector, agriculture and climate change etc. 

8. Energy-climate education and awareness-raising	Planned topics: energy, climate change and system dynamics; energy and climate literacy, energy-climate projects; youth-engagement methods; energy-climate projects in the Eco-schools programme 

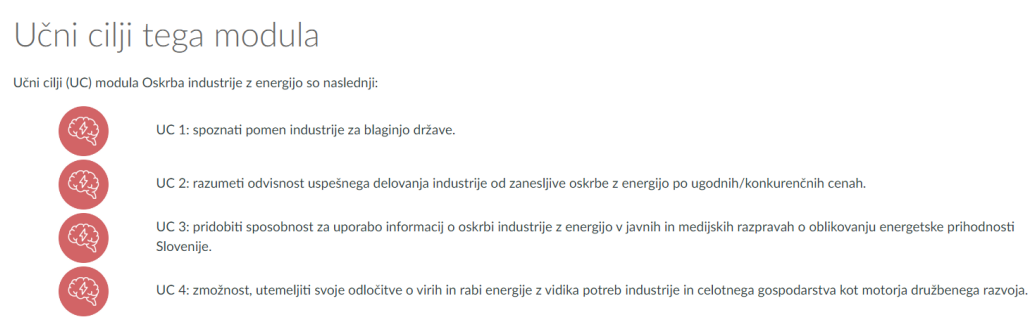
Table 13 offers a preview of a selection of modules from the online course *Energy transition*, published in the Canvas Free for Teachers LMS. The text in the screenshots is in Slovenian language, as is the course itself.

Table 13: Preview of online course's selected modules

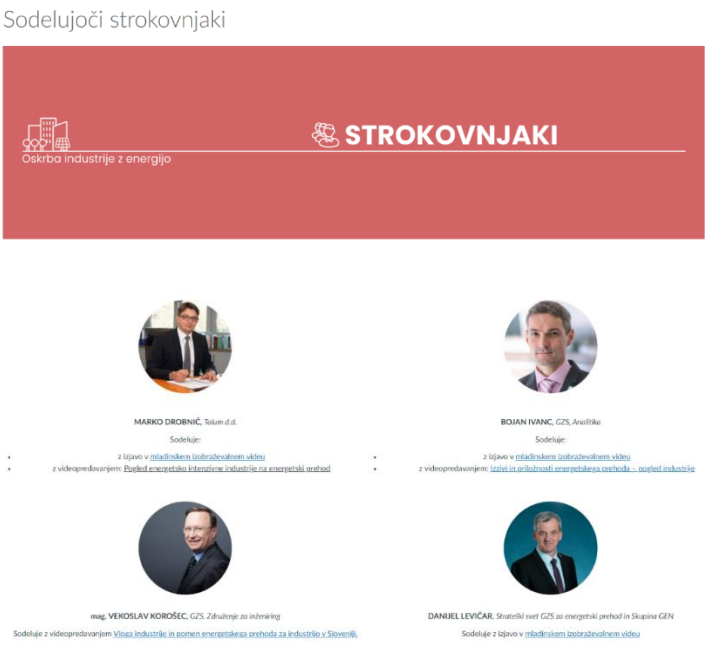
Screenshot, taken from the online course in Canvas LMS **Course registration is available here: https://canvas.instructure.com/enroll/KE8THP*
Introductory site with basic information and the welcome video


Module 1: Energy supply for the industry

Definition of the modules' learning goals:

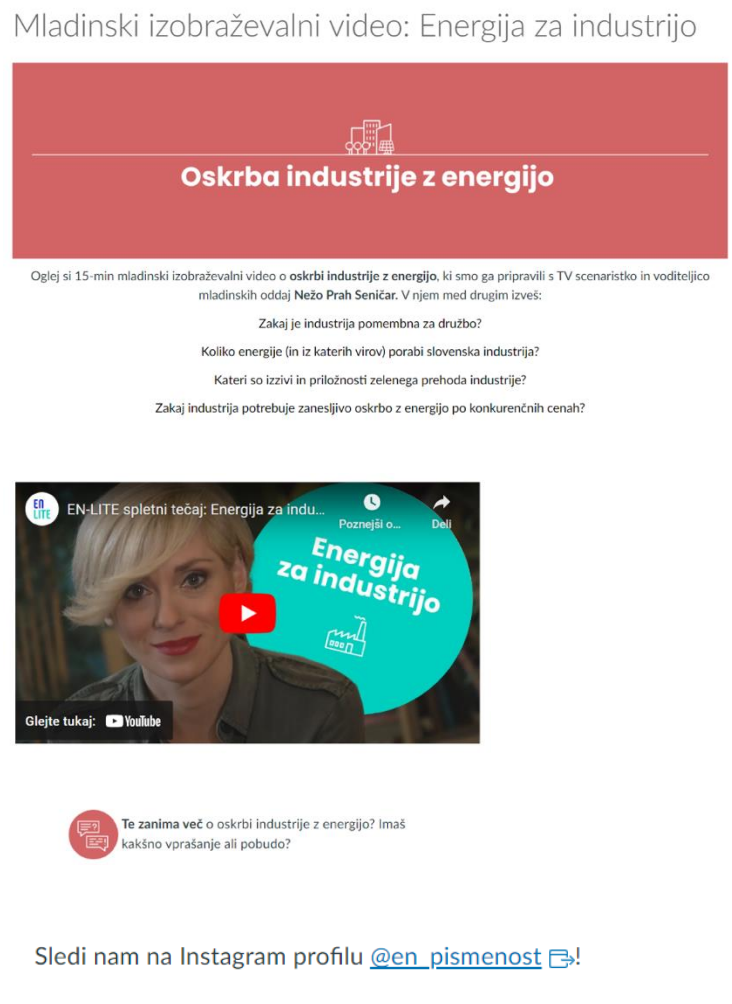


Presentation of the expert team, contributing to the content of this module:



Overview of module's key content:

Introductory content: the youth educational video



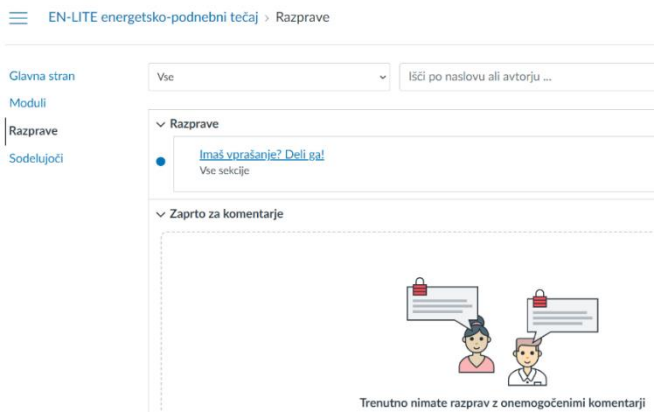
Other content: expert video lecture (example)

V tej **videopredstavitvi mag. Vekoslava Korošca z GZS** med drugim izveš:

- da je energetski prehod **največji in najdražji projekt po osamosvojitvi Slovenije**,
- zakaj bo trenutna energetska kriza **zeleni prehod še pohitrila**,
- koliko **pomembnejša je vloga industrije v Sloveniji** v primerjavi z drugimi državami članicami EU (in zakaj).

11 min

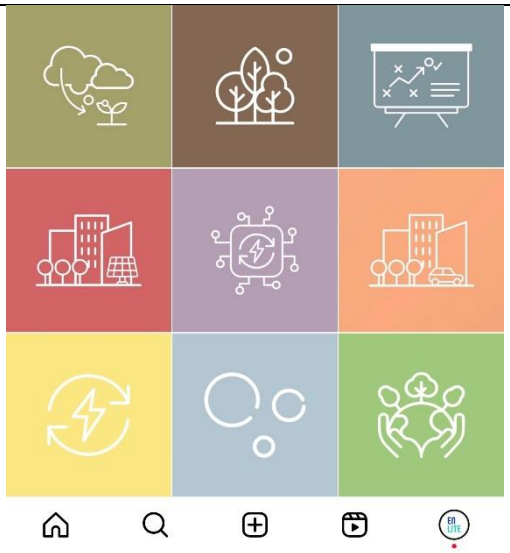
Discussion option (to be further developed)



6.3.2 Contribution to the microlearning and technology aspect

As part of our project, we have developed @en_pismenost, an educational channel on Instagram for microlearning about energy, climate and related topics. The general structure, graphic design, and approach to creating educational content might be applied also to other microlearning contexts in the energy and climate fields, targeting youth and young adults. Table 14 summarizes the key aspects of our microlearning channel that might be reused or remixed in other energy and climate projects.

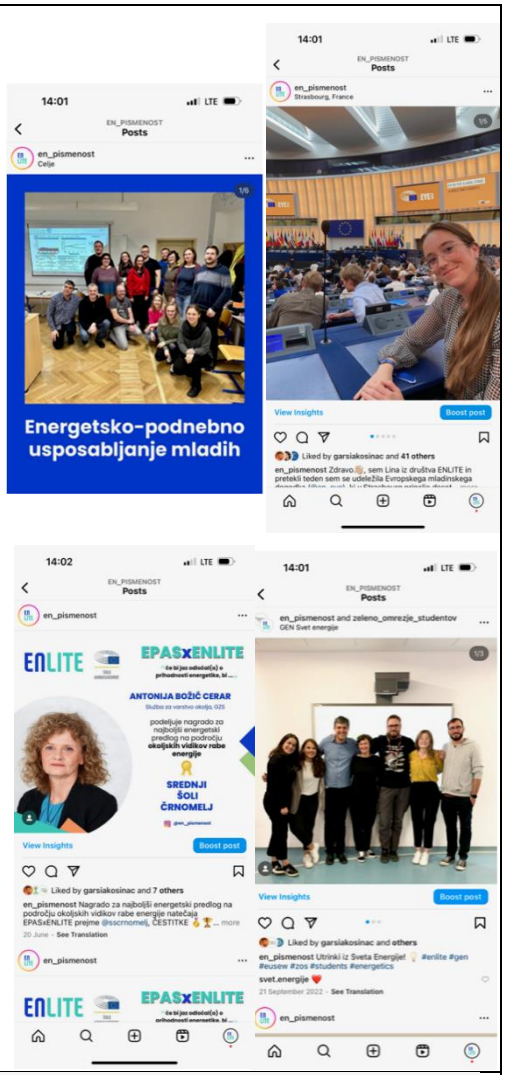
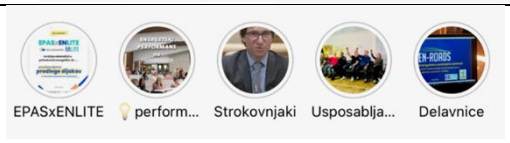
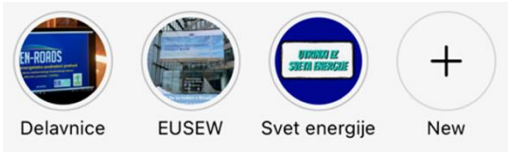
Table 14: The @en_pismenost microlearning channel on Instagram

The aspect of the @en_pismenost microlearning channel	**Brief description**	**Exemplary screenshot from Instagram**
Alignment of the microlearning channel's graphic design	Each content module has its own colour and icon. This concept is introduced in the very first posts in the channel's feed and is then consistently used throughout the series of educational posts. In this way, the followers/learners can easily find posts, covering topics of their interest.	 

	For example, the green colour covers the *Energy, society and environment* module. All educational posts, covering this topic later in the feed, are coloured green and can easily be found by scrolling.	     
Consistent approach to promoting the youth educational videos	All youth educational videos are launched/introduced on @en_pismenost in a graphically and contextually consistent way. The follow-up, more detailed educational posts are then easier connected to the video they refer to.	     

One-minute educational posts	Our textual, video or combined educational posts are structured in a way that they take a maximum of one minute for our followers to spend. However, most of the posts include an invitation where to find more information about a certain topic, e.g. link to a video, reference to the online course etc.	 Text-based educational post (example)  Video-based educational post (example)  Combined (text and video) educational post with an expert introduction (example)

Presenting the team of experts	All experts contributing to the youth educational videos and other learning materials/activities in our project are presented consistently, using colours, related to their modules and connected to their main topical contributions to the project.	    

Distinction between educational posts and other posts	A clear distinction is made and consistently followed throughout the channel's feed between the main/educational posts and all other posts, e.g. those presenting participation in workshops and other events, or other project activities, such as student collaborations, prize contests etc.	
A clear system of key project highlights	So far, seven categories of key project highlights have been established, covering e.g. the project's workshops, event participation, youth training, presentation of the expert team, and other important project activities.	 

Contribution's relevance and limitations: This topical contribution might be especially relevant for educational and other stakeholders, who are using social media in their projects. As regards the content aspects, this contribution is limited to energy and climate projects/activities due to the graphic design aspects. Additionally, the microlearning approach is planned to be implemented via Instagram. If other social media channels are used, e.g. Twitter or TikTok, appropriate adaptations to the concept need to be undertaken, e.g. the ratio of picture/graphic vs. text vs. video content changes. Our learners are youth and young adults. If other target groups are of primary importance, appropriate adaptations need to be undertaken, e.g. regarding the content and length of text, videos, style of infographics etc.

6.3.3 Contribution to the outdoor-indoor (place-related) aspect

As part of the educational project, we have developed a unique approach to the implementation of youth workshops, which combines outdoor and indoor elements. The first part of the workshops is implemented in a natural setting in an urban forest, which socially and emotionally impacts the implementation of the second, indoor part of the event, where energy and climate issues are discussed by using the En-ROADS simulator. In our case, the young learners highly appreciated the introductory activities, implemented in a natural environment of an urban forest. In this way, not only the cognitive (knowledge-related) but also the experiential, emotional and even philosophical aspects were taken into consideration during the discussion. These could be addressed much better in a natural environment than in an ordinary, closed classroom. The concept and programme of the workshop can be seen in detail in the invitation, shown in Figure 3 (licensed CC BY 4.0).

ENLITE

Mladi in energetsko-podnebni prehod

Interaktivna spoznavno-izobraževalna delavnica

Lokacija: Drevesna hiša v Mestnem gozdu Celje

Datum: nedelja, 12. junij 2022

Čas: 13h – 17:30

Število: do 15 udeležencev

Vabljeni predstavniki: Mladi za podnebno pravičnost, Mladinski svet Slovenije, Društvo za ZN za Slovenijo – mladinska sekcija, Društvo mladih geografov Slovenije, Zeleno omrežje študentov + druge mladinske organizacije

Izhodiščne skupne vrednote delavnice (prepletene bodo skozi vse dele interaktivnega dogodka)

- odprtost in povezovanje
- ambicioznost in kreativnost
- prizadevanje za preudarnost

ENLITE

Program interaktivne delavnice

Pozdrav gostiteljev: Društvo ENLITE (mag. Mojca Drevenšek) in Društvo Mestni gozd (mag. Robert Hostnik)

Energija gozda **- spoznavni del (13:00 – 14:45)**

Gozdni sprehod s kratkimi aktivnostmi:

- Gozd kot davni navdih za trajnostni razvoj (so-naravnost upravljanja)
- Blagodejnost gozdov za sodobnega človeka (razvoj čuječnosti, gozdna terapija)
- Vloge gozdov pri razumevanju naravnih ekosistemov (gozdna pedagogika)

(vodita: Robert Hostnik in Boštjan Hren, Društvo Mestni gozd, Zavod za gozdove Slovenije)

Energija in podnebje **- izobraževalno-ozaveščevalni del (15:00 – 16:45)**

Interaktiven uvodni pogovor, v katerem izmenjamo poglede mladih in mladinskih organizacij/gibanj na energetsko-podnebno tematiko. Skupaj poiščemo odgovore na vprašanja: kaj mlade v zvezi z energetsko-podnebnimi izzivi zanima, katere podatke ali znanja želite dobiti, kako boste lahko z več znanja boljši/aktivnejši/učinkovitejši v svojem delovanju? Izmenjava izkušenj o dosedanjih primerih dobre in slabe prakse, s katero ste se srečali pri svojih energetsko-podnebnih aktivnostih/projektih.

Energetsko-podnebna delavnica z En-ROADS simulatorjem (vodita: Garsia Kosinac, društvo ENLITE in Svet energije - GEN, in Mojca Drevenšek, društvo ENLITE)

Energetska gozdna pogostitev **- zaključni razmisleki (16:45 – 17:30)**

- Prigrizki gozdnih dobrot
- Druženje in sooblikovanje zaključkov* in
- Skupna opredelitev naslednjih korakov/ aktivnosti

**Op: predvideno je oblikovanje konkretnih zaključkov in priporočil, ki jih bodo sodelujoče nevladne organizacije/gibanja v zvezi z vključevanjem mladih v oblikovanje energetsko-podnebne prihodnosti posredovale političnim odločevalcem na pristojnih ministrstvih (energija, podnebje, izobraževanje).*

Kreativni dodatek za inspiracijo: Prisluhi v Mestnem gozdu **(od 18:00 naprej)**

Obisk kreativnega spektakla z Boštjanom Gombačem z gosti v okviru festivala Prisluhi v gozdu ob Drevesni hiši v Mestnem gozdu Celje.

Figure 3: Contribution to the outdoor-indoor aspect

The effects of this workshop concept are described also in the second part of section 6.2.2, where the methodological findings, related to our target group of young learners are discussed.

Contribution's relevance and limitations: We need to be aware of the importance the learners ascribe to the environment where open education, discussion and knowledge co-creation take place, and their place-related preferences. It might lead to significantly different results if the learning and discussion activities are implemented only indoors vs. outdoors, or combined. However, the differences between types of learners, depending on their age, educational background or other factors, should be taken into consideration.

The concept might apply to other energy and climate educational workshops or discussion events, and also to other outdoor settings, depending on the specific topic to be discussed. For example, if the energy and climate workshop focuses on economic aspects, it might be implemented in an industrial setting (a factory) but if the focus is mobility or agriculture, appropriate other thematic outdoor settings might be chosen for the event implementation, e.g. a traffic-free city centre or a field.

6.4 Recommendations for OER developers and OE practitioners

In addition to the topical contributions of the project, presented in section 6.3, which represent concrete possibilities to reuse our project's concepts, content and formats for similar, energy and climate topical projects, we can also extract a set of recommendations. These are based on the methodological findings, presented in section 6.2. In comparison to the project's topical contributions (section 6.3), these recommendations have a more general value and can be applied to a broader range of open education practices and the development of OERs related to different topics beyond energy and climate change, e.g. environmental, health and other, socially relevant topics. For the presented recommendations, we define the context in which it can be used and potential conceptual, topical or stakeholder limitations (Table 15).

6.4.1 Recommendations, related to the dimensions of openness

It is **recommended to be flexible about the tools**, used for acquiring learners' feedback, and for stimulating their networking and encouraging co-creation of knowledge. If the offline, 'live' options (e.g. open discussions in live workshops) are preferred to the online tools (e.g. collaborative social annotation of documents), it is **important to integrate the preferred options whenever possible**.

It is also **good to remain flexible about the type/format of learning materials** – the key educational outputs (OERs) and to listen carefully and take into consideration the ways the learners are interested in contributing to the content and the process of the project, e.g. if instead of video lectures given by experts, the learners suggest another type of learning material with their active role in creating them. Namely, realising the learners' co-creation potential is of crucial importance for the future of the project and the role the learners will see in it.

6.4.2 Recommendations, related to the specifics of the target group

It is **important to take into consideration the ambitions of the target group** (youth in our case) **and explore their motivations for acquiring knowledge**. How do they

want their position to change over time through the project activities, and how actively are they willing to collaborate as a result of their learning?

Additionally, **the specific features of the learners** (see section 4.2.1 on learners' analysis) **need to be adequately addressed**, e.g. the digital literacy of young learners and their social media use preference.

6.4.3 Recommendations, related to the usefulness of the project's content

It is **suggested to explore among the learners how they see the usefulness of the project content and the created learning materials**. In our project, implemented in a non-formal educational setting, the learners have expressed their strong opinion on the potential usefulness of the learning materials in their formal educational environments, e.g. in high schools or at the university. Vice versa, if we had developed learning materials for formal education, it might be worth exploring how these could be adapted for use also in non-formal education and awareness-raising. Namely, **the formal and non-formal educational sub-systems should be perceived as an integrated whole**, supporting each other, especially if the target group of learners are youth representatives.

If the learning materials are supposed to be adapted and used in a formal educational environment, it is **recommended to work closely with teachers, professors and mentors** to find out about the everyday teaching- and mentoring-related challenges they face and to analyse if and how these can be tackled through the developed OERs. It is advised to implement at least a part of the discussions with teachers, professors, and mentors **by having at the same time also their students in the room**.

If the topics of the project at hand are connected with other topics, for example as the energy and climate system are dynamically connected to other systems, e.g. the economy, socio-demographics, forests, agriculture etc., it is highly advised to **emphasize the system dynamic aspect**. This might facilitate the adoption of learning materials by a broader range of teachers, professors and mentors as it makes it easier for them to find connections between their subjects and the project topics, and to observe/discuss the same topic from a variety of viewpoints.

Table 15: Context and limitations of recommendations

Recommendations, related to the:	**Brief description of recommendations' content**	**Key limitation**
Dimensions of openness	Importance of being flexible about the learning process and the learning materials' content and format.	It depends on the nature of the educational project, and how much flexibility is allowed/tolerated. E.g. formal educational projects in high schools or at universities might offer less flexibility than non-formal awareness-raising activities, performed by communities or NGOs.
Target group	Need for consideration of learners' specific interests, needs, expectations and future ambitions, related to acquiring new knowledge and being part of the project.	Identification of learners' interests, needs and expectations must be implemented before and during the learning process. It might be harder to implement the analysis if the group is heterogeneous by age, educational background or other factors, relevant to the project.

The usefulness of content/learning material for both non-formal and formal education	Transformation (adaptation/application) of non-formal learning materials to be used in formal educational processes (and vice versa) might significantly improve the usefulness and value of the learning material. If applicable, the system dynamic aspect should be emphasized; it might facilitate the recognition of the usefulness of the content and materials for different subjects or fields of expertise.	If the topic is already covered in the formal educational materials and integrated into the curriculum, it might be harder to adapt/apply new or changed content from non-formal educational projects.

6.5 Design of the project's future development

Concrete ideas for future work on the project to achieve the long-term aims of this thesis have emerged from the methodological findings (section 6.2), the project's topical contributions to other energy and climate projects (section 6.3), and the recommendations for other OE practitioners and OER developers in energy and climate, as well as in other topical fields (section 6.4). These ideas for future work were co-created with our learners (youth representatives) and other key stakeholders in the project.

As shown in Table 16, we have categorised the ideas for the project's future development into three, interconnected groups that meaningfully complement each other, covering (1) the learning materials, (2) youth peer activities for raising energy and climate literacy, and (3) the youth policy-making engagement aspect.

Table 16: Key ideas for the future development of our educational project

The idea for future work	**Main goal and activities**
The learning materials aspect: development of learning materials for teachers, professors and mentors	Goal: To equip Slovenian educators (mainly the secondary school and university-level professors and mentors, but additionally also educators on other educational levels and those in the non-formal educational settings) with relevant energy and climate, high-quality interactive educational resources and training for teaching and motivating their students to further explore the energy and climate topics *inside* and *outside* the classroom. The learning materials will be based on the so far developed learning materials in our project (see section 6.1 on project results) but with adequate adaptation regarding the target audience (from youth to educators). It will emphasize the importance of systems thinking and increase the understanding of the interconnections between energy, climate, environment, socio-demographics, economics, forests, agriculture and other relevant topics. Activities: development of guidelines and ready-made interactive educational resources to be used both inside and outside the classroom for teaching energy and climate-related topics; categorisation of knowledge units/resources by subjects/courses and by the educational levels, aligned with the existing national standards/curricula, as well as with the nationally defined learning goals, for easier and more confident uptake by the educators; offer of online and live training for an interested cohort of educators to equip them with knowledge and ideas about teaching energy and climate topics and inspiring their young learners.

Youth peer activities aspect: Youth activation with their (younger) peers	Goal: Our most active and ambitious youth partners will take an active role in educating, raising awareness and/or activating their (younger) peers, e.g. in high schools, to get involved in the energy transition. Activities: The existing networks of high schools, for example, the EPAS (European Parliament Ambassador Schools), UNESCO Associated Schools Network and/or the Eco-Schools Programme network will be considered for collaboration. Together with these networks/programmes, we will develop suitable educational plans and define the educational conditions/certifications needed for the young 'ambassadors' to lead educational and awareness-raising activities with their (younger) peers.
The youth policy-making engagement aspect: Strengthening the role of youth in the energy and climate transition	Goal: To improve access for active youth to participate in energy and climate-related decision-making, based on acquired knowledge and expressed interests/ambitions of our learners. In 2023 and 2024 in Slovenia, the public consultation/participation processes around the NECP (National Energy and Climate Plan) are of the highest interest. Activities: Continuation of involvement in Slovenian and EU-level processes, related to the role of youth in the energy transition, especially around NECP (on the national level) and around the EYEN 2023 forum, updating the European position paper on the role of youth in the energy transition; adaptation of Student Energy's (Student Energy, 2023a; Student Energy, 2023b) Youth Impact Framework to Slovenian youth specifics.

All three ideas for future work are set ambitiously, yet realistically. The realization of some or all of the ideas for future work, presented in Table 16, will start in autumn 2023 and is planned to be partly or completely implemented by the end of 2024. In the

meantime, several other ongoing project activities, e.g. the youth workshops and training, microlearning via Instagram and online course upgrade, will continue to be implemented either in the same or in an upgraded way. However, the actual realization of our future ideas depends also on the financial aspects, whether our project will be (further) funded. Here, the specifics of OER business models will be taken into consideration (Ebner et al., 2014; Geser et al., 2019).

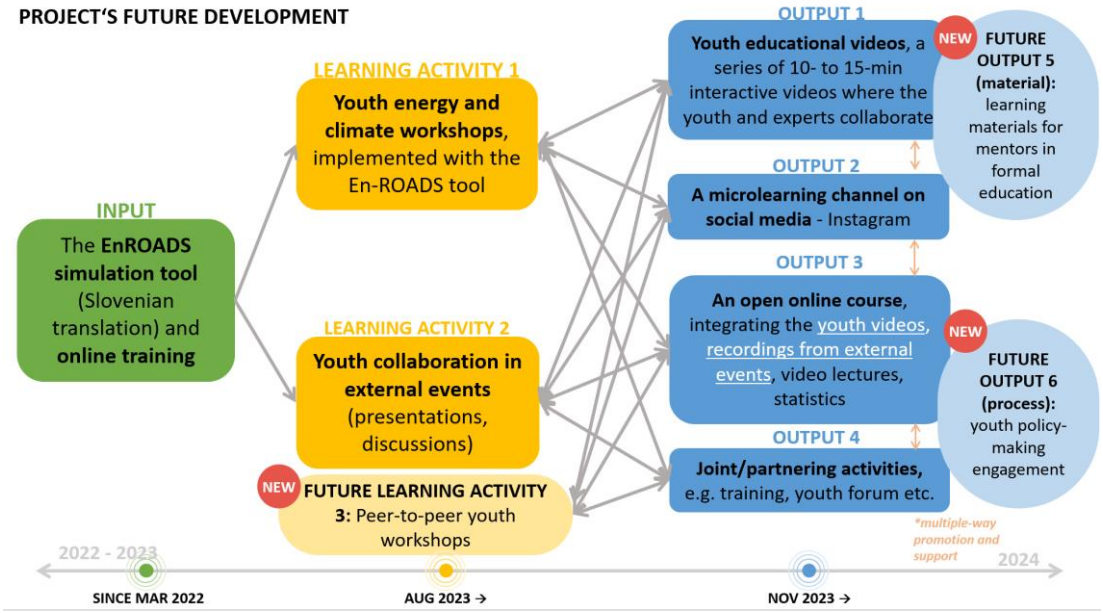


Figure 4: Project's future development

As can be seen in Figure 4, the existing and future learning materials and learning activities will create synergies and support an effective achievement of the aims of this thesis, related to raising youth energy and climate awareness, stimulating public discussion and encouraging knowledge-based youth activism for an effective energy transition.

7 CONCLUSIONS

In this thesis, we investigated the open educational approach towards raising awareness, stimulating public discussion and encouraging youth activism in the field of energy and climate change by developing and implementing a non-formal educational project, targeted at Slovenian youth. The work presents a new approach to using the existing and globally recognized En-ROADS energy and climate simulation tool. We developed a set of learning materials and implemented learning activities that complemented the use of the En-ROADS tool, based on open education, the co-creation of OER and microlearning, all in the context of strengthening the systems thinking perspective.

Our results show that the suggested approach and methodology are appropriate and contribute effectively to achieving the aims of this thesis. However, it is important to remain open to integrating the feedback of the learners and carefully adapting the initially set project plans throughout project implementation. Feedback integration and project adaptation are needed to keep the existing group of learners actively involved and to attract new learners to the project. This motivates the learners to become project ambassadors and to align their project-related activities as much as possible with their personal and/or organisational interests and preferences.

Among the main achievements of this work is a set of developed and implemented, practically tested and improved learning materials, adapted to the interests and needs of youth. They are freely and openly available, licensed CC BY, and can be reused by other non-formal or formal educators in the field of energy and climate change. Additionally, methodological findings and topical contributions can be (re)used by educational and other stakeholders, engaged in similar energy and climate educational projects. A set of general recommendations is developed that can be used in other topical projects beyond energy and climate change, covering socially relevant issues, e.g. mental health, gender equality, children welfare, racial justice etc.

The **project results have important implications** for the:

- status of energy and climate literacy among youth in Slovenia, which can be seen in the activation of youth within the policy-making processes, especially

the updating of the integrated national energy and climate plan (NECP) in Slovenia;

- short- and long-term plans of the educational project, run under the ENLITE Society for strengthening energy literacy, which encompasses also the development of learning materials for teachers, professors and mentors, as presented in section 6.5;
- future use of the En-ROADS online simulation tool around the world and its potential synergies with additional learning materials and learning activities, contributed by our project, as presented in sections 6.1, 6.2 and 6.3.

Additionally, this work revealed **new insights into the relationship between different dimensions of openness (mainly focusing on open education and OER), microlearning and systems thinking**:

1. The integration of open education with microlearning in the context of energy and climate change has proved to have a transformative potential for fostering an informed and engaged youth. The microlearning approach, implemented in the open educational environment, has facilitated bite-sized, focused learning experiences for active youth representatives, covering content which could be easily tailored either to the expressed needs and expectations of the learners or to the external circumstances that are of relevance to the young learners.
2. The application of systems thinking, particularly through the use of the En-ROADS simulation tool, has allowed learners to perceive the interconnectedness of energy systems, climate change, socio-demographics, land use (forests, agriculture), industry and other topics, thereby promoting a holistic understanding. This was combined with the microlearning approach, which enabled more detailed and particular explorations of topically specific aspects. In this way, both the holistic, high-level (systems thinking), as well as the particular, topically focussed (microlearning) approach have been connected into an integrated, comprehensive approach.
3. The synergy between open education/OER, microlearning, and systems thinking has paved the way for an engaging, responsive, and comprehensive learning experience in the field of energy and climate change. This innovative approach could serve as a blueprint for future educational initiatives in other

complex and rapidly evolving fields, as discussed in chapters 6.3 and 6.4 of this thesis.

Future work could investigate the impact of open education practices and OER on the youth's level of interest in learning about energy and climate change and their participation in energy-related policy-making in other regions of the EU and globally. Further studies could also explore alternative approaches to raising awareness and activating youth about energy supply and climate change issues, e.g. by offering varying amounts of open learning materials and activities, by introducing mobile microlearning or by strengthening the role of the open online course as part of formal education.

Another line of further work might also investigate the added value of suggested new approaches by comparing them with more traditional educational approaches, where measurements and metrics could be used for a more rigorous investigation of the advantages and disadvantages. This would require more cases and more time to overcome topical, geographical and other specifics of a certain situation, but could additionally contribute to spreading good practices in other contexts, including formal education.

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