Project Number: 2020-1-SE01-KA203-077872

Guidance document on setting up a joint curriculum on complex system studies for sustainability

Contents

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1. Background

Sustainability issues show the characteristics of complex systems, as they are part of the continuously changing, self-organizing, interdependent and adaptive systems in our world.

The CoSy Thinking project is funded, by the European Commission through the Swedish National Agency for the Erasmus+ Programme, Strategic partnerships for higher education, with the aim of providing undergraduate students with competencies in complex systems thinking and academic lecturers and managerial staff with knowledge, skills and tools for adapting their educational activities with a specific focus on sustainable development by integrating complex systems thinking.

The project identifies three main specific objectives:

- Strengthen the collaboration among academic institutions and provide them with a clearer picture of the range of opportunities between the universal and the particular.
- Provide academic lecturers and managerial staff with knowledge, skills and tools for adapting their educational activities with a specific focus on sustainable development.
- Provide undergraduate students with competencies in complex systems thinking as a basis for sustainability action and make them employable in interested organizations.

The main project results include:

- An inventory providing motivation and guidance for designing new courses specialized in complex systems thinking as well as for the integration of systems thinking through interdisciplinary approaches in existing courses.
- A toolkit consisting of a set of media-based teaching tools focused on Sustainable Development issues addressed to a multidisciplinary approach.
- A Joint Curriculum engaging Higher education decision-makers, experts and lecturers in defining shared complex systems and system thinking-based interdisciplinary learning paths and related curriculum in Sustainable Development.

This document provides motivation and guidance for designing new courses specialized in complex systems thinking as well as for the integration of systems thinking through interdisciplinary approaches in existing courses.

2. Why do we need to create learning experiences on complex systems thinking?

The aim of the CoSy Thinking project is to provide undergraduate students with opportunities to learn about complex systems, as well as provide short courses to lifelong learners active in agencies engaged in the 2030 Agenda. This will in turn benefit the organizations employing these students and hopefully, improve the contributions to the 2030 Agenda and the sustainable development goals. It contributes to increased demands for competencies related to sustainable development by focusing on complex systems thinking. Many presumptive employers have committed to the 2030 Agenda Transforming our World and have thereby entered an uncharted territory that requires new capabilities from their employees. The 2030 Agenda states 17 sustainable development goals which are integrated, indivisible and balance the economic, social

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and environmental dimensions of sustainable development (UN, 2015). Such an integration of the goals and the three dimensions requires a systemic approach (Stafford-Smith et al., 2017). This view is also emphasized by researchers connected to the UNESCO program on Education for Sustainable Development, identifying complex systems thinking as one of the key competencies for sustainability (Rieckmann, 2018). The OECD´s Future of education and skills 2030 argues in similar terms, as they see that the epistemic knowledge provided in university education must be supplemented by procedural knowledge for problem-solving which develops through complex systems thinking (OECD, 2018).

Wiek et al. (Wiek et al., 2011) defines complex systems thinking competence as ”the ability to collectively analyze complex systems across different domains (society, environment, economy etc.) and across different scales (local to global) thereby considering cascading effects, inertia, feedback loops and other systemic features related to sustainability issues and sustainability problem-solving frameworks”. Sustainability issues show the characteristics of complex systems, as they are part of the continuously changing, self-organizing, interdependent and adaptive systems in our world. Essential for a complex system is that the response of a combination of factors cannot be inferred from the response of each individual factor (van Mil et al., 2014).

Studies find that complex systems thinking needs to be trained (Andreeva, J.V. et al., 2017). Most academic disciplines conduct teaching and learning activities on issues related to sustainability, whether this is explicit or not. The same can be said about complex systems and systems thinking, they are often an implicit part of the subject to be learned. Without specific training, students restrict their understanding of systems as the parts included or parties involved, not as the system properties emerging from the complexity of interactions of the parts (Hallström & Klasander, 2017). This is also the approach taken in traditional, bureaucratic structures that address system issues by dealing with the parts (Scolozzi & Poli, 2015). Employees with better training would be able to see connections and that the whole is more than a sum of the parts.

Interviews with potential employers

In the CoSy Thinking project, we interviewed potential employers in each country. The interviews collectively emphasize the need for a balanced education that goes beyond pure specialization. Today's workforce and global challenges require individuals who can integrate knowledge from various disciplines, think critically, communicate effectively, and apply their expertise to solve complex problems. This shift toward interdisciplinary and holistic education reflects the changing nature of work and the demands of a rapidly evolving world.

The following items highlight several important aspects related to education and its connection to real-world applications, interdisciplinary approaches, and the changing demands of the modern workforce:

1. Translating Academic Knowledge to Real-World Solutions

One statement underscores the common challenge faced by university graduates. While they may possess academic knowledge, they often lack the practical skills and understanding needed to apply that knowledge effectively in real-world scenarios. This gap between theory and application can be addressed through experiential learning, internships, and practical projects.

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2. Holistic approach to Sustainability and Development

Another testimony emphasizes the importance of holistic education in sustainability and community development programs. These programs should not only provide knowledge but also develop essential skills such as management, communication, and problem-solving. This aligns with the idea that addressing complex global challenges requires interdisciplinary thinking and a well-rounded skill set.

3. Interdisciplinary Solutions and polymaths

The reference to past scientific advances coming from single disciplines and the call for polymathy and generalism highlight the evolving nature of problem-solving. While many 20th-century breakthroughs came from individual fields, today's complex challenges often require collaborative efforts across disciplines. Universities increasingly recognise the value of interdisciplinary education to produce graduates who can address multifaceted issues.

4. Practical Application in High-Tech Companies

The examples from Kilo. Health and Teltonika illustrate how modern companies value employees who can bridge the gap between different departments and understand the bigger picture. This aligns with the need for graduates to not only be specialists but also generalists who can work effectively in interdisciplinary teams.

5. Innovation and Motivation

The TransUnion communication manager highlights the importance of hiring motivated talents who are inclined to create, innovate, and challenge the status quo. This mindset is crucial in addressing complex and evolving problems, as it encourages employees to seek new approaches and solutions.

6. Complex Systems and Multifactorial Issues

The reference to the importance of knowledge related to complex systems underscores the need for an analytical and interdisciplinary approach when dealing with multifaceted challenges, such as environmental issues. Understanding how different factors interact is vital for informed decision-making and problem-solving.

The interviews confirmed that introducing system thinking may play an important role in making higher education more relevant to work life.

3. What do students and lifelong learners need to learn about complex systems thinking for sustainability?

The CoSy Thinking project underscores the importance of equipping students with a combination of technical skills, critical thinking abilities, interdisciplinary knowledge, and sustainability awareness to navigate the complexities of modern society and contribute to positive change. It focuses on competencies related to sustainability thinking, including problem recognition, information collection, decision-making, and taking responsibility. The goal is to prepare students to become socially responsible citizens who can contribute positively to the economy and address environmental challenges through education and communication.

As society is increasingly being faced with complex issues relating to various systems, it is vital for students to begin learning how to navigate and understand complex systems. In general, all over academic disciplines such knowledge would be based on understanding the following key elements of complex systems:

1. **System structure and behaviour**

Firstly, learners should be able to identify a system to understand its structure and behaviour. Systems consist of 3 key components: elements, interconnections, and purpose. To begin working on systems thinking for sustainability, students must identify the components of the system they wish to study. It is best to begin by identifying the elements of the systems and then asking, how these elements interact with each. Many interconnections within systems operate through the flow of information. This information plays a major role in determining how systems operate. Students can then begin asking whether these interactions produce an effect which is different to an effect produced when elements work alone. Also, does this behaviour persist in a range of different circumstances?

2. **Network Structures**

Complex systems, such as human societies, the world economy, ecosystems, urban areas, and climate, can be described as networks comprised of nodes and links. These systems exhibit diverse architectures, and their complexity is influenced by factors such as the number of nodes, the interconnections (links), the diversity of nodes and links, and the variability of node behaviors. Social networks, in particular, are highly complex due to the extensive and lasting interactions among individuals. Innovations in Information and Communication Technologies have further increased the complexity of relationships, leading to a transition from complexity to hyper-complexity in human societies.

3. **Out-of-Equilibrium Systems**

Complex systems are considered out-of-equilibrium systems in the thermodynamic sense. Inanimate matter-driven systems are influenced by force fields, while systems involving living beings are characterized by behaviors driven by the power of living matter to pursue goals through handling information. This concept highlights the importance of understanding the dynamic and non-equilibrium nature of these systems. Similar ideas can be found in economic theory as well as in the social sciences. Economic and social systems are not in equilibrium but in a constant dynamic change due to internal or external events.

4. **Defining boundaries and hierarchies within systems and the universe.**

Students need to learn how to define boundaries and hierarchies. The definitions are highly dependent on which function of a system that is under study.

5. **Emergence**

Recognizing how system-level properties and functions emerge from interactions between parts is a key, as this is one key feature in what makes system thinking stand out as different from reductionist approaches. Complex systems exhibit emergent properties, which are characteristics that arise from the interactions of components within the network. These emergent properties cannot be understood by simply summing up the properties of individual nodes and links. Some

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emergent properties are comprehensible and predictable using principles of non-linear dynamics, while others are comprehensible but unpredictable due to deterministic chaos. There are also emergent properties, such as life and intelligence, that are not yet fully understood or predictable.

Certain emergent properties are not fully understood and predictable due to several reasons:

Descriptive Complexity: Complex systems pose challenges for reductionist approaches to description.

Computational Complexity: Some complex systems present intractable computational problems due to their exponential complexity.

Intrinsic Limitations of Predictive Science: Inherent limitations in the predictive power of science, including Heisenberg's Uncertainty Principle and chaotic dynamics, contribute to unpredictability in certain emergent properties.

6. **Feedback and runaway loops**

Understanding feedback loops and their role within sustainability is vital for addressing many of the major global issues being faced today. Furthermore, understanding how these can develop into runaway loops is also of paramount importance. Feedback generally refers to a process by which a fragment of the outflow of a system is redirected to the input flow of that system. This then changes the systems current behaviour based on its previous behaviour. This feedback loop may be the equivalent of a vicious or virtuous loop, for example, loops that accelerate (positive loop) or decelerate (negative loop) climate change. When these positive feedback loops get out of hand this is known as a positive runaway loop. Concepts such as this are critical for students to understand so that the cause-and-effect relationships within complex systems can be examined and further understood.

7. **Leverage points**

Stemming from the previous topics, leverage points are an additional concept critical to students understanding of complex systems. Leverage points are places within the complex system whereby one small or seemingly insignificant alteration may produce large alterations to various other aspects of that system (Meadows, 1999). While it is important for students to understand the meaning of leverage points and their role within complex system-thinking, it is also of upmost importance for students to learn how to identify such leverage points so as to address our current grand challenges relating to sustainability to the best of their ability.

4. Discipline specific systems thinking

The social sciences and the humanities are faced with increasing complexity in social, political, and economic systems. It highlights the significance of advancing computational agent-based modelling, interdisciplinary research, and methodologies for measuring and categorizing complexity in social processes. These approaches are important for understanding and effectively responding to complex systems' dynamics.

For the natural science and engineering, complexity science, network theory, and out-of-equilibrium thermodynamics are highlighted as essential theories for teaching. Framing the learning with real-world applications makes it possible to connect concepts with tangible examples. Using inspiration from ecological systems could make it possible to develop dynamic and resilient engineered systems

The CoSy Thinking project observes that modern chemistry education is evolving to address interdisciplinary perspectives, complex systems, sustainability, and social impact. The shift includes teaching students how to think holistically about chemistry's role in society, the environment, and diverse systems. The introduction of systems thinking in chemistry education requires a shift from the traditional reductionist approach. This shift is essential for addressing complex challenges in sustainable development, where chemistry intersects with various systems. There is a case for integrating reductionist approaches with integrative-systems thinking to design sustainable chemical products. Things to learn in chemistry are:

- Identifying constraints on systems, including technical, economic, and regulatory constraints.
- Combining reductionist knowledge with systems thinking for sustainable designs.
- Designing chemical products that maintain efficacy while reducing hazards.
- Considering the entire life cycle to address different environmental impacts at different stages.
- Setting functional performance goals rather than predefined solutions.
- Integrating social justice discussions into the organic chemistry curriculum.
- Exploring the history and societal impacts of significant compounds.
- Engaging students in practical tasks like arrow-pushing mechanisms, predicting products, and identifying functional groups.

5. Approaches and practices to the study of complex system

Besides learning the inherent properties of complex systems, students need to learn approaches to study systems:

- Self-led independent research. It leads to a problem-solving, hypothesis-testing, analytical skills and active participation in the learning process.
- The use of the participatory multi-modelling process. This model can be used to explore the creation of a boundary object ecology. The participatory process of modelling can act as a leverage point by encouraging dialogue between stakeholders.

Some examples highlight various educational practices and programs that emphasize the importance of understanding and addressing complex systems, sustainability, and interdisciplinary approaches. Here's a breakdown of each example:

1) **"Global Development" Course**: This course focuses on critical analysis of global development theories, economic growth models, environmental sustainability, geopolitical dynamics, and social justice. Students engage in understanding the interconnectedness and complexities of these areas, preparing them to navigate the multifaceted challenges of global development.

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2) **"Problem-Based Learning Programs":** Problem-based learning involves understanding complex systems by delving into competing priorities and considering sustainability within various contexts. This approach encourages students to map systems, analyze interdependencies, and explore ways to maximize positive outcomes for both people and the environment.
3) **"SDG Development Education Masters - Game Creation":** This master's program engages students in the learning process by having them create a game about development education. Through the process of designing a game, students research, learn, and gain insights into the complexities of the system, fostering a deeper understanding of sustainability challenges.
4) **"Complexity and Sustainability in Social-Ecological Systems" Course - University of Waterloo:** This course centers on understanding sustainability within complex socio-ecological systems. Students investigate the challenges arising from these systems, covering social, ethical, economic, ecological, and political dilemmas. The course aims to prepare students to address real-world complexities.
5) **"Food Bioprocessing Schemes" and "Corporate Strategies on the Environment" - Circular Economy and Sustainability:** These examples highlight programs focusing on sustainability within specific industries, such as food bioprocessing and corporate strategies. They delve into circular bioeconomy, resource and by-product valorization, and the interplay between government policies, corporate strategies, and stakeholders.
6) **"Forecasting, Innovation and Change" Masters' Degree Curriculum - University of Bologna:** This curriculum aims to equip students with competencies to identify and interpret major drivers and trends shaping a changing world. It offers a global perspective on social, economic, and environmental issues, fostering critical, innovative, and multidisciplinary analysis.
7) **"Business Informatics" Curriculum - Riga Technical University:** This curriculum combines interdisciplinary aspects of information technology, computer science, and business development. It encourages the application of systems thinking in analyzing and optimizing system performance, enhancing students' ability to understand and manage complex systems.

Overall, these examples underscore the importance of interdisciplinary approaches, systems thinking, and sustainability education to address complex challenges and create a more sustainable and interconnected world.

6. How can students learn complex systems thinking for sustainability?

There are a wide range of educational strategies, tools, and resources aimed at enhancing learning outcomes and addressing complex topics effectively. These resources cover a wide range of interdisciplinary approaches and technologies that can greatly benefit students' understanding and engagement. Here's a summary of the key points found in the CoSy Thinking project:

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6.1 Educational Strategies

1) **Complex Systems in Policy Studies**: The Complex Systems Agenda for Teaching and Conducting Policy Studies emphasizes interdisciplinary skills by integrating social sciences, computer science, and statistics to equip students for analyzing intricate policy issues.
2) **AI Strategy in Business Education**: The 3S Process (Story, Strategy, Solution) framework aids business students in applying AI to solve business problems while focusing on problem definition, AI integration, and implementation strategies.
3) **Augmented Reality in Education**: The use of augmented reality in higher education, such as in teaching mechanical design, enhances learning by providing real-time instructions and highlighting relevant tools and materials.
4) **Embedding Projector (TensorFlow)**: An open-source tool for data visualization in high dimensions, helping students analyze data transformations and identify relationships between data points.
5) **Fuzzy Logic Toolbox (MATLAB)**: Enables modeling complex system behaviors using fuzzy logic rules, suitable for dealing with imprecise or partial truths in humanistic systems.

6.2 Interactive Tools for Learning

1. **Board Games for Systems Thinking**: Engaging board games designed to enhance systems thinking skills and promote understanding of sustainable development concepts.
2. **NetLogo Web**: Interactive simulations for understanding complex phenomena related to Earth science, recycling, osmotic pressure, and more.
3. **Simulink (MATLAB):** A programming environment for modeling complex dynamic systems using mathematical formulations, valuable for various engineering fields.

6.3 Video Lectures

1. "Sustainable Development & System Thinking" - Offers real-world examples of systems thinking in sustainable development and an introduction to the concepts.
2. "Taming Complexity: From Network Science to Controlling Networks" - Introduces methods for identifying controlling nodes in complex systems presented as networks.
3. Machine Learning for Fluid Mechanics" - Explores applications of machine learning in simulating fluid dynamics and turbulence, combining physics and artificial intelligence.
4. "Evolution of Complexity and Intelligence on Earth" - Provides a multidisciplinary perspective on the evolution of complexity and intelligence across various fields.

6.4 Best Practices

1. **Doughnut Economics**: Edgar Morin highlights the limitations of separate scientific disciplines and the importance of contextualizing knowledge, urging education to emphasize both human and biological aspects of learning.
2. **Learning by Doing**: Students engage in practical experiences, such as competitions and project-based learning, to develop skills, solve real-world problems, and enhance engagement.

Overall, the collection show cases of a variety of effective approaches, tools, and practices for enhancing learning outcomes, fostering interdisciplinary thinking, and addressing complex topics in education.

7. When and where do students learn complex systems thinking for sustainability?

The CoSy Thinking project studied effective methods to foster systems thinking and engage students in real-world contexts. These approaches provide students with valuable hands-on experiences that connect theoretical knowledge to practical applications and help them understand the complexities of various systems. Here's a breakdown of the additional resources you've provided:

7.1 Service Learning and participatory Processes

1. **Service Learning:** Service learning is a teaching strategy that involves students in community service activities to address real-world needs. It not only helps students understand course content but also develops their civic responsibility and appreciation for the discipline. This approach connects systems thinking with real-world application, such as in the chemistry classroom.
2. **Systems Thinking in science Education and Outreach:** Systems thinking has been integrated into environmental science and chemistry courses by using project-based and community-service-based learning to explore planetary boundaries, green chemistry, and UN sustainable development goals.
3. **Urban Green Areas Design:** Participatory processes are used to involve local communities in designing urban green areas. Face-to-face and online tools, reflection steps, discussions, and games are used to obtain a shared and people-oriented design, emphasizing inclusivity and community involvement.
4. **Strengthening relationships between community members:** The 11th sustainable development goal is dedicated to creating sustainable cities and communities. Students and life-long learners can contribute to achieving this goal by participating in volunteer activities and charity. It makes students aware of the problems that occur in the community or local area relevant to them. This leads to sharing experiences, discussing different perspectives, looking for solutions and consensus, and monitoring progress and the actual impact on the community. Although this type of learning usually takes part outside the university and teachers' guidance, such activities contribute to creating resilient and sustainable communities by generating strong bonds between the community members.

7.2 Exercises and Lectures for Regular Classes

1. **Interdisciplinary Sustainability in Plastics**: A course titled "Perspectives on Plastic" that takes an interdisciplinary, sustainability-related approach. It uses a systems-based

approach and a spiral-like scaffolding to create interconnected themes and ideas. The curricular structure builds on concepts while focusing on real-world applications.

2. **Lecture on Untangling Complex Systems:** The lecture "Untangling Complex Systems: A Grand Challenge for Science" presented by Prof. P. L. Gentili offers historical insights into the study of complex systems. It outlines the transition from investigating simple systems to complex systems and provides perspectives for the future. This lecture can be a valuable resource for students looking to grasp the fundamentals of complexity science. The link he provided (https://www.youtube.com/watch?v=OL5INA8oyf8) allows students to access this informative presentation.
3. **Urban Public Space Role Playing Game with LEGO:** -This exercise involves a role-playing game using LEGO to enhance urban public spaces through the transfer of properties and development rights. Students take on different roles representing stakeholders with varying interests in urban development. By engaging in the game, students learn about the complexities of urban planning and development, and they work to find solutions that balance various interests and public well-being. The exercise fosters critical thinking, negotiation skills, and an understanding of the dynamics of urban systems.
4. **Virus on a Network Exercise using NetLogo**: The "Virus on a Network" exercise, implemented using the NetLogo software, simulates the spread of a virus through a network. This exercise employs the SIR (Susceptible-Infected-Resistant) model to demonstrate how infections can propagate through interconnected nodes in a network.
5. **Virtual intelligent learning (tutoring) environments**: In the learning process, virtual intelligent learning (tutoring) environments are used. Such environments usually are designed to choose the learning path that fits the students' needs best by means of recommending the tasks, learning material, form of the material (text, videos, interactive tasks). Moreover, students can usually choose the convenient time for learning.
6. **"Learning programming by creating games":** An exciting approach to learn computational thinking, programming skills, and collaborative work was described in "Learning programming by creating games through the use of structured activities in secondary education in Greece" (https://doi.org/10.1007/s10639-020-10255-8). Students design an escape-house game and implement it in Scratch. During this activity, students create the content of the escape room, that is, tasks and activities to find the exit of the room / house. Although the suggested approach is aimed at developing computational thinking and programming skills, the assignment to design an escape room or house with tasks related to the specific topic can be used in many subjects even without using digital tools.

8. Challenges in setting up a joint curriculum for a master´s program on complex systems and sustainability

8.1 Challenges of doing interdisciplinarity

The challenges and considerations related to implementing interdisciplinary education, particularly in the context of creating courses that involve specialists from different disciplines. Interdisciplinary education involves integrating knowledge and methods from multiple fields to address complex problems or broaden students' perspectives. Some important points raised in the CoSy Thinking project were:

1. **Teacher Selection and Communication**: Identifying teachers and facilitators who have a strong interdisciplinary background and are skilled at effective communication is crucial. They should be able to translate complex concepts into understandable terms for students from diverse backgrounds.
2. **Shared Understanding of Concepts:** Establishing a common vocabulary and understanding of key concepts is essential. This can be achieved through workshops, introductory sessions, and resources that explain fundamental terminology and principles from various disciplines.
3. **Curriculum Design:** Creating a coherent curriculum that seamlessly integrates different disciplines requires careful planning and collaboration among educators. Focus on identifying common themes, concepts, and skills that can be connected across disciplines. Mapping out the curriculum with clear learning objectives will help maintain consistency.
4. **Addressing Varied Backgrounds:** When dealing with students from diverse educational backgrounds, it's important to design the curriculum to accommodate different levels of prior knowledge. This might involve offering pre-module resources or prerequisite courses that bring everyone to a foundational level of understanding.
5. **Intelligent Learning environments:** Utilizing technology, such as intelligent learning platforms or adaptive learning systems, can help students bridge knowledge gaps. These platforms can provide tailored resources and assignments based on individual students' needs.
6. **Balancing Depth and Breadth:** Striking a balance between providing in-depth knowledge in specific disciplines and offering a broader interdisciplinary perspective is a key. Identify core concepts and skills that are essential for interdisciplinary understanding.
7. **Assessment Strategies:** Design assessments that reflect interdisciplinary thinking. Encourage students to apply concepts from multiple disciplines to solve problems or analyze situations. This helps reinforce the idea of interconnectedness.
8. **Continuous Learning for Educators:** Teachers and facilitators should engage in ongoing professional development to stay updated on developments in their own fields as well as related disciplines. This will enhance their ability to deliver effective interdisciplinary education.
9. **Collaboration and Dialogue:** Regular interaction among educators from different fields is crucial for refining course content, discussing teaching strategies, and identifying areas for interdisciplinary collaboration.
10. **Flexibility and Adaptability:** Recognize that interdisciplinary education is dynamic and may require adjustments over time. Embrace flexibility to accommodate new discoveries, changing perspectives, and evolving methodologies.

By carefully addressing these considerations, you can enhance the success of your interdisciplinary courses and provide students with a well-rounded education that prepares them for tackling complex real-world challenges.

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8.2 How to secure progression in the program

In the CoSy Thinking experience, the necessary condition to secure progression in the program is that the participants keep in touch and continue to collaborate. Then, the International Offices of the five partners should be involved in the process of approving the curriculum in Complex Systems Thinking for Sustainability and to offer the master's program to students.

Gradual development of students' knowledge, skills, and competencies throughout the modules of the program is a challenge. Firstly, it is possible that the students taking a course have a different background and it is difficult to identify whether the competencies with which they enter the module are at a decent level because of the previous modules or the initial background. Secondly, it is possible that the content of different modules overlaps. To tackle both issues, several solutions can be implemented. For example, the iterative yearly analysis should be conducted to overview the contents of the modules and discuss possible overlaps or occurring knowledge gaps. Similarly, the students' feedback analysis can provide valuable insights on possible modifications of the program.

8.3 Challenges from different pedagogical practices

It is necessary to create a common understanding of the distinction between "skills" and "competencies". The word "skills" means the ability to apply knowledge to solve problems. The term "competencies" means the ability to use knowledge in real situations for the benefit of society. In the Bologna system of ECTS learning outcomes has to be formulated for both forms of knowledge.

It is also important to create a common understanding of what learning assessment means. Teachers must verify if students have learned all the knowledge, skills, and competencies that are listed in the learning outcomes of the various courses. Therefore, teachers must conduct an appropriate examination to assess and evaluate students learning.

The appropriate level of involvement of stakeholders and administrative personnel must be set in context. Some countries have deep traditions in cooperation between business and educational institutions while in others such cooperation is emerging. Although the real-life problems and cases are of high importance in analyzing sustainability issues, they are difficult to integrate in the courses if the relationships between the stakeholders and educational institutions are not strong enough. The strength of the relationship also results in different teaching approaches used in the learning process, that is, either more practical or more isolated problem approaches are presented to the students.

8.4 Challenges stemming from diverse approaches

8.4.1 How to count ECTS

It took some time to determine how to count the ECTS credits because each university adopts its own method. However, the ECTS has been formulated to allow credits taken at one higher education institution to be counted towards a qualification studied for at another. ECTS credits

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represent learning based on defined learning outcomes and their associated workload. At the end of a few meetings and discussions, we decided to introduce 30 ECTS credits for each semester. They correspond to 20 weeks of learning. One ECTS credit corresponds to 25-30 hours of learning.

8.4.2 Length of courses

We decided on the structure of the curriculum and the length of the courses. We considered three elements: (1) the total number of ECTS credits, (2) the number of courses proposed by each partner, and (3) the content of the courses. After pondering these elements, we determined the final structure of the curriculum and the length of the courses.

8.4.3 How to set learning outcomes

The learning outcomes have been primarily fixed considering the content of each course. Of course, it has also been crucial to consider the entire curriculum and the knowledge, skills, and competencies that we consider fundamental for preparing the new generations to tackle global challenges and promote a sustainable future.

8.4.4 How to manage mandatory and eligible courses

The distinction between mandatory and eligible courses has been made considering the content of the courses, the fundamental learning outcomes students should achieve at the end of the curriculum, and the concrete possibility of enrolling students coming from both STEM and SHS backgrounds. Since the number of courses for the STEM path was larger than that for SHS, more STEM courses have been fixed as eligible. The course entitled "Design\Build Studio (Landscape Planning)" proposed by the University of Perugia requires the physical presence of students. Therefore, it has been fixed as an eligible course. The other eligible courses do not require the physical presence of the students, and they can be attended online.

8.4.5 How to integrate modules in the programs of university.

In Kaunas University of Technology, most of the modules are 3 or 6 ECTS. In some cases, students can choose alternative modules or freely select one from the set of modules. Using this approach, it is easier to plan the semester curriculum if the alternative modules have the same number of ECTS, or if there is a combination of modules which result in the same sum of ECTS. The other partner universities apply a similar approach, however, the desired number of ECTS may differ. Thus, although the developed joint curriculum is planned to fulfill the appropriate number of ECTS per semester, the implementation of the courses can be supported by the administration as it fits only to the students of this program.

8.4.6 Administrative issues regarding the certification of the program

The certification of a new study program is a long process, which has slightly different opportunities in the collaborating universities. Common to all is that quality assessment is done by boards or councils, demanding a proper documentation of the proposed course, The documentation may include needs for physical and personal resource required to implement the program. It is recommended to the partnering university representatives to compare notes on these issues and plan in time for the certification processes.

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