Come ThinkAgain

Certification based Education Training System

D2.1 - Review of the state of the art & consolidated competences list

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Document History			
Version	**Date**	**Comments**	**Author**
1.0	07.10.2024	Ready for publication	Bernadette Spieler, Tobias Schifferle, Melanie Kieber, Harald Burgsteiner, Julia Lanz, Martin Kandlhofer, Sandra Tomeschek, Thomas Schaberreiter, Karl Kruusamäe, Farnaz Baksh, Marianne Kinnula
1.1	16.10.2024	Added EU logo and disclaimer on the title page; updated header and footer to match project deliverable template.	Karl Kruusamäe

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EXECUTIVE SUMMARY

This deliverable provides a comprehensive review of state-of-the-art competence frameworks in the EU and globally, as part of Task 2.1 of the ERASMUS+ ComeThinkAgain project. The objective is to identify and analyse how competences in Computational Thinking (CT), Entrepreneurship Education (EE), and Green Skills (GS) are currently integrated into educational systems. By examining existing frameworks, policies, curricula, and practical implementations, the deliverable aims to contribute to the development of a standardized global competence framework that promotes employability, creativity, and new career pathways.

The report begins with a detailed exploration of the definitions and importance of CT, EE, and GS, providing a foundation for understanding the relevance of these competences in the current and future job market. Existing frameworks such as DigComp (Digital Competence Framework), EntreComp (Entrepreneurship Competence Framework), and GreenComp (European Sustainability Competence Framework) are assessed in terms of their applicability, strengths, and gaps. Through a cross-analysis of these competences, synergies and overlaps are identified, highlighting the potential for integrated approaches to education that address multiple competence areas simultaneously.

Moreover, the deliverable evaluates various training methods and curriculum integration strategies across primary, secondary, vocational, and higher education settings. It emphasizes the importance of embedding these competences within educational frameworks to prepare students for the evolving labour market, particularly in sectors driven by digital transformation, sustainability, and entrepreneurial innovation.

Finally, the document proposes a consolidated ComeThinkAgain competence list, designed to enhance employability and foster interdisciplinary skills that align with market demands. This list serves as a stepping stone toward a globally recognized competence standard, supporting institutions in developing education and training programs that are relevant, forward-thinking, and aligned with sustainable development goals.

1. INTRODUCTION

1.1. Project Overview

Living in a rapidly changing world, there is a need to prepare our future generations for dealing with many aspects concerning modern life (e.g., digitalisation or climate change) by equipping them with the necessary skills to do so. With respect to this, interdisciplinarity and multifaceted competences are key in the 21st century also when addressing the challenges of tomorrow's professions. Thus, the ComeThinkAgain project aims to develop and implement a cross-sectoral, standardised training and certification system which builds on three competence pillars, interwoven with each other: computational thinking, entrepreneurship education, and green skills. Given the fact that teachers and trainers are educating the future workforce, the main target groups are teachers trained at Higher Education level and Vocational Education Training (VET) trainers. The outcome of the project will be a Micro-Certification based Education Training System called "ComeThinkAgain CETS (CTA-CETS)," offering micro-modules for both vocational and higher education at a European level, ensuring a workforce, which is ready for the future.

1.2. Purpose of the Document

With this document we want to provide a comprehensive analysis of the state-of-the-art approaches concerning the definition and education of computational thinking skills (CT), entrepreneurship education (EE) and green skills (GS) which comprise the three competence pillars of the ComeThinkAgain project. This will lead to a deeper understanding of the competences required in order to develop skills necessary for CT, EE and GS and support the creation of the preliminary competence list, the ultimate objective of this document. The structure of D2.1 comprises nine chapters, which are briefly presented below:

- **Chapter 1. Introduction** briefly introduces the ComeThinkAgain project and outlines the purpose and objectives of this document.
- **Chapter 2. Preliminaries** defines the key educational concepts that will guide the design of effective programmes for CTA-CETS.
- **Chapters 3 to 5** form a literature review of **CT**, **EE**, and **GS**, respectively. These chapters provide an overview of the importance, definitions and current trends in education concerning the three competence pillars CT, EE, and GS. They analyse scientific literature and proposed frameworks on which key-competences make up the respective field of competence and how these can be implemented in education. Additionally, commonly used existing training methods and pedagogical strategies are reviewed. These chapters help us to get a comprehensive understanding on which competences comprise CT, EE, and GS and thus to identify a list of competences further to be worked with in the ComeThinkAgain project.
- **Chapter 6. Overview of the competence frameworks aligned with ComeThinkAgain** outlines which competences make up CT, EE and GS according to the three competence frameworks proposed by the European Commission, DigComp, EntreComp and GreenComp. Since these competence frameworks fit well with the context and objectives of the ComeThinkAgain project, they provide the basis of orientation and thus are used as benchmarks for the further analysis the final list of competences.
- In **Chapter 7. Competence area cross-analysis**, a correlation of the competences and frameworks contributing to the education of CT, EE and GS found in literature with the DigComp respectively EntreComp and GreenComp frameworks as benchmarks is provided. The goal is to get an overview on how the frameworks are matching with

each other and the DigComp/EntreComp/GreenComp and to identify relevant competences missing by them if necessary. Additionally, this chapter outlines skill gaps as well as challenges in the education of the respective fields of competences.

- In **Chapter 8. Synergies and intersection analysis** we identify overlapping and complementary aspects of CT, EE and GS with each other and at the intersection of all the three competence areas. This will help determining synergies between CT, EE and GS and how specific competences can promote and strengthen not only one but all of the targeted competence areas in the ComeThinkAgain project.
- **Chapter 9. ComeThinkAgain competence list** is the central outcome of D2.1. It presents the preliminary competence list elaborated from the preceding chapters and creates the foundation of the key competences for CT, EE, and GS which we want to further work with and address within the ComeThinkAgain project and the CTA-CETS.

2. PRELIMINARIES

In developing a training and certification system, it is important to first define the key educational concepts that will guide the design of effective programmes. This section will explain the foundational terms: learning, understanding, skills, and competence; establishing the groundwork for how these elements interact and are developed. These definitions will form the basis for exploring how the ComeThinkAgain project builds interdisciplinary competences in computational thinking, entrepreneurship, and green skills.

Learning is the process through which an individual assimilates information, ideas and values and thus acquires knowledge, know-how, skills and/or competences (CEDEFOP 2014). It occurs when people make connections between new information and their existing knowledge. Learning is not a one-size-fits-all process; it varies based on internal factors such as motivation and external conditions like the learning environment (Kimble 2024; Weinstein, Madan, and Sumeracki 2018). By examining various learning theories, educators can design environments and strategies that better support individual growth and development (Saunders and Wong 2020).

Various theories explain the learning process, including behaviourism, which focuses on stimulus-response connections, and cognitive theories, which emphasize understanding and mental processes. Learning can occur through methods like conditioning, association, and problem-solving, and is influenced by factors such as motivation, reinforcement, and the learner’s environment (Kimble 2024).

Understanding refers to the ability to grasp the meaning, significance, or nature of something, which goes beyond merely recalling facts. In educational psychology, true understanding requires integrating new information with prior knowledge to form meaningful connections (Editors of Encyclopaedia Britannica 2024).

According to (Hounsell 2005), genuine understanding requires relating knowledge to one's existing experiences, helping learners make sense of the world. The success of achieving this level of understanding depends heavily on the ability of educators to recognise students' existing conceptions and help anchor new knowledge within those frameworks. When students achieve this, learning becomes deeper and more transformative.

Skills are specific abilities or expertise that are developed through practice and learning. In the educational context, skills represent the application of knowledge gained through learning and understanding, allowing individuals the power of doing something competently (Anon 2024).

The European Qualification Framework (EQF) categorises skills as being cognitive and practical. A cognitive skill refers to logical, intuitive, and creative thinking, while practical involves manual agility combined and the use of methods, materials, tools, and instruments (Pereira, Amaral, and Mendes 2023).

Unlike hard skills, which are role-specific, soft skills are broadly transferable across industries. Soft or interpersonal skills are useful for enabling individuals to work effectively in teams and organisations (Donovan 2024).

Skill development is a key focus of the European Union’s flagship initiatives aimed at improving socio-economic outcomes. These strategies emphasise the need for a highly skilled workforce, particularly in soft skills like entrepreneurship, coping skills, and learning how to learn. Such skills are crucial in helping students transition smoothly from education to the workforce, enabling them to solve problems creatively and succeed in the labour market (Cinque 2016).

Competence refers to the ability to apply knowledge, skills, and personal, social, or methodological abilities in work or study situations, as well as in personal development. It includes more than just cognitive elements; it also encompasses functional aspects like technical skills, interpersonal attributes (e.g., communication, teamwork), and ethical values. This broader view of competence highlights the importance of combining different abilities to perform effectively in various contexts (CEDEFOP 2014).

To achieve real competence, learners must actively engage with and construct their own understanding of the subject, rather than passively absorbing information, making the knowledge personal and meaningful to them (Hounsell 2005).

Having a shared understanding of competence is vital for ensuring that educational programmes that aim to develop competence meet the needs of individuals, society and the labour market, nationally and internationally (Vitello, Greatorex, and Shaw 2021). In the report, they delve into six principles to explore the multidimensional nature of competence and its relevance in education:

1) Competence is linked to a domain and dependent on context.
2) Competence is a holistic concept; highlighting three interconnected aspects of competence: the person, the context and the action.
3) Competence is about consistent performance across contexts within a domain, which supports predictions of future performances.
4) Competence involves applying contextually appropriate knowledge and skills.
5) Competence involves psychosocial factors, which affect performance and influence learning.
6) Competence is connected to a specified level of learning or ability.

A **competence framework** is a structured model that defines and organizes the specific skills, knowledge, attitudes, and behaviors required for individuals to perform effectively in a particular domain, profession, or context (IAEA 2018). It serves as a guideline to ensure that learners or professionals acquire the necessary competences to meet job requirements, achieve personal development, or address societal challenges.

3. COMPUTATIONAL THINKING

3.1. *Definition and Importance*

3.1.1. Definition of CT

Papert used the concept of "Computational Thinking" first in his book "Mindstorms: Children, Computers, Powerful Ideas" (Papert 1980) without explaining the concept in detail. However, his work contains some of the basic ideas of Computational Thinking (CT). More than 40 years ago, he pointed out that children can learn to manage computers and that these experiences can influence their fundamental way of learning and thinking. To advance this idea, years earlier Papert had co-developed the LOGO programming language, in which a turtle is moved across the screen by programming commands, leaving a line along its path. He is also considered the founder of the learning theory of constructionism. According to Resnick (1996), constructionism is based on the assumption that learning is an active process that is most effectively achieved through the construction of meaningful artifacts. Resnick is known for the development of the block-based programming software Scratch, which is largely based on Papert's philosophy.

Wing (2006) later adopted the term CT again and defined it as the way computer scientists think. This statement is vague, especially for someone unfamiliar with the profession. However, Cuny et al. explain that it is the thought processes used to formulate a problem so that its solution can be executed by an information-processing agent (Cuny, Snyder, and Wing 2010).

"*Computational Thinking is the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent*" (Cuny et al. 2010)

This definition is similar to that of Aho (2012). He considers CT as a thinking process for formulating problems so that their solutions can be represented in computerized steps and as algorithms.

According to Lodi and Martini (2021), Wing's 2006 article sparked a variety of initiatives to promote computer science education. As a result, numerous researchers are trying to define computer science (CS) and its elements. Lodi (2020) examined 16 articles dealing with the definition of computer science. According to him, the most commonly used definitions are similar in many ways. There is a consensus that computer science is a way of thinking that is used to solve problems. The solution is presented in a form that can be executed by a processing agent. Shute, Sun, and Asbell-Clarke (2017), who analyzed various definitions and models of CT on the basis of a review, also state that CT is a basis for problem-solving in which solutions are constructed that can be transferred to other contexts. They thus understand CT as a collection of skills that are used specifically in computer science and generally for problem-solving.

The idea that CT can be used for problem-solving far beyond computer science is not fully supported in the computer science community. Denning (2017) emphasizes that the popularity of CT has led to misinterpretations. He criticizes that CT is attributed interdisciplinary benefits for which there is no evidence, and that expectations of a universal problem-solving tool are raised that cannot be fulfilled. For him, CT is closely linked to the concepts of computer science and is used to calculate computational models. According to Denning and Tedre (2019), it encompasses the mental skills and practices necessary to design computations so that computers can do the work for us and explain and interpret the world as a complex of information processes.

Tedre, Denning, and Toivonen (2021) emphasize that the use of computers plays a central role in the application of CT. They state: «*If there were no computers, just algorithms, computing* *would be mostly an abstract exercise in abstract logic with much more limited practical use in the world. »*

In contrast, Kafai, Proctor, and Lui (2020) emphasize that the different perspectives of CT complement each other and should not be seen as competing. They view the diversity of perspectives as a resource that contributes to a better understanding of the complex environment in which computer science teaching and learning is situated.

Finally, the definition of the International Society for Technology in Education (ISTE) and the Computer Science Teachers Association (CSTA) should be mentioned. These are two associations that promote computer science education internationally. ISTE and CSTA (CSTA 2011; ISTE and CSTA 2011) attribute the following aspects to computer science education:

- Formulate problems so that computers and other tools can be used to solve them;
- Organize and analyse data logically;
- Representing data in the form of abstractions, such as models or simulations;
- Automate solutions through algorithmic thinking;
- Identify, analyse and integrate possible solutions with the goal of achieving the most efficient and effective combination of solution steps and resources; and
- Generalizing and transferring the problem-solving process to a wide range of problems.

To formulate these aspects, more than 700 computer science teachers, researchers and computer scientists were interviewed.

3.1.2. Importance of CT

The problem-solving strategies of computer science are often considered in the context of the relevant skills and competences of the 21st century - known as 21st Century Skills or 21st Century Competencies. These are skills and abilities that are particularly in demand in the 21st century. These include critical and analytical thinking, problem-solving skills, creativity, communication and much more.

Many agree that the thinking and working methods used in computer science are of general value. They help to solve problems more effectively and enable precise planning, work and communication within a team. Wing (2006) confirms this by stating that computer science is part of every child's analytical skills alongside reading, writing and arithmetic. Genner (2019) also mentions CT in her collection of the essential professional skills of the digital age. She analysed and compiled 26 models and almost 100 competences and skills in this regard. Wehrl (2019) also emphasizes that every child should learn the basics of computer science, as computer science permeates most professional fields and everyone needs to understand its basics. These ideas are also supported by many countries. For example, the Eidgenössische Kommission für Kinder- und Jugendfragen (2019) calls for children and young people to learn both technical and social skills for their lives and their future working world, including IT.

This demand has also been voiced by international institutions. Ananiadou and Claro (2009) state in their OECD document that coping with today's flood of information requires special skills. These include searching, selecting, evaluating and organizing information. They also mention restructuring and modelling information and one's own ideas. Computational Thinking deals precisely with these skills - collecting, analysing, abstracting, presenting, modelling and evaluating data.

The non-profit organization Institute for the Future (IFTF) (Institute for the Future 2020) also lists CT in its report on the ten most important future skills. Similarly, the DQ Institute (DQ Institute 2020) lists 24 digital skills in its framework, including content creation and computer literacy, which includes CT. The DQ Institute measures global digital literacy and is supported by the IEEE Standards Association, the OECD and the World Economic Forum (WEF). The WEF (World Economic Forum 2015) itself lists ICT skills as one of the critical skills of the 21st century in a meta-analysis, referring to the ability to use and create technology-based content, process information and program computers.

Finally, Burke, O'Byrne, and Kafai (2016) point to the need for young people to understand algorithmic decision-making processes. They should also be able to collaborate with humans as well as with artificial intelligence and machines. CT plays a central role in this. In this way CT helps to better understand machines and their processes. Understanding something means losing the fear of the unknown and gaining a certain degree of autonomy.

3.2. Current Trends and Developments

The examination of the definition of CT has shown that CT clearly encompasses problem-solving strategies related to the discipline of computer science. Lodi and Martini (2021) continue that CT is a component of computer science and not a new discipline. Nevertheless, the fields only overlap. For example, the problem-solving strategies of CT go beyond the field of computer science, and analogies to problem-solving process models in psychology can be recognized. This is not surprising, as CT deals with thinking strategies.

Despite being an actively researched field for almost 20 years since Wing's reintroduction of the term in 2006, no general definition of CT has been agreed on by the scientific community. However, according to a systematic review by the European Commission. Joint Research Centre. (2022b), three general areas in which definitions of CT can be contextualized where identified:

1) CT as a way of thinking for the development of solutions solvable by computers.
2) CT as a thinking process model for problem-solving.
3) CT as a thinking skill that can be used to solve real-world problems.

The authors of the study express, that irrespective of the definition, CT is always more than problem-solving and includes a next step where solutions must be "expressed in a way, that allows a computational agent to execute it" (European Commission. Joint Research Centre. 2022b). Therefore CT is not about thinking "like a computer" but rather "like a computer scientist" (Grover and Pea 2018) or more general, solving any problem in everyday life more effective (Curzon et al. 2019). Even if definitions vary and some include domain-general problem-solving, many of them are very strongly connected to programming or more abstract principles of computing (Tang et al. 2020). The European Commission review lists three main but intertwined categories of CT definitions (European Commission. Joint Research Centre. 2022b):

1) ***generic definitions*** *i.e., CT as a thought process that resonates with computing/programming disciplines, but can be independent of them;*
2) ***operational-model definitions****, which break down CT into sets of fundamental competences/practices, like abstraction and generalisation, that are firmly rooted in computer science and computing but are applicable elsewhere; and*
3) ***definitions bound to educational and curricular frameworks*** *that essentially involve problem-solving approaches inspired by computer science or are applicable in computing.*

While there are many concepts associated with generic or domain-specific rooted definitions, "abstraction", "algorithmic thinking", "automation", decomposition" and "generalization" can be seen as a common base of concepts (Curzon et al. 2019; European Commission. Joint Research Centre. 2022b).

There are several extensions of the CT definition to add different aspects to generic CT, such as **computational participation**'s social cultural dimensions: *"[…] computational participation is the ability to solve problems with others, design systems for and with others, and understand the cultural and social nature of human behavior, by drawing on concepts, practices, and perspectives fundamental to computer science."* (Kafai 2016) **or computational literacy**'s sociocultural dimension: "[…] *defining computational thinking as a* *literacy integrates the literatures on computational literacy, new literacies studies, new media studies, and computer literacy* (Jacob and Warschauer 2018)*.*

As another trend, Dindler et al. (2022) propose the concept of **computational empowerment** which expands the generic definition of CT and adds a broader goal of developing an understanding for the effects of digital technology on life and society. This is achieved by providing a framework to analyse and reflect technology (Dindler et al. 2022).

Curzon et al. (2019) state, that CT can be assessed either through programming or through general problem-solving. Given this project's holistic approach of ComeThinkAgain CETS microcrendentials targeting students in different countries and different qualification areas, one cannot specify a certain level of programming skills or specific programming languages as a prerequisite. Knowing that CT is always closely linked to computer science, this suggests that the definition of CT used in this project must be from the generic category to not make it computer science only.

3.2.1. Efforts to bundle CT competences from the literature

Zhang and Nouri (2019) confirm that there are differentiated ideas about the operationalization of CT in the curricula of different countries as well as in the literature. This is also evident in Figure 1, which lists various CT competences. Some of these competences are frequently mentioned in the literature, while others are only mentioned occasionally.

	Barr and Stephenson (2011)	Brennan and Resnick (2012)	Selby (2012)	Grover and Pea (2013)	Seiter and Foreman (2013)	Kalelioglu, Gülbahar, and Kukul (2016)	Angeli et al. (2016)	Repenning, Basawapatna and Escherle (2016)
Abstraction	✓	✓	✓	✓	✓	✓	✓	✓
Algorithm	✓	✓	✓	✓	✓	✓	✓	
Data	✓	✓		✓	✓	✓		
Decomposition	✓	✓	✓	✓	✓	✓	✓	
Parallelisation	✓	✓		✓	✓	✓		
Testing & Debugging	✓	✓		✓		✓		✓
Control structure	✓	✓		✓		✓		
Automation						✓		✓
Generalisation			✓			✓	✓	
Simulation	✓		✓			✓		
Event		✓						
Being incremental & iterative		✓						
Expressing & connecting & questioning		✓						
Reusing & remixing		✓						
Efficiency & performance constraints				✓				
Systematic processing				✓				
Conceptualising						✓		

Figure 1: List of computational thinking skills in the literature according to Zhang and Nouri (2019)

Figure 2 shows another set of CT operationalizations from Shute et al. (2017) based on different models. In particular, the authors focus on articulating CT competences in such a way that they can be linked to school subjects at the K-12 level (kindergarten through 12th grade). This distinguishes their approach from models that focus narrowly on programming aspects.

Brennan and Resnick (2012), Grover and Pea (2018), the K-12 Computer Science Framework Organization (2016), and Weintrop et al. (2016) distinguish between CT concepts and CT practices when specifying CT. Concepts describe the cornerstones of computer science problem-solving strategies; practices represent the actions and processes that are practiced and applied in implementing the concepts. For example, Grover and Pea's concept of logic and reasoning involves analysing situations, making decisions, and drawing conclusions. A related practice is problem decomposition - the breaking down of a problem into smaller sub-problems. This makes it easier to categorize the actual problem and keeps the problem-solving process manageable. This principle is also known in computer science as the "divide and conquer" method.

Facet	Definition
Decomposition	Dissect a complex problem/system into manageable parts. The divided parts are not random pieces, but functional elements that collectively comprise the whole system/problem.
Abstraction	Extract the essence of a (complex) system. Abstraction has three subcategories: (a) *Data collection and analysis*: Collect the most relevant and important information from multiple sources and understand the relationships among multilayered datasets; (b) *Pattern recognition*: Identify patterns/rules underlying the data/information structure; (c) *Modeling*: Build models or simulations to represent how a system operates, and/or how a system will function in the future.
Algorithms	Design logical and ordered instructions for rendering a solution to a problem. The instructions can be carried out by a human or computer. There are four sub-categories: (a) *Algorithm design*: Create a series of ordered steps to solve a problem; (b) *Parallelism*: Carry out a certain number of steps at the same time; (c) *Efficiency*: Design the fewest number of steps to solve a problem, removing redundant and unnecessary steps; (d) *Automation*: Automate the execution of the procedure when required to solve similar problems.
Debugging	Detect and identify errors, and then fix the errors, when a solution does not work as it should.
Iteration	Repeat design processes to refine solutions, until the ideal result is achieved.
Generalization	Transfer CT skills to a wide range of situations/domains to solve problems effectively and efficiently.

Figure 2: Summary of the Computational Thinking facets according to Shute et al. (2017), incl. definition.

At this point, we would also like to briefly discuss an area of computer science that has become increasingly popular in recent months and years. We are talking about artificial intelligence and machine learning.

In contrast to conventional programming, machine learning, according to Tedre et al. (2021), does not specify rules for calculating a function. Instead, a machine is made to learn approximations to a function. According to the authors, this fact means that several CT concepts, including debugging, problem-solving, correctness and fictitious machines, are unsuitable for machine learning or need to be extended. In addition, machine learning introduces new concepts that were not previously considered aspects of CT, such as neural networks, data preparation and training, and reinforcement learning.

	CT1.0	CT 2.0
Problem solving: Stage 1	Formalize the problem	Collect data from the intended context
Problem solving: Stage 2	Design a solution	Filter and clean data. Label data.
Problem solving: Stage 3	Implement the solution in a stepwise program	Train a model from the available data
Problem solving: Stage 4	Compile and execute the program	Evaluate and use the model
Universality of solution	Weakly context-dependent	Strongly context-dependent
Goodness of solution	In some cases clearly works or doesn't. Can be formally proven to be either correct or incorrect (at advanced levels). Effectiveness can be proven.	Models may display higher or lower confidence. Efficiency can be established through testing. Statistically better or worse (at advanced levels).
Testing	Black-boxed or glass-boxed cross checking of the outputs and the program code	Evaluate the model against predictions, completely black boxed
Debugging	Tracking and tracing program states and code for error.	Experimenting with data, parameters, and hyperparameters, based on trial and error
Philosophy of problem solving	Deductive	Inductive
Structure	Transparent. Visualization tools available.	Black boxed
Notional machines	Stepwise, deterministic, discrete flow of program through states (as contents of memory locations).	Parallel, possibly nondeterministic, passing data through a network
Complexity concerns	Prepare for worst case, optimize for average case	No time / space variance between passing data through a network
Portability	Tedious to make portable to different platforms.	Straightforwardly portable
Trial and error	Discouraged	Necessary
Software life cycle	Traditional, well established life cycle. Clear versioning.	More data create new "versions". Documenting is based on empiricism and reporting of training data.
Syntax and semantics	Syntactically strict, highly structured	Data can be unstructured, loose semantics

Figure 3: Comparison of current computational thinking practices with the extended computational thinking 2.0 practices according to Tedre et al. (2021).

All these changes challenge traditional views of CT instruction in grades K-12. Tedre et al. (2021) refer to the expansion of current CT concepts and practices as CT 2.0. Figure 3 shows a comparison between traditional CT practices compared to the extended CT 2.0. To promote CT 2.0, they suggest that children learn to create their own data sets. Learners can generate such data using a webcam, microphone, photos, or other sensors. With the information collected, children can then train their own machine learning models and create personal automations without the need for traditional programming skills. Google's Teachable Machine or the website MachineLearningForKids.co.uk, for example, are ideal for such undertakings. The latter was developed by Dale Lane, a software developer at IBM.

Another example of expanding traditional CT concepts is «AI Literacy», which Casal-Otero et al. (2023) identify as both a cognitive and pedagogical challenge in K-12 education. Understanding how AI works empowers students to engage critically with technology, fostering both critical thinking and CT skills. Critical thinking helps students assess AI's capabilities and limitations, while CT skills like problem-solving, abstraction, and algorithmic thinking enable them to understand and interact with AI systems.

In many cases, subjects such as math and technology are used as vehicles for embedding foundational CS concepts. This approach is followed in various education systems where subjects are tailored to include both computational and digital competences and prepare students for the digital demands of the future. Figure 4 effectively categorizes the diverse CT skills into two principal groups, emphasizing their relevance to both general problem-solving and specific programming and computing contexts.

Computation Thinking associated with generic problem solving	**Computation Thinking associated with programming and computing**
Abstraction	Algorithmic Thinking
Data Analysis	Algorithm Design
Data Collection	Automation
Data Representation	Boolean Logic
Decomposition	Computation
Efficiency	Computational Modelling
Evaluation	Conditionals
Generalisation	Data Types
Logics & Logical Thinking	Events
Modelling	Functions
Patterns & Pattern Recognition	Iteration
Repeating Patterns	Loops (Repetition)
Simulation	Modularisation
System Thinking	Parallelisation
Visualisation	Sequencing
	Testing & Debugging
	Threads (Parallel Execution)

Figure 4: Categorization of CT skills in problem-solving and programming contexts as derived from the study by the European Commission Joint Research Centre (2022).

In examining the landscape of CT within educational frameworks, Ezeamuzie and Leung (2022) proposed different models and frameworks to describe CT competences. The following table summarizes these different perspectives and highlights how different researchers have conceptualized CT elements in different studies. This synthesis not only reflects the evolving understanding of CT, but also underscores the multidimensional nature of CT skills recognized in education worldwide.

Table 1: Synthesis of the CT understanding according to Ezeamuzie and Leung (2022).

Author(s)	Definition
(Bers et al. 2014)	CT variables – debugging, sequences, correspondence, flow control
(Yadav et al. 2014)	CT concepts – problem identification, decomposition, abstraction, logical thinking, algorithms, debugging
(Atmatzidou and Demetriadis 2016)	CT dimensions – abstraction, generalisation, algorithms, decomposition, modularity
(Atmatzidou and Demetriadis 2017)	CT concepts – abstraction, generalisation, algorithms, decomposition, modularity, debugging
(Looi et al. 2018)	CT skills – decomposition, algorithms, abstraction, generalisation, evaluation
(Witherspoon et al. 2018)	CT concepts – sequences, conditionals, iteration
(Tran 2019)	CT concepts – sequences, algorithms, looping, debugging, conditionals
(Nam, Kim, and Lee 2019)	Forms of CT – sequencing, problem-solving
(Calderon et al. 2020)	CT elements – abstraction, decomposition, data, algorithms, sequences
(Chen, He, and Yang 2020)	CT items – creativity, valuableness, simplification, embedding, simulation, transformation
(Angeli and Valanides 2020)	CT elements – algorithm, sequencing, decomposition, debugging
(Noh and Lee 2020)	CT components – data collection, data analysis, structuring, decomposition, modelling, algorithm, automation, generalisation
(Yin et al. 2020)	CT subskills – decomposition, abstraction, algorithm, pattern generalisation
(Uzumcu and Bay 2021)	CT dimensions – problem understanding, flowchart, operators, conditionals, loops, parallelism, decomposition, abstraction, pattern, algorithms, evaluation, debugging

To improve the understanding of how different factors influence prospective teachers' computational thinking (CT) skills, this study examined the CT skills that have been emphasized in previous studies. The results of 38 studies were used to categorize and analyze nine different CT skills. These skills include critical thinking, creative thinking, abstraction, troubleshooting, decomposition, problem-solving, algorithmic thinking, programming or coding skills, and understanding CT concepts. Detailed definitions of these CT skills are listed in Table 2.

Table 2: Categorization of the nine different CT skills derived from Dong et al. (2024)

CT Skills	Definition
Abstraction	Identifying and extracting relevant information to define main ideas (Barr and Stephenson 2011; Grover and Pea 2013; Wing 2006)
Critical Thinking	The use of cognitive skills or strategies that increase the probability of a desirable outcome (Halpern 1996)
Decomposition	Breaking down data, processes, or problems into smaller, manageable parts (Atmatzidou and Demetriadis 2016)
Programming or Coding Skills	The knowledge and skills gained through learning computer programming or coding could develops capabilities to think conceptually and problem solve at multiple levels of abstraction (Popat and Starkey 2019; Wing 2006)
Debugging	Find your own mistakes and fix them (Atmatzidou and Demetriadis 2016; Berland and Lee 2012; Yadav et al. 2014)
Problem-solving	The final step of logical thinking (Ngan and Law 2015)
CT Concept	Pre-service teachers' understanding of CT evolved from how calculations are made by computers to how complex problems can be solved through step-by-step plans (Umutlu 2021)
Creative Thinking	'Creative thinking' reveals the kind of thinking that leads to new insights, novel approaches, fresh perspectives, whole new ways of understanding and conceiving of things (Eragamreddy 2013)
Algorithms	Creating an ordered series of instructions for solving similar problems or for performing a task (Barr and Stephenson 2011; Grover and Pea 2013)

Wing (2006) identified 11 thinking processes within computational thinking (CT), including abstraction, algorithm design, decomposition, pattern recognition, and data representation. Additionally, Hsu, Chang, and Hung (2018) incorporated further computational thinking steps found in previous studies, as detailed in Table 3.

Table 3: The classification of pre-service teachers' CT skills by Hsu, Chang, and Hung (2018)

#	Thinking steps	Definition	Resource
1.	Abstraction	Identifying and extracting relevant information to define main ideas.	(Barr and Stephenson 2011; Grover and Pea 2013; Wing 2006)
2.	Algorithm Design	Creating an ordered series of instructions for solving similar problems or for performing a task.	(Barr and Stephenson 2011; Grover and Pea 2013)
3.	Automation	Having computers or machines do repetitive tasks.	(Fletcher and Lu 2009; Forrest and Mitchell 2016; Kafai and Burke 2013)
4.	Data Analysis	Making sense of data by finding patterns or developing insights.	(Angeli et al. 2016; Atmatzidou and Demetriadis 2016; Basu, Biswas, and Kinnebrew 2017; Cesar et al. 2017; Choi, Lee, and Lee 2016; Magana and Silva Coutinho 2017)
5.	Data Collection	Gathering information	(Barr and Stephenson 2011; CSTA 2011)
6.	Data Representation	Depicting and organizing data in appropriate graphs, charts, words, or images.	(Benakli et al. 2017; Gynnild 2014; Manson and Olsen 2010; Stefan et al. 2015; Weintrop et al. 2016)
7.	Decomposition	Breaking down data, processes, or problems into smaller, manageable parts.	(Kilpeläinen 2010)
8.	Parallelization	Simultaneous processing of smaller tasks from a larger task to more efficiently reach a common goal.	(Barr and Stephenson 2011)
9.	Pattern Generalization	Creating models, rules, principles, or theories of observed patterns to test predicted outcomes.	(ISTE and CSTA 2011)
10.	Pattern Recognition	Observing patterns, trends, and regularities in data.	
11.	Simulation	Developing a model to imitate real-world processes.	(Barr and Stephenson 2011; Grover and Pea 2013; Wing 2006)
12.	Transformation	Conversion of collection information.	(Wing 2006)
13.	Conditional logic	Finding the associated pattern between different events.	(Grover and Pea 2013)
14.	Connection to other fields	Finding the relationships between information.	(CSTA 2011)
15.	Visualization	Visual content is easier to understand	
16.	Debug & error detection	Find your own mistakes and fix them	(Atmatzidou and Demetriadis 2016; Berland and Lee 2012; Yadav et al. 2014)
17.	Efficiency & performance	Analyse the efficiency of the final results in order to achieve a more perfect goal.	(Grover and Pea 2013)
18.	Modelling	Solve the current problems through the model architecture or develop a new system.	(Barr and Stephenson 2011; ISTE and CSTA 2011)
19.	Problem-solving	The final step of logical thinking.	(Kim and Kim 2016; Ngan and Law 2015)

In summary, the definitions and classifications of CT must always be seen in a broader context.

3.2.2. DigComp

The Digital Competence Framework, commonly known as DigComp, is a comprehensive structure developed by the European Union to describe and improve the digital competence of individuals.

Figure 5: The five main areas of digital competences

The framework divides digital competence into five main areas:

1. **Information and data literacy**: This includes identifying, locating, retrieving and storing digital data, information and content. It also includes assessing the relevance and purpose of these digital resources.
2. **Communication and collaboration**: This includes interacting, communicating and collaborating using digital technologies, managing digital identity and reputation, and using digital technologies to participate in society.
3. **Digital content creation**: This is about creating and editing new digital content, understanding copyright issues and integrating digital content into existing knowledge.
4. **Security**: This is about protecting devices, personal data and privacy in digital environments as well as dealing with health and environmental issues related to the use of digital technologies.
5. **Problem-solving**: This includes recognizing needs and technological solutions, using digital tools in innovative ways and continuously updating one's digital skills.

DigComp provides a clear pathway for assessing and developing these skills at different levels, from the basics to highly specialized skills. It serves as a guide for educational programs, policy decisions and workplace training aimed at improving digital literacy.

More about the DigComp in Section 6.1.

3.2.3. More CT Frameworks

The Computational Thinking for Science (CT-S)

The CT-S (Computational Thinking for Science) framework (Hurt et al. 2023) was developed to integrate computational thinking into K-12 science education by considering the interaction between computational tools and cognitive processes. The focus is on the bidirectional exchange of information between the thinker and the computational tool, rather than just the transmission of instructions to a tool. This framework emphasizes the importance of understanding the functioning and role of computational tools in scientific inquiry and learning activities.

CT-S		Cognitive Processes		
		Reflective Use	Design	Evaluation
		of a computational tool for		
Science Activity	Data Collection	How can I use the time-lapse photography feature on my phone to collect data on how fast my plants grow?	How could I change my robot's code so that it would randomly sample the quadrats for my ecological study?	If this pseudocode for getting the temperature sensor readings was running on my computer, under which conditions would it work well, and when might it fail?
	Data Processing	Which features in the spreadsheet software can help me identify the relationship that exists between force, mass, and acceleration?	I have images that show the sun's height above the horizon from every day of the year from a given location taken at solar noon; what would I need software to do to help me find patterns related to seasonal changes?	I am using software to create a data visualization of how the air quality in my city changed due to forest fires; what are the software's affordances and limitations for helping me communicate those data?
	Modeling	How can I use an orrery to predict the next transit of Venus?	What rules would I need to include in a plate tectonics simulation to accurately model different types of plate boundaries?	Which aspects of this digital model accurately reflect natural selection and which do not?
	Problem-Solving	I want to share my experimental procedure for measuring the speed of sound with a lab partner who is blind; how can I use their screen-reading software to make sure the procedure will be communicated correctly?	My classmates gave different arguments about climate change; how could I create an algorithm to evaluate the claims and reasoning of their respective arguments?	I need to test a phone app that was designed to call an emergency contact when it detects a car crash; how should I test it and how will I know I have sufficiently tested it?

Figure 6: Computational Thinking for Science framework derived from Hurt et al. (2023)

Computational Systems Modeling Framework

The Computational Systems Modeling Framework was developed to bridge systems thinking (ST) and computational thinking (CT) in education, with a focus on their application in K-12 education. This framework emphasizes the importance of modelling practices that integrate both ST and CT and provide a robust approach to understanding complex systems through computational methods.

The Computational Systems Modeling Framework developed Shin et al. (2022) presents several new insights about computational thinking (CT) that build on existing concepts while introducing new perspectives:

- **Integration of Systems Thinking (ST) and CT**: In contrast to traditional approaches that treat CT in isolation, this framework emphasizes the importance of integrating systems thinking. This approach enables a more holistic understanding of complex systems through the use of computational methods.
- **Focus on modelling practices**: The framework highlights the central role of modelling practices in both ST and CT. It emphasizes that the ability to create models is critical not only in computer science, but in all disciplines that deal with complex systems.
- **Pedagogical application and scalability**: Insights are provided into the implementation of the framework in education, particularly with regard to K-12 education. The paper discusses the potential for scalability and adaptation of the framework across different educational levels and subjects and suggests that it can

serve as a foundation for interdisciplinary education that connects computational thinking to other areas of study.

- **Cognitive and metacognitive skills**: The framework explores how cognitive and metacognitive skills intersect in the application of CT and ST and provides a deeper understanding of how students learn and apply these skills in problem-solving scenarios.

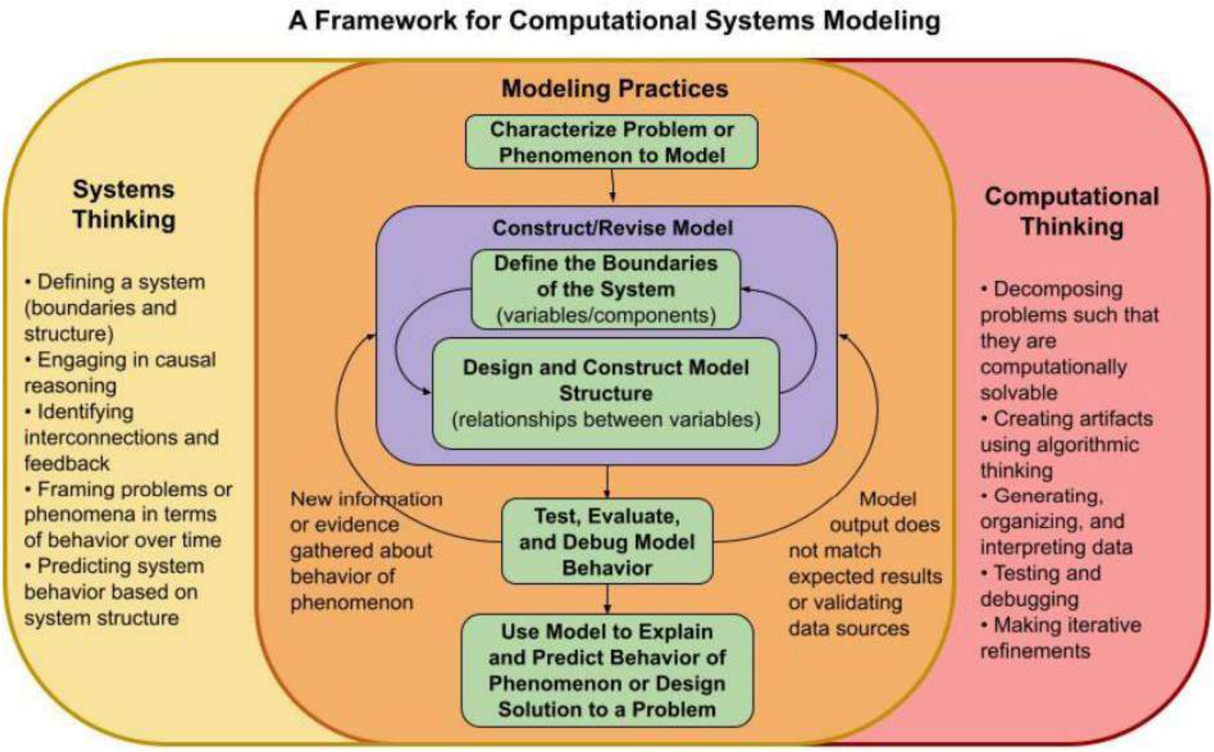

Figure 7: Framework for Computational Systems Modeling by Shin et al. (2022)

3.3. Curriculum Integration

Since 2016 there is a strong effort establishing CT skills in compulsory educations curricula. However, this is also accompanied by challenges: competition with other subject in the curricula, difficulties with assessments or a lack of teachers, who are appropriately qualified to guarantee a successful transfer of CT competences, are mentioned to be among the most elevated challenges in the study of the European Commission. Joint Research Centre. (2022b). In addition, it is a necessity for students in initial vocational education and training (iVET) to develop sufficient CT skills to be prepared for the increasing requirements of the labour market regarding digital competences. Despite this necessity, CT skills are still underrepresented in most of iVETs curricula, and the sector is facing difficulties in addressing these demands. On of the main challenges within iVET is, similar to compulsory education, a lack of sufficiently educated trainers and educators (European Commission Joint Research Centre, 2022).

Researchers also aimed to explore how CT is incorporated into curricula across various countries and educational levels. Table 4 summarizes the finding with a focus on the partnering countries of the ComeThinkAgain project.

Table 4: Current state of CT integration in curricula according to (European Commission. Joint Research Centre. 2022b; L. Tamborg and Nøhr 2023; Niemelä et al. 2022)

Austria	Germany	Spain
CT has been part of the curriculum since 2016 and is compulsory at all levels of general education. CT was introduced in primary schools in 2021 and lower secondary schools in 2018 under "Basic Digital Education," covering programming and IT skills. Regional authorities can integrate CT into subjects based on local policies. From grade 9, computer science is mandatory. Since 2022/23, digital literacy is uniformly taught in grades 5-8.	There is currently no unified national curriculum that explicitly integrates CT. The approach to promote CT varies by federal state and school type. Some federal states and schools integrate CT skills into computer science and mathematics lessons, as well as in digital education projects. In the curricula of the individual federal states, there are often general requirements for digital competences, but the specific implementation and extent of CT topics can vary.	Spain's national curriculum for primary education currently lacks a specific focus on CT, but revisions are underway that are expected to include CT skills. In 2018, a report recommended integrating CT into the curriculum. Many Spanish regions are already incorporating CT and digital activities into their educational initiatives, particularly in mathematics and through cross-curricular approaches. Some regions also offer robotics-focused subjects in upper secondary education. The 2021 Education Law introduced digital competence as a cross-curricular topic, directly referencing CT skills.
Belgium	**Ireland**	**Estonia**
In Belgium Flanders, CT is part of the curricula and integrated across various subjects. Since 2019, Digital Competence, including CT, is required in lower secondary education. In the French Community of Belgium, a new curriculum will make CT a compulsory subject in primary and lower secondary schools, focusing on coding, programming, and problem-solving skills.	CT has been part of the curriculum since 2016. It is included in the elective coding short course at lower secondary level, and is central to the computer science specification for senior cycle students. Guidelines for computer science courses and pedagogical support for programming and CS are available, along with a variety of tasks designed to integrate CT into CS classes. CT is also mentioned in the draft primary curriculum, although it has not yet been approved.	CT is not taught as a separate subject but is integrated into informatics and various elective technological courses. The curriculum emphasizes digital competence, which encompasses CT-related skills. At the high school level, elective courses such as programming, robotics, and software development foster CT, though their availability often depends on school resources and teacher expertise. Some schools emphasize CT within dedicated informatics courses, while others incorporate it through digital competence lessons integrated across different subjects.

Finland	Switzerland	Denmark
The national core curriculum integrates CT across subjects, with CT and programming identified as key focus areas alongside media literacy and ICT. In basic education (grades 1-9), CT is included in subjects like mathematics and crafts, with maths teachers playing a key role. Upper secondary schools can offer courses in programming, CT, and computer science.	CT skills are part of "Media and Informatics", a compulsory subject implemented at the primary and secondary level, but they are also integrated across other subjects. Curricula define learning outcomes for "Media and Informatics", some of which relate to the concept of CT. For example, students are expected to analyse simple problems, describe solution procedures and implement them in programs.	Currently, Denmark is deciding how to implement CT in the compulsory school curriculum. CT skills were part of a pilot program started in 2019 called "Technology Comprehension". The pilot project ended in 2022 and was evaluated twice. The results of these evaluations will guide the development of a national implementation strategy for primary and secondary education, which has not yet been announced. The general expectation is that the national implementation decision will include an integration of CT content in the mathematics curriculum.

As this curricula review shows, many countries integrate CT skills into mathematical education. Therefore, the competence of computational mathematics (Mathews and Fink 2015) is being increasingly recognized as a key competence in educational curricula, reflecting the growing emphasis on CT skills within mathematics. This focus highlights the importance of equipping students with the ability to apply computational methods to solve mathematical problems. Consequently, this trend underscores the relevance of computational mathematics in fostering critical thinking and problem-solving skills among learners worldwide.

3.4. Existing Training Methods

3.4.1. Primary and Secondary Education

Curzon et al. (2019) emphasize the importance of developing individual components as a foundation for mastering computational thinking as a whole. They argue that CT knowledge promotes skill development and emphasize the need for teachers to identify and address difficult concepts to help students overcome the challenges that occur. The authors also emphasize the importance of intrinsic motivation for practicing CT-skills. It is crucial that the practice sessions are fun, engaging and take place in a realistic context. This applies to both primary and secondary education, but the teaching methods can vary. For instance, primary education often uses approaches like the unplugged method, while secondary education adopts more advanced techniques like project-based learning. In addition, the education community is encouraged to create clear progression pathways for students starting in elementary school to continually develop and refine these skills over time. They also point out that programming is an essential component for the full development of computational thinking skills.

Over the last decades, Computational Thinking (CT) has been integrated across various academic disciplines. Researchers have explored diverse educational strategies to enhance student learning in this area, see Table 5. It is important to keep in mind, that these training methods are used both in primary as well as in secondary education.

Table 5: Overview of learning strategies for computational thinking as shown in Hsu et al. (2018)

Strategy	Explanation
1. problem-based learning	The definition of problem-based learning is helping students to set their own learning goals through a problem scene. Students will explore the learning solution by themselves, and report their own learning conclusions and feedback to the team. Problem-based learning is not only used to solve problems, but also to enhance students' understanding of new knowledge through appropriate questions (Wood 2003).
2. collaborative learning (teamwork)	Group learning is divided into: collaborative learning and cooperative learning. In cooperative learning, partners split the work, solve subtasks individually, and then assemble the partial results into the final output. In collaborative learning, group members are required to complete the task together, negotiate, and share meanings relevant to the problem-solving task (Dillenbourg 1999; Roschelle and Teasley 1995).
3. project-based learning	Project-based learning (PBL) is a model that organizes learning around projects. Projects are complex tasks, based on challenging questions or problems, that involve students in design, problem-solving, decision making, or investigative activities; PBL gives students the opportunity to work relatively autonomously over extended periods of time, and culminates in realistic products or presentations (Jones, Rasmussen, and Moffitt 1997).
4. game-based learning	Game Based Learning (GBL) is similar to Problem Based Learning (PBL), wherein specific problem scenarios are placed within a play framework (Barrows and Tamblyn 1980). GBL can provide a Student-Centred e-Learning (SCeL) approach (Motschnig-Pitrik and Holzinger 2002). Moreover, games include many characteristics of problem-solving, e.g. an unknown outcome, multiple paths to a goal, construction of a problem context, collaboration in the case of multiple players, and they add the elements of competition and chance.
5. scaffolding	Scaffolding provides the framework of learning to help the students learn the new knowledge at the beginning. The purpose of scaffolding is to train the students to solve problems independently.
6. problem-solving system	To find the solution to problems through logical or special methods, and to understand the goals of the problem and apply the appropriate abilities and methods to solve the problem.
7. storytelling	Pesola (1991, p. 340) suggested that storytelling is "one of the most powerful tools for surrounding the young learner with language.'' According to Isbell (2002), many stories that work well with children include repetitive phrases, unique words, and enticing descriptions. These characteristics encourage students to join in actively to repeat, chant, sing, or even retell the story. Much of the language children learn reflects the language and behavior of the adult models they interact with and listen to (Strickland and Morrow 1989). "Listening to stories draws attention to the sounds of language and helps children develop a sensitivity to the way language works" (Isbell 2002).
8. systematic computational strategies	Systematic computational learning theory provides a formal framework in which to precisely formulate and address questions regarding the performance of different learning algorithms so that careful comparisons of both the predictive power and the computational efficiency of alternative learning algorithms can be made.
9. aesthetic experience	Aesthetic experience provides the means through which meanings that are ineffable, but full of feeling, can be expressed and understood, helping us to tolerate ambiguity, to discern subtle relationships, and to focus on details (Kokkos 2010).
10. concept-based learning	Concepts are a way to organize and make sense of learning. The students try to define the attributive differences among different concepts. Other researchers have made use of concept-based models or graphic organizers. The model described here relies heavily on including attributes that can be generalized to multiple instances. The other concept depends on the definition of the concept of exclusion featuring a collection of example facts (Boudah et al. 2000; Erickson 1998; Kameenui and Carnine 1998).
11. HCI teaching	Human-Computer Interaction teaching (HCI teaching) is suitable for all grades of college students to learn natural science, and is also a common online teaching method (McCoy and Ketterlin-Geller 2004).
12. design-based learning	Design-based learning is integrated design thinking and processes in the curriculum, which can be applied to many subjects. It asks students to set up their own goals and to create ideas to achieve them.
13. embodied learning	Theories of embodied cognition argue that mental modal simulations in the brain, body, environment and situated actions are composed of central representations in cognition. Based on embodied cognition, body movements of performing natural science experiments can provide learners with external perceptions for better knowledge construction.
14. teacher-centered lecture	Students put all the focus on the teacher and concentrate on lectures without collaborative learning activities. Students will not miss the key points through the teacher guiding all of the activities.
15. Critical computational literacy	A concept of "computational literacy" helps us better understand the social, technical, and cultural dynamics of programming. Critical computational literacy emphasizes how to use the computational method, and what can be done.
16. Universal Design for Learning	The basis of Universal Design for Learning (UDL) is grounded in emerging insights about brain development, learning, and digital media (Hitchcock et al. 2002). It arouses the learners' interest through multiple methods of communication and expression.

Figure 8: The number of computational thinking studies for each learning strategy as seen in Hsu et al. (2018)

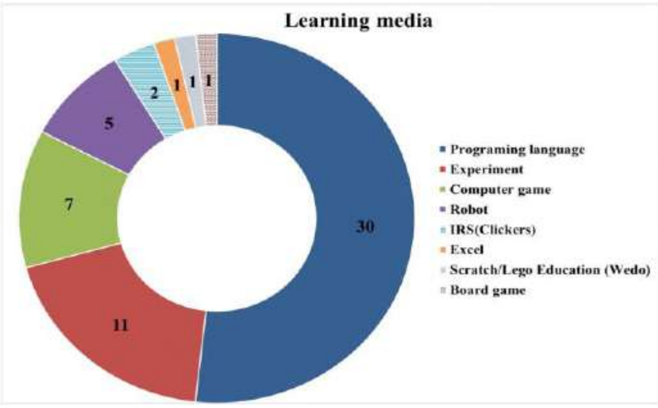

Figure 9: The number of CT papers by teaching instruments employed according to Hsu et al. (2018)

Computational Thinking encompasses a variety of tools and methods that facilitate the integration of programming concepts in various educational settings. One prominent approach is the use of programming and robotics, where students apply computational thinking principles to solve problems and operate robots to improve their understanding of algorithms and automation. Another important method is “Making,” or "Maker-Education" where CT is combined with hands-on activities that allow students to construct physical projects and digital artifacts that require iterative design and problem-solving skills. In addition, 'unplugged' activities are used to teach CT without computers, focusing on games and interactive exercises that develop logical thinking and algorithmic concepts in a tangible and accessible way. The use of educational games is also an important strategy, where educational games provide a dynamic environment for the application of CT skills and encourage students to engage in complex problem-solving while interacting in a virtual or board game environment.

Different approaches emphasize the flexibility and adaptability of CT in promoting critical thinking and problem-solving skills across different domains and age groups (Montuori et al. 2024).

CT & Programming/Robots

As shown by Lye and Koh (2014), programming exposes students to computational thinking and is therefore a strategic educational approach for fostering CT. Research efforts emphasize the importance of programming not only as a technical skill, but also as a critical component in the development of comprehensive CT skills. For example, studies highlighted in a recent meta-analysis and systematic review emphasize that programming provides a practical context for applying and improving CT skills (Bati 2022; Belmar 2022).

This approach not only facilitates the understanding of complex computational concepts, but also improves learners' problem-solving skills, reasoning and systematic thinking. This synthesis of programming and CT is becoming increasingly important in curricula to prepare students for the demands of the digital age.

In a meta-study conducted by Hsu, Chang, and Hung (2018) various programming teaching tools were identified and can be seen in Table 6 below.

Table 6: Programming teaching tools according to Hsu, Chang, and Hung (2018)

Teaching tools	Explanation
1. LOGO	LOGO is a computer programming language that is easy to learn and use. Students can use it to draw patterns, calculate and emit sounds, and it is also a new way for elementary students to learn the computer programming language.
2. LEGO	Lego is command box programming that combines building with the familiar LEGO bricks, using easy-to-use coding software, making coding fun and relevant for elementary and middle school students.
3. ViMAP	ViMAP programming language is an open-source programming language and modeling environment designed for the K12 science classroom. ViMAP also allows children to create their own programming commands.
4. MATLAB	MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment. It allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages (C, C++, C#, Java, and so on.)
5. Alice	Alice is an open-source object-based educational programming language with an integrated development environment (IDE). It uses the functions of drag and drop to create computer animations with 3D models.
6. Turtle Art	Turtle Art is software with a Logo-inspired graphic "turtle" that combines with Scratch-like snap-together visual programming elements and colorful art.
7. Scratch	Scratch is an online visual programming language developed by MIT Media Lab. Users can create online projects and make them into anything by coding with simple blocks.
8. Scratch4SL	S4SL is based on Scratch and is a new easy way to add behaviors and interactivity to your objects in Second Life. It uses the graphical programming language to create a project by dragging graphical blocks.
9. Code.org	Code.org is a website that includes free coding lessons and which also attempts to encourage teachers to include more computer science classes in the curriculum. The users use Blockly to write code. This is an interesting virtual computer programming language, like a markup language.
10. AgentCubes	AgentCubes is an educational programming language for kids to create 3D and 2D online games and simulations. It is a computational thinking tool to teach kids computational thinking through game and simulation design based on the Scalable Game Design curriculum.
11. Scalable Game Design	The Scalable Game Design is a curriculum to learn about computational concepts at the level of computational thinking that is relevant to game design as well as to computational science.
12. Java	Java is an open source computer-programming language. The main belief of Java is that it can run on all platforms that support Java without the need for recompilation.
13. C	C is an imperative computer programming language and a typical machine instruction, which provides a bridge to embed and operate systems with various types of application software.
14. C++	C++ is a compiled language, with implementations of it available on many platforms. The efficiency and flexibility of C++ has also been found useful in many other contexts.

CT & Maker-Education

Making is also seen as the optimal method for promoting computational thinking (CT). The philosophy of constructionism founded by Seymour Papert plays a fundamental role in this. According to Assaf (2019), making involves tinkering, experimenting and inventing, using both traditional manual tools and digital tools such as 3D printers, laser cutters or microcomputers. Garzi et al. (2019) add that making involves building, disassembling, developing and modifying objects in order to realize one's own ideas.

The openness of this approach makes it possible to integrate making into different subjects. For example, the development of a weather station that uses a microcomputer to measure air pressure can be linked to subjects such as computer science, natural sciences, technology and textile design. It is obvious that such creative processes stimulate and promote problem-solving thinking and therefore represent an ideal playing field for the application of CT.

Computational Thinking (CT) and Making, often referred to as "computational making" (Figure 10), is a pedagogical approach that combines the principles of CT with hands-on, creative problem-solving activities (Rode et al. 2015). This method uses the tangible aspects of making - such as tinkering, building and designing - to improve students' understanding of abstract computational concepts. Different computational making practices can be seen in Figure 10.

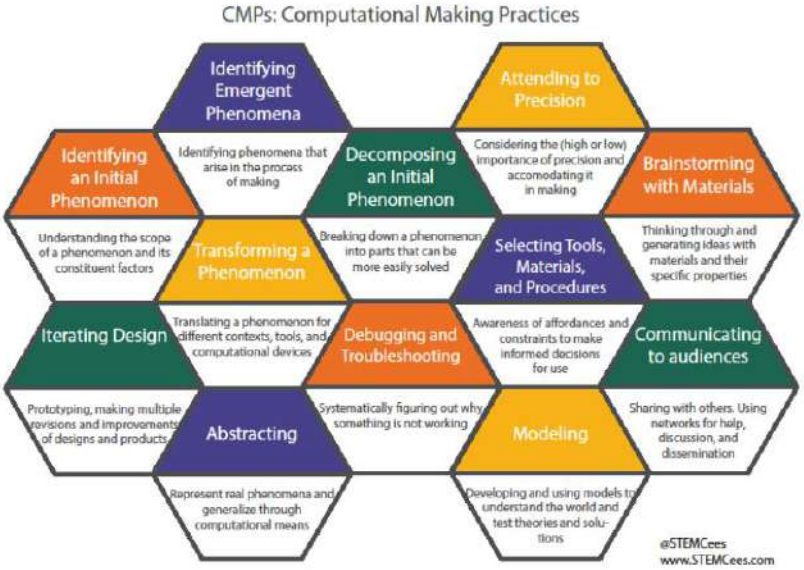

Figure 10: Computational making practices according to Gravel (in press)

When learners struggle to solve problems at an abstract level, they often succeed using tangible objects, as multiple representations of the same knowledge enhance understanding (Juškevičienė 2020). As shown by Martinez and Stager (2013), the playful approaches of making and tinkering can foster problem-solving skills in students. For example, the literature on this topic explores how microcontrollers such as Arduino or BBC micro:bit can facilitate tinkering by giving students the opportunity to engage in physical computing projects that require programming and computational thinking (Juškevičienė 2020).

These studies highlight the importance of integrating computational tinkering into STEM lessons to create an environment that encourages student learning and engagement with computational concepts.

Maker Education can also be effectively integrated into both Entrepreneurship Education (EE) and Green Skills (GS), fostering innovation and sustainability by encouraging hands-on learning, problem-solving, and the development of environmentally conscious solutions. In EE, making facilitates the creation of new products by involving students in iterative design processes. This method allows them to test, prototype, debug and continuously improve their ideas and products. The hands-on nature of making not only promotes creativity and innovation but also teaches students how to efficiently manage resources, assess market demands, and develop value-driven solutions (Unterfrauner, Voigt, and Hofer 2021).

Regarding Green Skills, problem-based activities in Maker Education can encourage students to tackle real-world sustainability challenges. By applying CT, they can analyse complex environmental issues, such as resource efficiency and waste reduction, and create practical, eco-friendly solutions (Lo 2024). This approach connects students' creative processes with the development of sustainable products or services, promoting a deeper understanding of both environmental responsibility and entrepreneurial opportunity.

CT & Games

Game development as a pedagogical approach has been shown to significantly enhance computational thinking (CT) skills. This approach engages students not only in playing games but also in creating them, which exposes them to essential CT concepts such as system design, problem-solving, and algorithmic thinking (Varghese and Renumol 2024). The process of designing games involves students conceptualizing game mechanics and rules, which mirrors the logical structuring and step-by-step construction inherent in programming (Kafai 2005).

Through iterative game design, students are challenged to solve and optimize problems, thereby deepening their understanding of both the theoretical and practical aspects of CT (Papert 1980). This hands-on methodology fosters an experiential learning environment where students can apply computational concepts directly and observe the outcomes, making the learning process both effective and engaging (Wu 2018; Yadav, Stephenson, and Hong 2017).

CT Unplugged

As the name implies, unplugged tasks can be completed without digital tools, often with just pen and paper. Among other things, they emphasize that unplugged activities show that computer science is not synonymous with the use of computers. It is also emphasized that this type of task can make computer science concepts metaphorically comprehensible, i.e. it is constructivist and action-oriented. In this context, a quasi-experimental study by Del Olmo-Muñoz, Cózar-Gutiérrez, and González-Calero (2020) suggests that primary school pupils have a clear advantage if they first practise CT with unplugged computer science tasks and later switch to plugged CT tasks on the computer instead of starting directly with plugged exercises.

Brackmann et al. (2017) came to a similar conclusion in their quasi-experiment with pre- and post-tests. In their study with 5th and 6th grade learners, the experimental group spent a total of ten hours on unplugged tasks that promoted CT skills such as decomposition, pattern recognition, abstraction, and algorithmic thinking. The control group, on the other hand, received no treatment. The increase in CT skills was highly significant with a strong effect in the experimental group, while the control group also showed an increase in skills, but this was not significant and had no effect.

Examples of CT Unplugged are as follows:

- Bebras Challenges

The "Informatik-Biber" is a global competition aimed at fostering computational thinking and problem-solving skills among students from various educational levels. Originating from a model established in Lithuania, the competition has expanded worldwide, engaging participants with a range of "unplugged" and interactive tasks that require no prior programming knowledge. These challenges are designed to demonstrate that computer science is not just about coding but involves critical thinking, logic, and creative problem-solving. The "Informatik-Biber" seeks to demystify computer science for students and spark their interest in digital thinking and applications, making it an influential tool in educational contexts across the globe.

- CS Unplugged

"CS Unplugged" is an innovative educational initiative that provides a collection of free learning activities teaching computer science concepts without the need for computers. These activities are available on their website, csunplugged.org, where numerous lesson plans are designed to convey various computational topics. Each of these lessons often includes references to the specific computational thinking (CT) competences that they aim to develop. Additionally, these references explain how each lesson enhances particular CT skills, providing educators with a clear roadmap on how to integrate these concepts into their teaching. This approach makes computer science accessible and engaging for students, emphasizing problem-solving, logical reasoning, and creative thinking skills that are crucial in understanding the underlying principles of the discipline.

- Others

Another example is "Informatik ohne Strom," translated as "Computer Science Without Electricity". This term refers to a pedagogical approach that teaches fundamental computer science concepts without the use of computers or any electronic devices. The method is closely aligned with the CS Unplugged approach, which focuses on delivering computer science education through engaging, hands-on activities that illustrate key ideas such as algorithms, data representation, and computational thinking. Through interactive activities, games and puzzles students learn the processes of computers in a tangible and often collaborative way.

The Swiss teaching resource "Connected 2" also incorporates several CS Unplugged approaches. Activities to teach computational concepts involve physical objects, making complex ideas more understandable and engaging for students. By removing the technological barrier, students can focus on the core ideas of computer science in a creative and engaging environment.

More CT-Interventions

With the increasing importance of CT as highlighted in the previous chapters, there are growing global and European initiatives to integrate CT into formal education using a variety of different approaches. Together, these organizations play a crucial role in the embedding of CT into education, offering different resources to engage and inspire learners and educators.

When we look at the European level, there are initiatives such as EU code week[1], a grassroots movement run by volunteers who promote coding in their countries as a code week ambassador. Another example is the The European Coding Initiative[2]. Founded in 2014, this collaborative effort seeks to promote coding and CT skills across all educational levels and in informal learning environments. The initiative hosts workshops, hackathons or coding boot camps and uses a variety of different methods like for example unplugged activities or problem-based learning scenarios. Helping kids to become computational thinkers is the main aim of another initiative called Barefoot Computing[3]. By offering free lesson plans, teacher training and interactive tools barefoot computing aims to bring CT into the classroom. Other European initiatives are Computing at School[4], Programamos[5], Code It Like A Girl[6].

Not only on a European level but also on a global scale, there are several organizations that have committed to promoting CT. One of them is Code.org[7]. This major nonprofit organization is dedicated to expanding computer science education access for all ages and backgrounds, with a strong focus on diversity and the inclusion of girls and women in STEM. Code.org provides online resources, teacher training, and curriculum development for computational thinking, while actively promoting the participation of female students and educators. Their initiatives include programs designed to inspire and support girls in coding, ensuring a more inclusive tech field. Another initiative is CoderDojo[8], where fostering CT takes place through

[1] https://codeweek.eu/
[2] http://www.allyouneediscode.eu/about
[3] https://www.barefootcomputing.org/about-barefoot
[4] https://www.computingatschool.org.uk/
[5] https://programamos.es
[6] https://www.codeitlikeagirl.com
[7] https://code.org
[8] https://coderdojo.com

collaborative and hands-on learning in a free network of coding clubs. Other global initiatives are Code Club[9], Kodable.com[10], TheTech.org[11] but there many more[12].

3.4.2. CT & VET Education

While the literature on CT primarily emphasizes primary and secondary education, the integration of CT into vocational education and training (VET) has received comparatively little attention. Entering the era of the industrial revolution 4.0, there is a growing need for VET graduates to possess skills that are aligned with the demands of this evolving industry (Kruse, Di Gropello, and Tandon 2011; Lee, Kao, and Yang 2014). According to Kruse et al. (2011), critical thinking and problem-solving skills are the most important skills that need to be added to education methods and curricula on the VET level.

Since CT is not explicitly integrated into VET curricula, we will first focus on the topics in computer science. Currently, computer science in VET schools is predominantly application-focused rather than interdisciplinary. The curricula often vary between schools but tend to emphasize, for instance, standardized software applications, basic data processing, network systems, or cybersecurity threats. The perspective is more about practical skills and fundamental knowledge rather than a broad, cross-disciplinary perspective. This approach reflects a broader trend seen 10-15 years ago, when primary and secondary schools were also not as advanced in integrating interdisciplinary concepts. Over time, schools have recognized that tools and technologies continuously evolve, leading to a need for new digital skill requirements (digital adaptability).

As seen above, problem-solving skills play a big role in regards of CT in VET. One way of enriching VET education with problem-solving skills is the framework below by Hermans et al. (2024). The framework integrates key elements of CT. Decomposition helps students break down complex problems, abstraction focuses on critical details, and algorithmic thinking guides the creation of step-by-step solutions to explore, evaluate, and refine ideas. This framework is ideal for VET education, as it leverages the unique advantage of VET in providing a direct pathway to tackling real-world challenges within authentic vocational settings.

While problem-solving is a key component in promoting CT skills in VET, the literature emphasizes a variety of additional teaching methods. Hermans et al. (2024) propose problem-based learning (PBL), project-based learning (PjBL), and design-based learning (DBL) as effective approaches to incorporate CT into VET. An analysis of several studies shows that these methods are commonly used, frequently in combination with programming tasks and collaborative learning activities (Hermans et al. 2024). Other teaching methods for VET found in literature are the blended teaching approach, a combination of online and offline components (Huang and Hsin.Chun-Te 2024), as well as the microlearning approach where learning content is broken down into smaller and more manageable segments (Leela, Chookeaw, and Nilsook 2020).

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[9] https://codeclub.org
[10] https://www.kodable.com
[11] https://www.thetech.org
[12] https://publications.jrc.ec.europa.eu/repository/handle/JRC104188

Engineering Design Process Step	Description
1. Identify and define problem(s)	The goal should be for students to deal with ill-defined problems, identify the necessary constraints imposed on the problem, and acknowledge desired specifications. It is important that the problem is open-ended with many possible solutions.
2. Research the need or problem	Students must conduct some background research. Students should understand that there are many things to consider when solving an issue and recognize that they need to fully explore the challenge to be well-informed as to how to solve it.
3. Develop possible solution(s)	Recording multiple ideas for the task takes into consideration the need for planning, resources, and teamwork.
4. Select the best possible solution(s)	Students need to be able to justify and reason their own solution to pursue.
5. Construct a prototype	The prototype is a representation or model (physical, virtual, or mathematical) of the final solution. It is important to allow students to fail and learn from those failures as they iterate on their solution.
6. Test and evaluate the solution(s)	Students must create fair tests based on the constraints and requirements of the problem to judge whether their prototype is successful. Determining appropriate testing procedures may cause students to reengage in the research step (2) as they determine what methods and tools will help determine how well their prototypes meet the requirements.
7. Communicate the solution(s)	Part of engineering is sharing your ideas and findings with others for feedback and marketing purposes.
8. Redesign	Redesigning the key problems with the intent to optimize the design.

Figure 11: Alignment of computational thinking practices with the problem-solving cycle

VET & 21st Century Skills

In today's rapidly evolving workforce and society, VET students are compelled to acquire more than just application-based knowledge. They must also develop skills that involve higher-order thinking. This dual focus on practical expertise and advanced cognitive abilities is essential for preparing students to navigate the complexities of modern careers and adapt to the ever-changing demands of the job market. To tackle that challenge, educators, education specialists and business leaders have developed the "P21 Framework for 21st Century Skills" to establish a support systems students need to thrive in the workplace, daily life and as active citizens (Partnership for 21st Century Skills 2019).

Learning skills aspect	Indicators	Item
Creativity	Creative thinking	4
	Creative in collaborating	4
	Implementing innovation	2
Critical thinking	Effective reasoning	3
	Systemic thinking	3
	Complex assessment	2
	Quality of decision making	2
Problem-solving	The quality of the problem	3
	Complexity of ways	4
	Solution analysis skills	3
Communication	Clarity of verbal articulation	1
	Effectiveness in listening	1
	Clarity of purpose of communicating	1
	The use of ICT in communicating	1
	Flexible compromises	1
Collaboration	Collaborative work responsibilities	1
	Efficiency of use	2
	Effectiveness of use	2
Digital literacy	Understanding of purpose & benefits	5
	Understanding of digital ethics	5

Figure 12: 21st century learning skills aspects as seen in (Mutohhari et al. 2021).

By combining CT skills with 21st century skills, educators ensure that students develop a well-rounded set of competences vital for success in today's fast-paced world. These include critical thinking, creativity, collaboration, communication, and digital literacy—key abilities for tackling complex challenges and thriving in dynamic work settings. Through this holistic approach, students are empowered to become innovative thinkers and valuable contributors to the modern workforce.

4. ENTREPRENEURSHIP

4.1. Definition and Importance

Entrepreneurship is a multifaceted concept that includes various definitions and perspectives reflecting its dynamic and evolving character.

According to the EntreComp framework (European Commission. Joint Research Centre. 2016), entrepreneurship involves acting upon opportunities and ideas to create value for others, which can be financial, cultural, or social (Vestergaard, Moberg, and Jørgensen 2012).

In the report "Entrepreneurship Competence: An Overview of Existing Concepts, Policies and Initiatives" (European Commission. Joint Research Centre. Institute for Prospective Technological Studies. 2015) entrepreneurship is closely linked to economic outcomes, including economic growth through innovation (Acs and Audretsch 1988), job creation (Birch 1979; Blanchflower 2000; Parker 2009) and productivity gains (Van Praag and Versloot 2007). These outcomes are often achieved through the restructuring of productive activities and the use of knowledge and technology transfer (Acs et al. 2009; Ács, Autio, and Szerb 2015; Grimaldi et al. 2011; Plummer and Acs 2014; Terjesen and Wang 2013). The concept of entrepreneurship has grown beyond its original economic domain and has influenced various aspects of society and politics.

Gianesini et al. (2018) emphasizes that entrepreneurship in today's economy means creating new opportunities despite complexity and uncertainty. It is seen as an important driver of economic growth and sustainability as well as a mechanism for social development (Farhangmehr, Gonçalves, and Sarmento 2016).

Kyndt and Baert (2015) utilizes Kuratko's definition of an entrepreneur (Kuratko, Frederick, and O'connor 2012). According to this definition, an entrepreneur is a person "who organizes, manages and assumes the risks of a business". Modern entrepreneurs are innovators who recognize opportunities, turn them into marketable ideas and create value through various resources while managing competitive risks to generate profits.

Reis, Fleury, and Carvalho (2021) use Schumpeter (1934) definition of entrepreneurship in his work, which defines entrepreneurship as a "set of behaviours that raises and manages economic resources to create value". According to Lazear (2005), entrepreneurs have the ability to assess risks. Experimentation, action and reflection are essential for learning entrepreneurial thinking (Eggers, Lovelace, and Kraft 2017).

Research in the field of entrepreneurship is constantly being driven forward, however, and as a result the term entrepreneurship is constantly being redefined and the theoretical foundations reformulated (Moog et al. 2015).

According to economists and policy makers, higher levels of entrepreneurial activity generally lead to more innovation and economic growth (Sánchez 2013). Hence, the importance of improving entrepreneurship education programs to foster the development of the desired entrepreneurial competences becomes evident (Thomas and Mueller 2000).

4.2. Current Trends and Developments

The field of entrepreneurship and entrepreneurship competences is very complex and there has already been conducted considerable research in this area. Many studies and frameworks aimed to identify and categorize competences in the field of entrepreneurship.

In the following, 10 publications and frameworks are presented, each of which has identified entrepreneurship competences and their approaches to categorizing these competences.

4.2.1. EntreComp: the entrepreneurship competence framework

With the EntreComp Framework the European Commission provides a definition of entrepreneurship as a competence (European Commission. Joint Research Centre. 2016).

The framework divides the competences into three key competence areas: Ideas and opportunities, Resources and Into action.

Each of these areas comprises five competences, which form the building blocks for the definition of entrepreneurship.

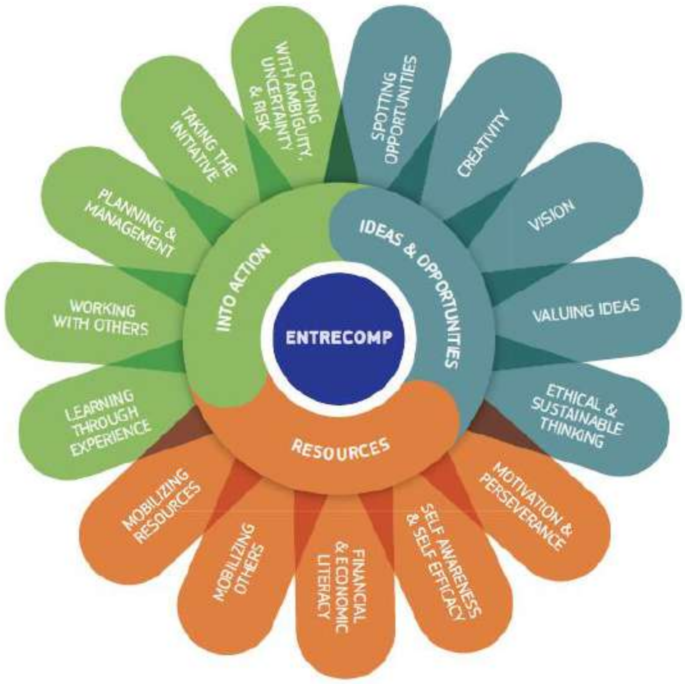


Figure 13: EntreComp key areas and competences[13]

4.2.2. Entrepreneurship Competence: An Overview of Existing Concepts, Policies, and Initiatives - Final Report

The aim of the report is to provide an overview of existing theoretical and practical approaches to the definition of the entrepreneurship competence, as one of the eight key competences for lifelong learning identified by the Council of the European Union (European Commission. Joint Research Centre. Institute for Prospective Technological Studies. 2015).

In this report, an extensive literature review, an inventory of existing European initiatives and in-depth analysis of ten case-studies were carried out. As a result, 42 implementation actions were identified and a list of 292 competence statements was extracted. These competences were divided into 3 main conceptual areas:

1) **operational and contextual competences**: this includes all competences relating to knowledge and skills about entrepreneurship;
2) **entrepreneurial competences**: this area includes those competences related to the identification, exploration, evaluation and exploitation of value creation opportunities;

[13] https://www.gzs.si/entrecompfood/vsebina/Entrepreneurship/About-EntreComp

3) **conceptual and relationship competences**: this includes attitudes and action-oriented skills.

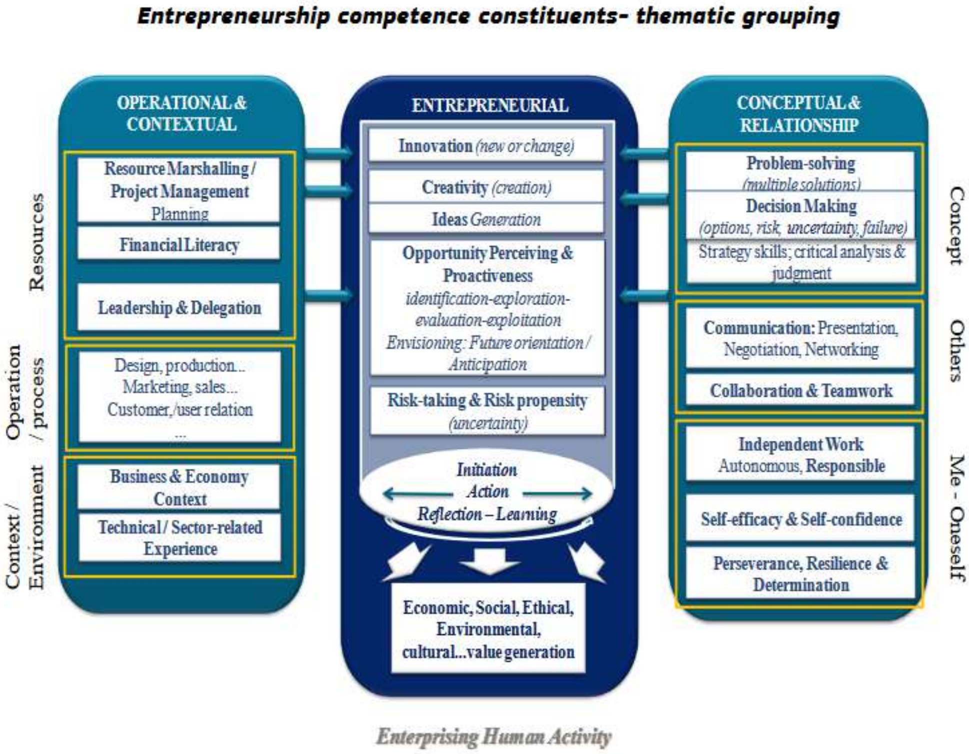


Figure 14: Entrepreneurship competences grouped into 3 main conceptual areas (European Commission. Joint Research Centre. Institute for Prospective Technological Studies. 2015)

4.2.3. A Competency-Based Perspective on Entrepreneurship Education: Conceptual and Empirical Insights

The paper by Morris et al. (2013) aims to provide further insights into the competencies that are most critical for entrepreneurial success.

By conducting a Delphi study, 13 entrepreneurial competencies were identified:

1) **Opportunity Recognition**:
   - the capacity to perceive changed conditions or overlooked possibilities in the environment that represent potential sources of profit or return to a venture
2) **Opportunity Assessment**:
   - the ability to evaluate the content structure of opportunities to accurately determine their relative attractiveness
3) **Risk Management/Mitigation**:
   - the taking of actions that reduce the probability of a risk occurring or reduce the potential impact if the risk were to occur
4) **Conveying a Compelling Vision**:
   - the ability to conceive an image of a future organizational state and to articulate that image in a manner that empowers followers to enact it
5) **Tenacity/Perseverance**:
   - the ability to sustain goal-directed action and energy when confronting difficulties and obstacles that impede goal achievement
6) **Creative Problem-solving/Imaginativeness**:
   - the ability to relate previously unrelated objects or variables to produce novel and appropriate or useful outcomes

7) **Resource Leveraging**:
   - the skills at accessing resources one does not necessarily own or control to accomplish personal ends
8) **Guerrilla Skills**:
   - the capacity to take advantage of one's surroundings, employ unconventional, low-cost tactics not recognized by others, and do more with less
9) **Value Creation**:
   - the capabilities of developing new products, services, and/or business models that generate revenues exceeding their costs and produce sufficient user benefits to bring about a fair return
10) **Maintain Focus yet Adapt**:
   - the ability to balance an emphasis on goal achievement and the strategic direction of the organization while addressing the need to identify and pursue actions to improve the fit between an organization and developments in the external environment
11) **Resilience**:
   - the ability to cope with stresses and disturbances such that one remains well, recovers, or even thrives in the face of adversity
12) **Self-Efficacy**:
   - the ability to maintain a sense of self-confidence regarding one's ability to accomplish a particular task or attain a level of performance
13) **Building and Using Networks**:
   - social interaction skills that enable an individual to establish, develop and maintain sets of relationships with others who assist them in advancing their work or career

4.2.4. The Great Eight Competencies: A Criterion-Centric Approach to Validation

In his work, Bartram (2005) defines eight key competencies, which he refers to as The Great Eight.

Table 7: Titles and High-Level Definitions of the Great Eight Competencies (Bartram, 2005)

Competency domain title	Competency domain definition
Leading and Deciding	Takes control and exercises leadership. Initiates action, gives direction, and takes responsibility.
Supporting and Cooperating	Supports others and shows respect and positive regard for them in social situations. Puts people first, working effectively with individuals and teams, clients, and staff. Behaves consistently with clear personal values that complement those of the organization.
Interacting and Presenting	Communicates and networks effectively. Successfully persuades and influences others. Relates to others in a confident, relaxed manner.
Analyzing and Interpreting	Shows evidence of clear analytical thinking. Gets to the heart of complex problems and issues. Applies own expertise effectively. Quickly takes on new technology. Communicates well in writing.
Creating and Conceptualizing	Works well in situations requiring openness to new ideas and experiences. Seeks out learning opportunities. Handles situations and problems with innovation and creativity. Thinks broadly and strategically. Supports and drives organizational change.
Organizing and Executing	Plans ahead and works in a systematic and organized way. Follows directions and procedures. Focuses on customer satisfaction and delivers a quality service or product to the agreed standards.

Adapting and Coping	Adapts and responds well to change. Manages pressure effectively and copes well with setbacks.
Enterprising and Performing	Focuses on results and achieving personal work objectives. Works best when work is related closely to results and the impact of personal efforts is obvious. Shows an understanding of business, commerce, and finance. Seeks opportunities for self-development and career advancement.

4.2.5. Entrepreneurial Competences: Comparing and Contrasting Models and Taxonomies

The study of Gianesini et al. (2018) compares three models from Morris et al. (2013), Bartram (2005) and the EntreComp Framework.

As a result of this publication, 15 skills were identified that were included in at least one of the three models:

1. **Mobilizing resources** (EntreComp)
2. **Interacting & Presenting** (Great Eight)
3. **Organizing & Executing** (Great Eight)
4. **Leading & Deciding** (Great Eight)
5. **Analyzing & Interpreting** (Great Eight)
6. **Entrepreneurial and commercial thinking** (Great Eight)
7. **Identifying** (and assessing) **business opportunities** (all three models)
8. **Risk management** (and coping with risk) (all three models)
9. **Planning & Management** (EntreComp)
10. **Convey a compelling vision** (13 Entrepreneurial Competencies Model, EntreComp)
11. **Mobilizing resources / networking** (13 Entrepreneurial Competencies Model, EntreComp)
12. **Value creation/Ethical and sustainable thinking/ Adhering to Principle and values** (all three models)
13. **Resilience & Coping** (all three models)
14. **Mobilizing others / networking / supporting and cooperation** (all three models)
15. **Learning** (EntreComp, Great Eight)

4.2.6. Entrepreneurial competencies: Assessment and predictive value for entrepreneurship

The paper by Kyndt and Baert (2015) analyses the results of a survey in which entrepreneurs' competencies were assessed, which are considered important for entrepreneurs' success.

The questionnaire included 12 competencies:

1. Perseverance
2. Self-knowledge
3. Orientation towards learning
4. Awareness of potential returns on investment
5. Decisiveness
6. Planning for the future
7. Independence
8. Building networks
9. Ability to persuade
10. Seeing opportunities
11. Insight into the market
12. Social and environmentally conscious conduct

4.2.7. The Empretec program: the entrepreneur's guide

The United Nations Conference on Trade and Development, short UNCTAD, published an Entrepreneur's Guide (UNCTAD 2015) as part of its Empretec program in which 10 key entrepreneurial competencies were identified. These competencies were divided into 3 clusters:

- **Planning cluster**
  - Goal-setting
  - Information-seeking
  - Systematic planning and monitoring
- **Achievement cluster**
  - Opportunity-seeking and initiative
  - Persistence
  - Fulfilling commitments
  - Demand for efficiency and quality
  - Taking calculated risks
- **Power cluster**
  - Persuasion and networking
  - Independence and self-confidence

4.2.8. Exploring the Entrepreneurial Intention-Competency Model for Nascent Entrepreneurs: Insights From a Developing Country Context

In the publication by Botha and Taljaard (2021), entrepreneurship competencies were divided into four categories in order to examine the relationship between entrepreneurial intention (EI) and entrepreneurial competencies (ECs).

The four selected higher-order categories were adopted and adapted from Winterton, Delamare-Le Deist, and Stringfellow (2006) and Cheetham and Chivers (1996):

- **Cognitive competence**:
  - refers to underpinning theory and concepts as well as informal tacit knowledge gained experientially; knowledge, the "know that" is underpinned by understanding, the "know why."
- **Functional competence**:
  - refers to skills or know-how and things that a person should be able to do and to demonstrate.
- **Social/personal competence**:
  - refers to behavioural competencies or knowing how to behave; some behaviours and attitudes related to EC are having a positive attitude towards change and showing initiative.
- **Meta-competence**:
  - refers to as a comprehensive concept of the multidimensional construction of competence; it further refers to the element that facilitates the acquisition of the other competencies.

As a set of competencies, the core entrepreneurial competencies according to Morris et al. (2013) were adapted and categorized:

- **Cognitive**
  - Conveying a compelling vision
  - Creative problem-solving
  - Opportunity recognition

    - Opportunity assessment
- **Social/personal**
    - Building and using networks
    - Self-efficacy
    - Tenacity/perseverance
- **Functional**
    - Value creation through innovation
- **Meta**
    - None

4.2.9. Consolidating core entrepreneurial competences: toward a meta-competence framework

Core entrepreneurial competence	Code	Core entrepreneurial competence	Code
Openness to experience	C6	Goal-driven and goal-setting	C54
Emotional stability	C8	Need for power	C58
Resistance to stress	C9	Need for dominance	C59
Internal locus of control	C10	Self-confidence	C60
Sobriety	C12	Self-esteem	C61
Need for achievement	C13	Self-reliance	C62
Passion	C14	Decision-making	C65
Proactiveness	C19	Integrity	C67
Risk-taking propensity	C20	Norm orientation	C68
Innovativeness	C22	Previous contact with venture capitalists	C73
Creativity	C24	Being autonomous	C75
Originality	C27	Disagreeableness	C76
Look for products that provide real benefit	C34	Conscientiousness	C77
Social abilities	C38	Extraversion	C78
Belief in effect of personal effort on outcomes	C49	Protestant work ethic beliefs	C97
Persistence	C51	Tenacy	C98

Figure 15: Core entrepreneurial competences (Reis et al. 2021)

The study by Reis et al. (2021) identified 98 entrepreneurial competences through an extensive literature review, 32 of which can be described as core competencies (Figure 15) that achieve a high level of consensus in the literature. In their publication, they present a meta-competence framework, using the identified competences and grouping them into 9 clusters, as follows:

1) learn with feedback,
2) strategic foresight,
3) flexible emotional stability,
4) business passion,
5) leadership,
6) communication,
7) facing innovation challenges,
8) market forecasting,
9) self-confidence with optimism and ambition.

4.3. Existing Training Methods

4.3.1. Training Methods

Entrepreneurship education has, especially in recent years, become an important field where learners are equipped with the necessary skills, knowledge and mindset to become successful entrepreneurs. There are a variety of training methods for teaching entrepreneurship skills. In the literature as well as in practice, these are divided into different categories. Depending on the definition and boundaries of the categories, the approaches used may also overlap in some cases.

1) **Project-based learning**

   In project-based learning, students (usually in groups) are asked to work on solutions to specific problems or case studies. Project-based learning aims to build a bridge between theory and practice. Student companies are also a popular approach in this area. Students set up and run a fictitious company as part of their classes and learn all aspects of entrepreneurship and business management hands-on (McCrea 2013). Entrepreneurial projects, such as the development of business ideas or the creation of business plans, also offer the opportunity to combine the theory of entrepreneurship with practical projects (Block et al. 2023; O’Brien and Hamburg 2019; Samuel and Rahman 2018).

2) **Simulations / Games**

   Business simulations and business games have also proven to be effective tools in entrepreneurship training. In these simulations, students also have the opportunity to manage a company and make all the associated decisions in a risk-free environment, thereby gaining experience. Virtual business games, in which realistic scenarios from the business world are simulated, also offer students these advantages. (Block et al. 2023; Samuel and Rahman 2018)

3) **Design Thinking**

   Creativity-enhancing methods, design thinking or brainstorming sessions, are also a useful tool for teaching entrepreneurship skills. Here, students slip into the role of designers who develop innovative products or collect business ideas. (Block et al. 2023; O’Brien and Hamburg 2019; Samuel and Rahman 2018)

4) **Competition-based methods**

   The development of business plans and business ideas can also contribute to entrepreneurship lessons by submitting them to (student) competitions. Students can present their ideas and work and receive important feedback from a jury. (Block et al. 2023; Samuel and Rahman 2018)

5) **Guest lectures and workshops**

   Traditional lecture approaches can also make an important contribution to entrepreneurship education. Guest lectures by experts from the economy and workshops in particular offer students valuable insights into the business world. (Block et al. 2023; Samuel and Rahman 2018)

6) **Reflective and theory-based methods**

   Reflective and theory-based methods are a traditional yet powerful tool in entrepreneurship education. Theoretical lessons can be used to impart basic knowledge on topics such as business model development, market analysis and financial planning. In addition, students can, for example, analyse case studies of successful or failed companies to promote their entrepreneurial thinking. (Block et al. 2023; O'Brien and Hamburg 2019; Samuel and Rahman 2018)

4.3.2. Curriculum Integration

The integration of entrepreneurship into education is becoming increasingly important worldwide. Entrepreneurship is seen as a key competence in many countries when it comes to driving innovation, economic growth and employment. Educational institutions play a central role, as they prepare young people for the challenges of the global market. Different countries take different approaches to integrating entrepreneurship into their curricula.

The following table summarizes information and links on the topic of entrepreneurship as a competence and entrepreneurship education in the EU and specifically in the project partner countries.

Table 8: Entrepreneurship education in the EU

Source	Information and Links	
Youth Wiki: Europe's Encyclopedia of National Youth Policies	• 33 countries participate in the Youth Wiki. • 3. Employment & Entrepreneurship / 3.8 Development of entrepreneurship competence ○ Austria ○ Belgium (Belgium-Flemish-Community; Belgium-French-Community; Belgium-German-Speaking-Community) ○ Denmark ○ Estonia ○ Finland ○ Germany ○ Ireland ○ Spain	**General**
European Commission - Entrepreneurship education	Projects: ▪ EntreComp ▪ Entrepreneurship Education: A Guide for Educators ▪ EntreTime ○ entreTime is an entrepreneurship education initiative, funded by the European Union, aimed at upskilling educators within higher education. ○ 3 Month course ○ entreTime Programme Toolkit: ▪ entreTime Learning Programme "Entrepreneurial Learning – Training Modules for Educators"; available on the resources page in the top menu of this website ▪ Open online course "entreTime Train-the-Trainer" ▪ Online Course User Guide, Syllabus, and accompanying Slidedecks and Reflection Exercises ▪ TES created a virtual Guide for Teachers ▪ Entrepreneurship Education: Teacher Education as critical success factor ▪ The Budapest Agenda - Enabling Teachers for Entrepreneurship Education ▪ Study 'Entrepreneurship Education: A road to success' ▪ The Oslo Agenda for Entrepreneurship Education in Europe	**General**

	• Study: Entrepreneurship Education at School in Europe (2016) • Student Mini-Companies in Secondary Education (2005)	**Primary and Secondary Education**
	• HEInnovate: self-assessment tool for universities that aim to be entrepreneurial (under the responsibility of the Directorate-General Education and Culture) • Study: Effects and impact of entrepreneurship programmes in higher education (2012) • Entrepreneurship in higher education, especially within non-business studies (2008) • European survey on Higher Education Institutions (2008): ◦ Main results of the survey ◦ Annex A: Tables ◦ Annex B: Good Practice examples	**Higher Education**
	• Final Report of the Expert Group, 'Entrepreneurship in Vocational Education' (2009)	**VET**

5. GREEN SKILLS

5.1. Definition and Importance

At the latest, the appearance of Limit of Growth in 1972 by Meadows et al. has brought awareness for environmental matters on a global level, paving the way for discussions about integrating topics on sustainability in education (Bianchi 2020). It took another 40 years until the most commonly referred to key competences in sustainability were articulated by Wiek, Withycombe, and Redman (2011) yet there is still a lack of consensus on terminology and agreement on a specific framework resulting into a "sea of labels [and] terminological confusion" (Brundiers et al. 2021; Sterling et al. 2017).

To define sustainability competences one first needs to talk about the definition of sustainability in general. In principle expressing the same attitude, the definitions of sustainability found in literature vary. Wiek et al. (2016) state that "[s]ustainability is the collective willingness and ability of a society to reach or maintain its viability, vitality, and integrity over long periods of time, while allowing other societies to reach or maintain their own viability, vitality, and integrity". According to GreenComp the European sustainability competence framework (European Commission. Joint Research Centre. 2022a), "[s]ustainability means prioritizing the needs of all life forms and of the planet by ensuring that human activity does not exceed planetary boundaries." and thus also directly addresses the planet itself.

In order to ensure a sustainable transition of our society, individuals need to be equipped with related competences. Looking at the definition of sustainability competences, the situation is similar. Brundiers et al. (2021) summarises sustainability competences as "the entirety of individual dispositions comprising knowledge, skills, motives, and attitudes necessary to solve sustainability-related problems and advancing sustainable development in a range of different contexts, including private, social and institutional". GreenComp (European Commission. Joint Research Centre. 2022a) states that "[a] sustainability competence empowers learners to embody sustainability values, and embrace complex systems, in order to take or request action that restores and maintains eco-system health and enhances justice, generating visions for sustainable futures.". Although the number of education programs with a focus on sustainability has increased in the previous years, it is still challenging for all stakeholders to capture the competences addressed (Brundiers et al. 2021).

Sustainability key competences are most often discussed in the context of sustainable education whereas the term green skills rather refers to the skills needed by the present and future workforce in employment. In this case "green" is derived from the idea of a green economy (Bianchi 2020). The CEDEFOP (2019) together with the International Labour Organization (ILO) analysed six EU countries (Denmark, Germany, Estonia, Spain, France, UK) and identified common practices and differences on needed skills for green jobs across the countries. They use the definition of green jobs accordingly to Renner, Sweeney, and Kubit (2008): "[...] as positions in agriculture, manufacturing, construction, installation, and maintenance, as well as scientific and technical, administrative, and service-related activities, that contribute substantially to preserving or restoring environmental quality. [...] this includes jobs that help to protect and restore ecosystems and biodiversity; reduce energy, materials, and water consumption [...] and minimize or altogether avoid generation of all forms of waste and pollution."

As stated in goal number four of the sustainability development goals (United Nations. Department of Economic and Social Affairs, Sustainable Developement 2015), quality education with an explicit focus on sustainable development is of uppermost importance for a sustainable transformation by the year 2030. Also, the European Union's Green Deal relies on well-trained and educated individuals to achieve its aim of making Europe the first climate neutral continent worldwide by 2050. Therefore, sustainability competences are of great significance regardless of age and must be encouraged from early childhood on (European Commission. Joint Research Centre. 2022a; Vesterinen 2024). Due to the fact that a great extent of the frameworks produced in the previous years cover only higher education there is double the need to focus on elementary and primary education as well as adult learning (Bianchi 2020).

5.2. *Current Trends and Developments*

5.2.1. GreenComp – The European sustainability framework

The European sustainability framework – also known as GreenComp – provides a structured guide of competences to improve and support the development of skills, knowledge and values the society relies on to be able to live and act sustainably. It should help to integrate sustainability competences in training and education and is not limited to a certain group of age or level of knowledge. The framework comprises 12 competences which are categorized into four thematic areas (European Commission. Joint Research Centre. 2022a):

1) Embodying sustainability values: includes valuing sustainability, supporting fairness, promoting nature
2) Embracing complexity in sustainability: includes system thinking, critical thinking and problem framing
3) Envisioning sustainable futures: includes futures literacy, adaptability and exploratory thinking
4) Acting for sustainability: includes political agency, collective action and individual initiative

More information on GreenComp can be found in Section 6.3.

5.2.2. Key competencies of sustainability according to Wiek et al. (2011) and Wiek et al. (2016)

Systems-thinking competency "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." (Wiek et al. 2011, p. 207) *Anticipatory/futures-thinking competency* "ability to collectively analyze, evaluate, and craft rich "pictures" of the future related to sustainability issues and sustainability problem-solving frameworks". (Wiek et al. 2011, pp. 208–209) *Normative/values-thinking competency* "ability to collectively map, specify, apply, reconcile, and negotiate sustainability values, principles, goals, and targets". (Wiek et al. 2011, p. 209) *Strategic-thinking competency* "ability to collectively design and implement interventions, transitions, and transformative governance strategies toward sustainability". (Wiek et al. 2011, p. 210) *Interpersonal/collaborative competency* "ability to motivate, enable, and facilitate collaborative and participatory sustainability research and problem solving". (Wiek et al. 2011, p. 211)	*Integrated problem-solving competency* is a meta-competency of meaningfully using and integrating the five key competencies [left] for solving sustainability problems and fostering sustainable development (Wiek et al. 2016, p. 243). It is the ability "to apply different problem-solving frameworks to complex sustainability problems and develop viable solution options" in order to "meaningfully integrate problem analysis, sustainability assessment, visioning and strategy building" (Wiek et al. 2016, p. 251)

Figure 16: Definition of key competencies (Brundiers et al. 2021).

The most influential framework for sustainability competencies is the one Wiek et al. (2011) developed in 2011 related to the field of higher education. To many authors of following frameworks, it also served as a basis to be further modified (Bianchi 2020). The framework consists of five key competencies, especially targeting the ability to solve sustainability problems and challenges. Thus, the latter is also handled as a sixth "meta"-competence expressing the capability to combine the five key competencies for dealing with sustainability related challenges. Wiek et al. (2011) classify competences such as critical thinking or communication as basic competences and of general importance. These are therefore not the focus of this framework, since the authors want to pay more attention to competences particularly linked to sustainability which have not been addressed in traditional education so far. The five key competencies represented are: system-thinking competence, anticipatory competence (or futures thinking), normative competence (or values thinking), strategic competence (or strategic thinking) and interpersonal competence (or collaboration competence). Figure 1 points out the definitions of the five respectively six key competencies.

5.2.3. Key competencies of sustainability according to Brundiers et al. (2021)

Brundiers et al. (2021) conducted a Delphi study of 14 experts in sustainability education reviewing the work from Wiek et al. (2011) and Wiek et al. (2016). In the course of this, two new competences were added and a hierarchy of the competencies list was suggested. The additionally proposed competencies are "implementation" and "intrapersonal" competencies (Figure 17). Intrapersonal competency refers to a set of skills related to self-reflection about one's position on the local and global level e.g. being aware of one's own behaviour and its effects. Implementation competency includes the ability to actively realise solutions once they are found as well as evaluate the realisation process. The experts suggest value-thinking competency as orientation for all the other competencies due to the fact that they should be guided along sustainability values.

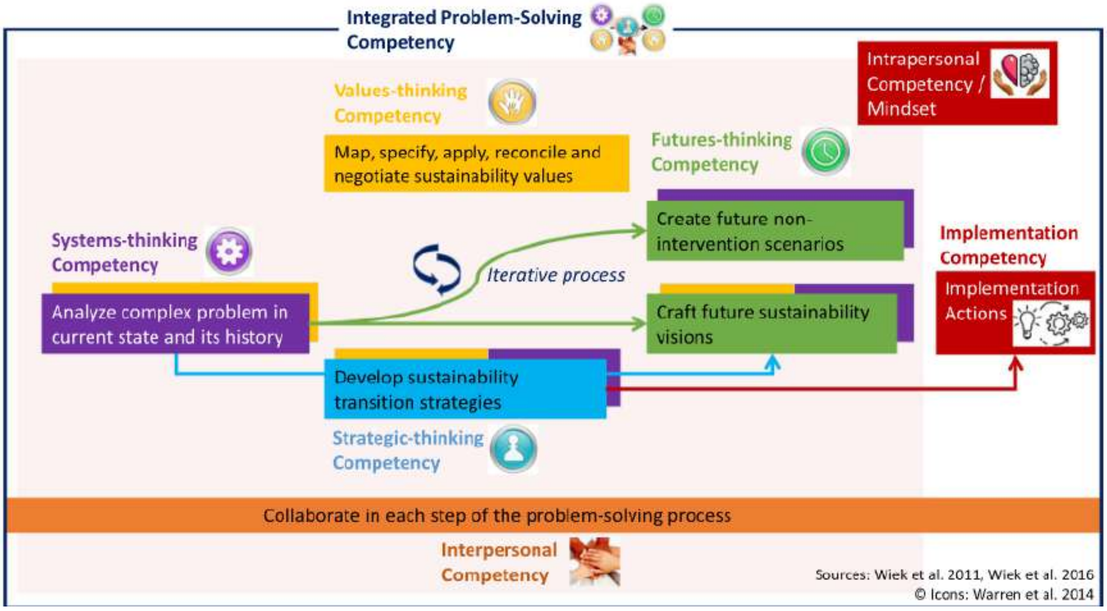


Figure 17: Key competencies framework according to Wiek et al. (2011) with addition of new competencies in red boxes. The debate on the classification of the intrapersonal competency as a competency is not finished. (Brundiers et al. 2021)

Additionally, they put the sustainability key competences in context with basic competences (as Wiek et al. (2011) mentioned) and topical knowledge, as is depicted in Figure 18. In order to solve sustainability problems, it is also important to possess knowledge in certain disciplines e.g. geography or chemistry.

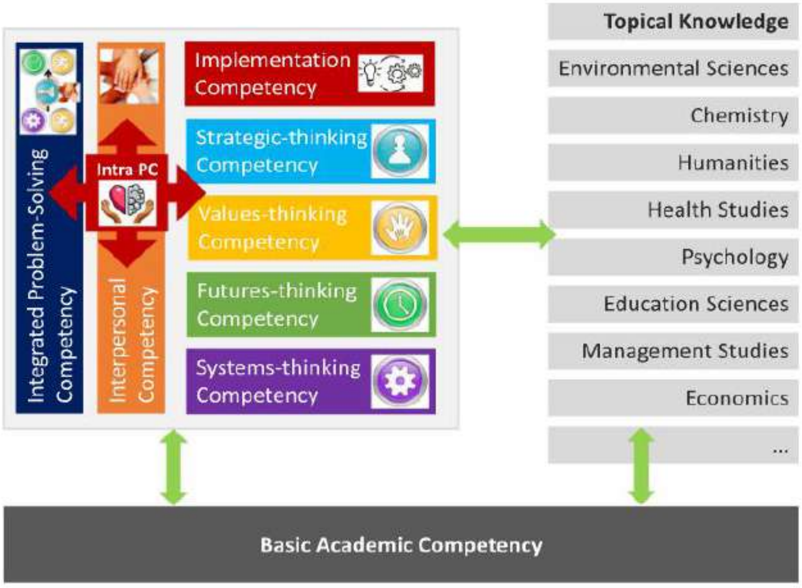


Figure 18: Sustainability key competencies linked with basic academic competency and topical knowledge. Intra PC is referring to intrapersonal competency (Brundiers et al. 2021).

5.2.4. Key competencies of sustainability according Redman and Wiek (2021)

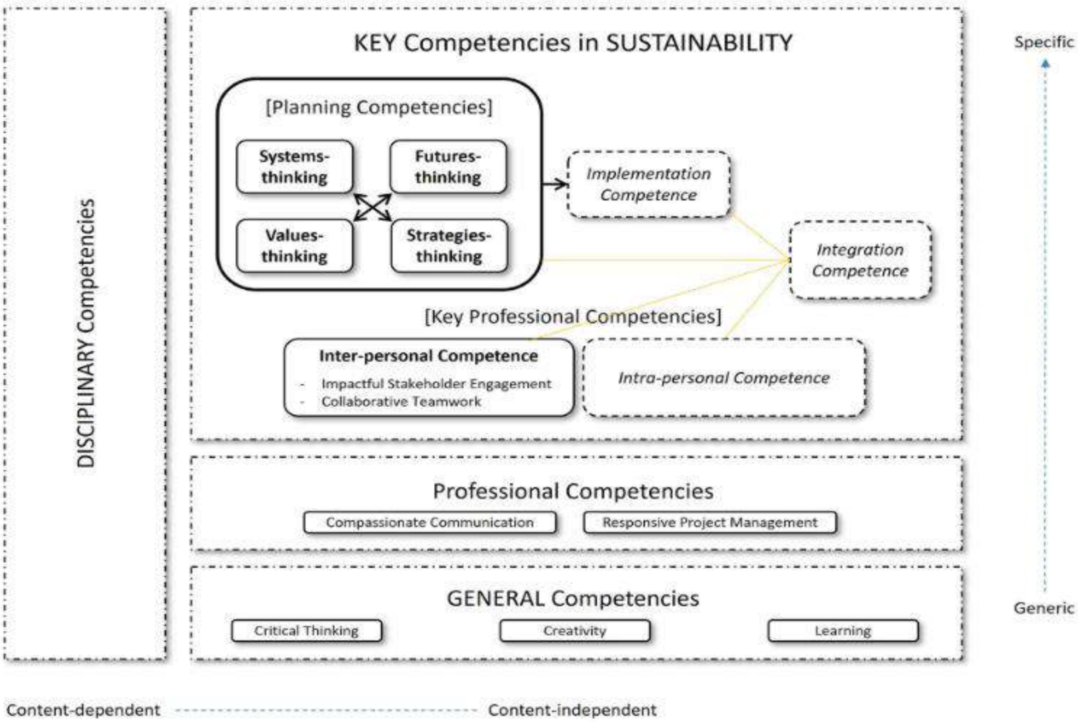


Figure 19: Competencies framework of sustainability (Redman and Wiek 2021).

Redman and Wiek (2021) carried out a systematic literature review and scanned about 270 relevant articles on sustainability competencies with a focus on the academic field, beginning with the framework of Wiek et al. (2011). The framework consists of 8 key-competencies, as they were already proposed among others by Wiek et al. (2011) and Wiek et al. (2016). Additionally, Redman and Wiek (2021) supplemented it by general, professional and disciplinary competencies. To promote sustainability transformation knowledge in certain disciplines like climate or energy is required. The authors categories these into content-dependent competencies. General competencies refer to skills evolved in the 21st century not explicitly linked to sustainability, for instance critical thinking. Project management and communication skills are summarized by the authors as professional skills. Furthermore, they point out that this is not a list of competencies to choose from, instead all these competencies are necessary to enable a sustainable transformation. Figure 19 shows their unified framework of competencies.

5.2.5. Framework for education in sustainability (Juuti et al. 2021)

The project "Schools Educating for Sustainability: Proposals for and from in-service teacher education" conducted by Juuti et al. (2021) focuses on teacher education to advance sustainable development of society. To realise this, both, competency dimensions and topic dimensions must be addressed in education, whether at school or in teacher education. Topic dimensions are categorised along the fields of environmental and natural resources; responsible use of digital technology; dialogue, diversity and inclusion; and economy and financial literacy. These dimensions cover the central topics contributing to global change in sustainability issues. Environmental and natural resources thematise important topics in environmental education such as climate change or the limited availability of natural resources. To use digital technologies holds great potential for dealing with global sustainability issues and includes topics like being critical of information and fake news. Intercultural competencies are important when it comes to adopting other perspectives which is crucial for dealing with sustainability on different levels (e.g. local and global) and is in focus of the dimension of dialogue, diversity and inclusion. In order to promote a resource-conserving and sustainable economy growth competencies in economy and financial literacy are inevitable as they involve topics like the efficient use of materials and resources. Regarding the competency dimensions, the authors use the key competencies proposed by Wiek et al. (2011). With the output of their study, they suggest a framework on how to design the five key competencies according to each of the different topic dimensions. Figure 20 shows as an example of the framework for the dimension of environmental and natural resources.

COMPETENCY	DESIGN PRINCIPLE
Systems-thinking competency	Understanding that natural resources are finite and that the way we use them has consequences for the environment (and thus for humanity, since we are part of an ecological system).
Anticipatory competency	Previewing consequences (positive and negative) for the environment, of how we choose to use natural resources
Strategic competency	Studying, previewing, and testing sustainable ways of using natural resources.
Normative competency	Analyzing present norms and values, to identify changes that are necessary to preserve the natural and social environments.
Interpersonal competency	Presenting individual/group perspectives on the use of natural resources and their consequences for the environment and accepting the need to compare them with other points of view.

Figure 20: Design principle for the dimension of environmental and natural resources (Juuti et al. 2021)

5.2.6. Flower Model (Vesterinen and Ratinen 2024)

Vesterinen and Ratinen (2024) conducted a literature review study and created a model for sustainability education especially in primary school settings, as well using the framework of Wiek et al. (2011) as the basis of their “flower model”. In order that primary school children can acquire sustainability skills the most important factor is, according to them, collaborating, cooperation and interaction with other children and teachers about daily live sustainable actions. Collaboration therefore represents the centre of their flower model. To the other competences (systems-, future- and value-thinking competence and action-oriented competence) they each assign a concept to connect the relating competence to the centre of the flower (collaboration). For example, by thinking about and solving sustainability related problems occurring in daily live children are supposed to develop system-thinking skills. In order to self-confidently and responsibly participate and act within environmental and sustainable related activities, empowerment helps individuals to do so and is thus connected to action-oriented competences. An important skill to develop future-thinking skills is the ability to imagine a sustainable future because this is what drives the idea forward. The authors labelled this connection as imagination. Finally, to successfully collaborate it is crucial to be in close dialogue with each other and social interactions are a good way to teach value-thinking competences. The flower’s stalk is symbolic for the connection with nature. To be well connected with nature positively impacts sustainable behaviour and environmental consciousness. Figure 21 visualises the described flower model according to Vesterinen and Ratinen (2024).

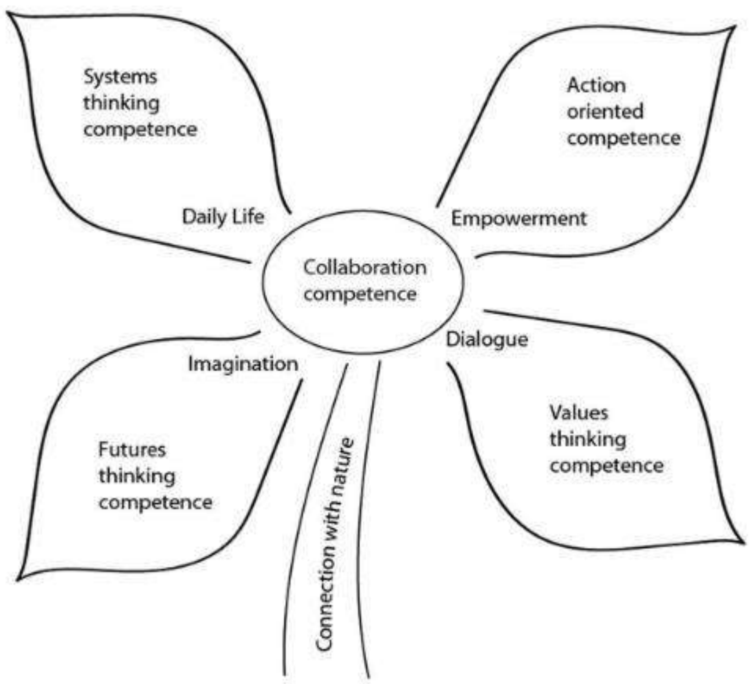


Figure 21: Flower model of sustainability competences according to Vesterinen and Ratinen (2024).

5.2.7. Green Skills Framework (Kwauk and Casey 2022)

In their work, Kwauk and Casey (2022) criticise the frequently occurring perspective that climate change is a challenge which can only be approached by using technology. This view implies that sustainability competences and green skills are located within the field of STEM (science, technology, engineering and mathematics). For the authors it is therefore of importance to position green skills beyond STEM skills in order to act more gender-inclusively and to provide knowledge and competences for all learners. Thus, Kwauk and Casey (2022) created a green skills framework which not only serves skills for green jobs but also considers skills for a green transformation and, at their intersection, green life skills. In this framework, within the first paradigm "skills for green jobs" the transformation towards a green economy is seen from a technical point of view and covers competences related to STEM skills. The paradigm of "green life skills" focuses on competences aiming to make individual behavior more sustainable and greener. The last paradigm, "skills for green transformation" frames the climate crisis as a structural problem of inequality and therefore covers skills needed to critically reflect e.g. social, political and economic conditions. Figure 22 indicates the green skills framework by Kwauk and Casey (2022).

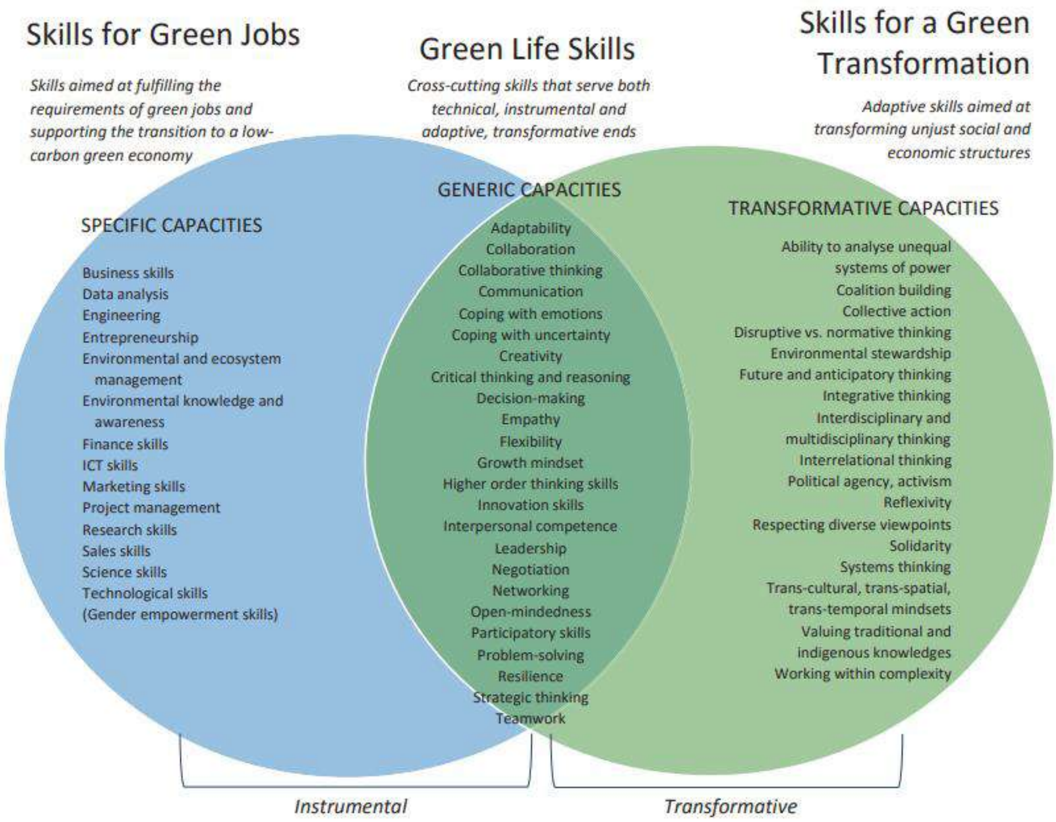


Figure 22: Green skills framework according to Kwauk and Casey (2022)

5.2.8. Skills for green jobs (European Centre for the Development of Vocational Training 2019)

In the study of the European Centre for the Development of Vocational Training (2019) and the International Labour Organisation (ILO) reports of six European countries on the practices around green jobs and green skills were analysed and common handling and differences across the countries elaborated. The involved countries are Denmark, Estonia, France, Germany, Spain and the UK. The authors found that there mostly are no clear definitions of what green jobs or green skills are which makes comparison difficult. The perspectives range from greening traditional occupations (Spain) to very clear ideas of (UK) or no definition (Estonia) on green skills. Also, within countries the concepts can vary. For instance, the focus of the UK previously was to reduce carbon emissions to advance a green economy but recently changed to a broader approach also concentrating on new technologies or sustainable consumption, which as well hampers comparison. In Figure 23 and Figure 24 concepts of green skills of selected countries are shown as examples.

Green skill needs in Estonia: sectoral examples

Agriculture: there are skill needs related to the growth of automation, bio-energy, and biomass. Also required are support for environment-friendly management (such as the growth of organic farming) and more green jobs which consider environmentally friendly soil use.

Forestry: new green jobs in forestry are considered to be those where various skills are combined together in a different, more interdisciplinary way. Forestry workers are required to have additional knowledge in chemistry, biochemistry, and economics of engineering, product and technology development, which should be taken into account when designing future curricula. According to the recent skills forecast, around three quarters of the forestry workforce need to be provided with vocational education, and a quarter with higher education. Industry partners argue for greater vocational focus and a more holistic training approach, to include economics, entrepreneurship and forest management.

Construction: construction curricula need to include more courses on environmental impact evaluation, energy certification, environmental management systems and sustainable construction across all occupations. This would be in line with the Renewable energy implementation plan that includes the construction of example low-energy houses.

Transport: skill requirements are mostly related to the use of environmentally friendly technologies and procurement: it is suggested that the public sector could contribute by demanding the use of sustainable, green technologies and giving them preference in procurement.

Energy: 40% of workers in basic energy occupations are currently aged 50 or older, so new employees will be needed to replace retired workers. The growth rate in mining, heat energy, gas and electricity engineers is considered inadequate, given that the number of applicants for energetics and mining specialisation is stable in higher education. It is essential that professional knowledge and skills are promoted for the sector. In addition to professional skills, employees across the sector are expected to have general skills such as communication, management and collaboration skills.

Read more on p. 21 of the full report: Cedefop (2018f). *Skills for green jobs in Estonia: an update.* http://www.cedefop.europa.eu/en/uploads/dfu/countryreportestonia

Figure 23: Green skills concept of Estonia.

Skills for a green economy	Skill needs
Skills supporting resource efficiency	• Strategic business management to build resource-efficient business models leading to bottom line benefits and in preparation for new regulations • Business/financial accounting services around carbon and natural environment accounting • Skills to design and adopt technologies, products and processes increasing resource efficiency, including lean manufacturing • Project management skills with clear understanding of resource efficiency • Operator level actions to maximise resource efficiency (e.g. reducing waste in production)
Skills supporting low-carbon industry	• Scientists and engineers with training or transferable knowledge for nuclear and renewable energy (including wind and marine) • Technicians with training or transferable knowledge to install energy efficiency measures and retrofit at a household and business premises level • Skills to design and adopt technologies, products and processes to minimise carbon emissions • Operator level actions to minimise carbon emissions (e.g. driving in a fuel efficient manner)
Skills supporting climate resilience	• Scientific and technical skills such as modelling and interpreting climate change projections • Risk management such as assessments of future resource availability • Skills to design and adopt technologies, products and processes to improve climate resilience • Operator level actions to improve climate resilience (e.g. retrofitting water efficient technologies in households and business premises)
Skills to protect and manage natural assets	• Accounting services for the natural environment • Understanding of environmental impact assessments • Understanding and interpretation of environmental legislation targets, ecosystem services design and management and land use planning • Skills to design and adopt technologies, products and processes to manage natural assets

Figure 24: Definition and needs of green skills in England.

5.3. Existing Training Methods

The idea of educating for a sustainable transition is not yet common sense in education policies across EU countries despite being in relevant focus in recent years (European Commission. Directorate General for Education, Youth, Sport and Culture. 2021). Integrating sustainability in curricula still remains a difficulty and there is a necessity for research on how to approach teaching, learning and implementing existing frameworks in sustainability education (Bianchi 2020; European Commission. European Education and Culture Executive Agency 2024; Redman and Wiek 2021). However, it is agreed upon in literature that teaching sustainability requires a pedagogy which encourages an action-oriented, hands-on and learner-centred approach instead of a mere knowledge transfer (European Commission. Directorate General for Education, Youth, Sport and Culture. 2021; European Commission. European Education and Culture Executive Agency 2024; Sipos, Battisti, and Grimm 2008).

5.3.1. Curriculum Integration

The work of the European Commission. European Education and Culture Executive Agency (2024) together with Eurydice analyses school curricular concerning relevant sustainability competences and measures to support educators and schools on primary and secondary level in 39 European countries. The authors filter three different learning approaches in teaching sustainability: cross-curricular, project based or as a stand-alone subject. As part of the cross-curricular approach, which means integrating sustainability into all subjects, there exist different learning strategies across European education systems. Table 9 summarises the findings of the authors upon how sustainability is cross-curricularly embedded (European Commission. European Education and Culture Executive Agency 2024).

Table 9: Cross-curricular methods for teaching sustainability.

In the general objectives of education (p.26)	e.g. one of Hungary´s objectives in education is to create awareness and values for environmental topics
As a key competence area of its own (p.26)	e.g. the Flemish part of Belgium defines sustainability competences as one of the 16 key competences in its curriculum
As one of the major sub-themes linked to one or several key competences (p.27)	e.g. in Spain sustainability related concepts are part of the eight key competences relevant for all areas
As a cross-curricular theme outside the main key competences framework (p.27)	Sustainability education as a cross-curricular topic is e.g. not part of the curricular but in a separate document, e.g. in Estonia sustainability is part of eight cross-curricular themes

Another option to integrate sustainability in an interdisciplinary manner into the curriculum is by project-based learning. This approach refers to the inclusion of sustainability topics across disciplines which enables students to experiment and experience sustainability related concepts beyond regular subjects. Usually, the organization of projects can be carried out by the schools very autonomously with basic frameworks provided by the curriculum. Teaching sustainability as a separate subject is the least common method. The authors suggest that interdisciplinarity is inherent to sustainability and thus it requires a broad approach which is challenging to realise in a separate subject (European Commission. European Education and Culture Executive Agency 2024).

The overall results of the European Commission. European Education and Culture Executive Agency (2024) analysis reveal that all of the examined European countries cover sustainability topics in the curriculum which are incorporated in the subjects natural sciences, citizenship education and geography in most cases. In addition, most education systems treat sustainability competences in a cross-curricular way. Table 10 gives an overview on how sustainability is integrated in education systems across selected European countries in primary and secondary education (ISCED 1, 24 and 34).

The study of the European Commission. Directorate General for Education, Youth, Sport and Culture (2021) provides a comprehensive overview on approaches, practices and measurements of embedding education for environmental sustainability in national education systems. According to the authors, education for sustainability is not only about teaching content: "[i]n addition to content (learning ´about´), learning should occur ´in´ the environment studied, ´through´ a supportive culture, and should foster behaviours ´for´ environmental sustainability" (European Commission. Directorate General for Education, Youth, Sport and Culture. 2021). Therefore, sustainability should be taught along three dimensions: cognitive, socio-emotional, and behavioural. The cognitive dimension refers to the gain of knowledge and understanding about environmental and sustainability concepts. Developing values, responsibility and respect towards environmental and sustainable issues is achieved by the socio-emotional dimension. The behavioural dimension relates to the development of skills connected to sustainability consciousness. Furthermore, sustainability education requires according to the authors a "whole-institution approach" (European Commission. Directorate General for Education, Youth, Sport and Culture. 2021). This means not only incorporating sustainability related concepts in curricula but also making them a basic principle of action for schools as institutions including high-quality training for staff and leaders as well as green infrastructure and sustainable management, which aims to provide a general supportive setting for learners. As a fourth pillar, this completes the dimensions for education for sustainability, visualized in Figure 25.

Table 10: Overview of the integration of sustainability education in Austria, Germany, Spain, Belgium, Ireland, Estonia, Finland, Switzerland and Denmark (European Commission. European Education and Culture Executive Agency 2024)

	Curricular integration				
Country	**General objective**	**Cross-curricular**	**Project-based**	**Separate subject**	**Remarks**
Austria	x	x	x		
Germany		x			
Spain	x	x	x	x (optional)	
Belgium		x			Refers only to ISCED 1 and ISCED 24 for the French-speaking part of Belgium. In the German-speaking part of Belgium sustainability education is included as a general objective whereas for the French- and Flemish-speaking part it is not.
Ireland		x			
Estonia	x	x	x		
Finland	x	x			
Switzerland		x			Refers only to ISCED 1 and ISCED 24. An educational reform for ISCED 34 is going on
Denmark			x		

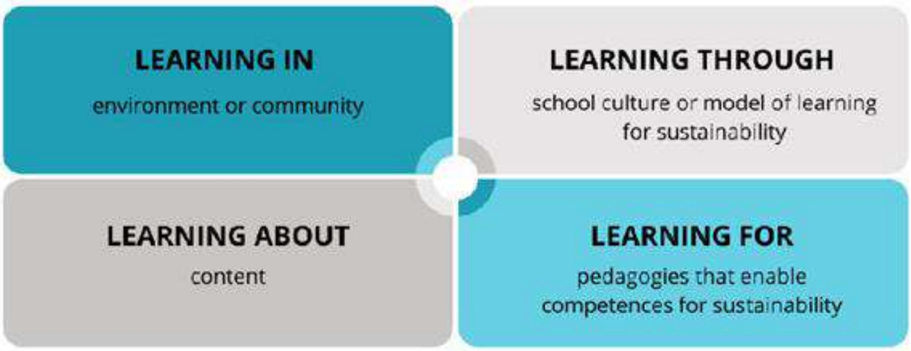


Figure 25: Four dimensions of education for sustainability according to (European Commission. Directorate General for Education, Youth, Sport and Culture., 2021, p.10)

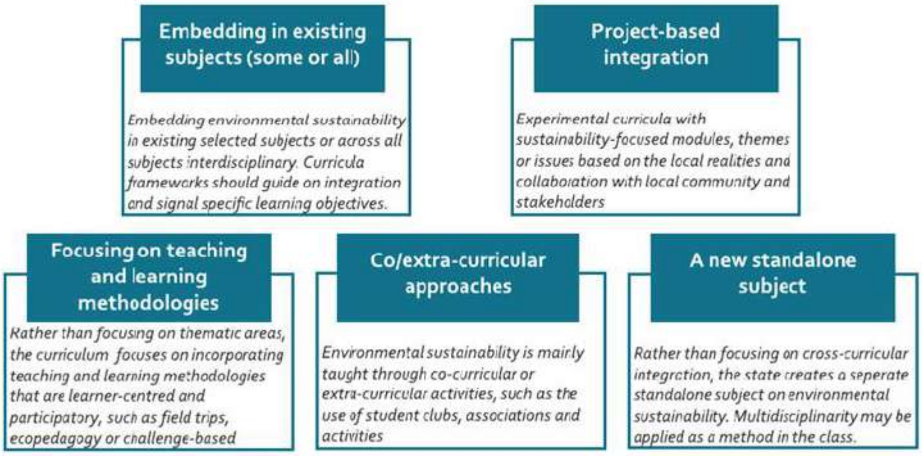


Figure 26: Mainstream approaches to embed sustainability education in curricular (European Commission. Directorate General for Education, Youth, Sport and Culture. 2021)

Additionally, solely including sustainability themes in school curricular is not enough for it to be adequately taught. Rather, due to its complexity, transformative and transdisciplinary approaches are needed. To ensure a sustainable transformation of society, instead of simple knowledge transfer, a shift towards a more caring and positive mindset concerning the environment is required. Figure 26 shows mainstream approaches on how to embed sustainability education in school curricular according to the European Commission. Directorate General for Education, Youth, Sport and Culture (2021).

5.3.2. Training Methods

Primary and secondary education

Research shows, that in many countries still it is about knowledge transfer when it comes to teaching sustainability, which is not enough in order to develop sustainable competences and behavior. To make sustainability mainstream it therefore requires appropriate training methods (European Commission. European Education and Culture Executive Agency 2024).

The European Commission. European Education and Culture Executive Agency (2024) discusses within their study suitable strategies which are summarized in Table 11.

Table 11: Suitable strategies for teaching environmental sustainability according to (European Commission. European Education and Culture Executive Agency 2024)

Strategy	Explanation
1. Game-based learning using digital tools (p.93)	Engaging and interactive sustainable strategy games enable learners to experience their own behaviour. They support students to gain knowledge and to develop important green skills. Besides they carry the potential to achieve the wanted changes in values and attitudes. Digital tools promote empathy in children when the content and interaction are prosocial and the screen time is balanced with a face-to-face time. But the usage of digital technology also carries limitations e.g. a lack of in socio-economic disadvantaged areas.
2. Learner-centred pedagogy (p.94)	Focuses on learners as active constructors instead of passive learners. Learner-centred methods stimulate students to reflect their knowledge and learning processes in order to guide them and are seen suitable for education for sustainability as they can promote behavioural and transformative change. Digital tools can help to provide individual learning environments to promote learner-centred approaches.

3. Art-based enquiry experiences (p.94f)	Arts-based learning approaches are increasingly being used as they are said to positively contribute to personal and social change. It can help learners to imagine a sustainable way of living and to develop a personal connection with the environment which is an important driving factor regarding sustainable transformation.
4. Outdoor education (p.95)	Outdoor education enables learning by experiences in and with nature and is seen as effective when teaching sustainability values and attitudes. It enables children to reflect their behaviour by learning in reality and has a positive impact on the motivation to learn.
5. Project and problem-based learning (p.95)	In a project and problem-based learning approach learning takes place via solving real world problems by engaging with the environment. It effectively enables transformative learning while meeting the complexity and interdisciplinarity of sustainability. It fosters creativity and critical thinking skills as well as self-efficacy.
6. Forrest, earth and eco-pedagogies	These pedagogies aim at promoting and improving the personal relationship and affection to nature resulting in an intrinsic motivation to life in a pro-environmentally way. Are usually combined with outdoor learning.
7. Further teaching tools mentioned	Civil Discourse Engagement in a single local discourse Exploring different contexts of an issue Computer modelling Gamification Experimental field work with a basis in problem-based education Escape Rooms Indigenous and wild pedagogy

Jeronen, Palmberg, and Yli-Panula (2016) analysed 24 scientific articles according to teaching methods for biology education as well as for education for sustainability in primary and secondary school level. The authors come up with in total 22 teaching strategies which are visualized and listed according to the frequency of reference in Figure 27.

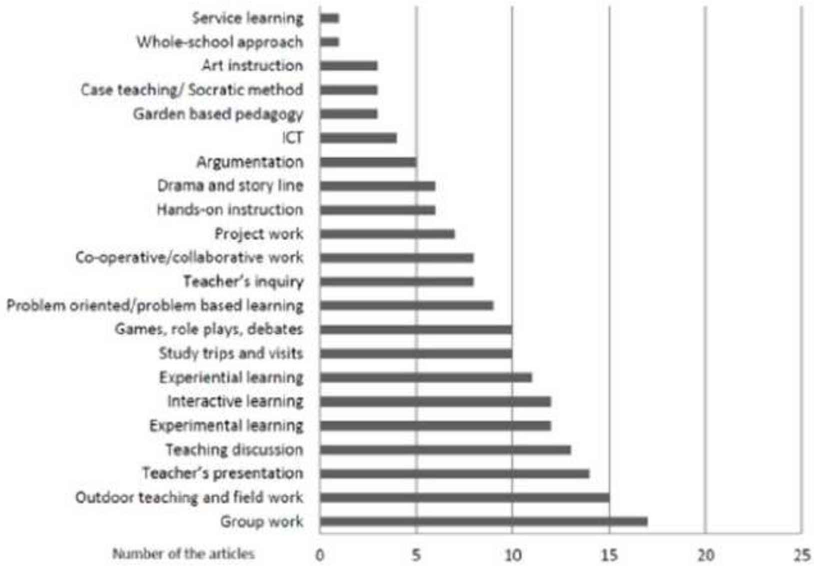


Figure 27: Teaching methods in education for sustainability according to (Jeronen et al. 2016)

The most highlighted teaching methods are the ones, which allow learners to actively engage in the learning process and enable group work. Specifically outdoor education, including field trips and field work, is a popular teaching method which offers an important learning environment for developing a deeper connection with nature and thus increases sustainable and environmental consciousness and attitudes (Jeronen et al. 2016).

The European sustainability framework, GreenComp, as well suggests pedagogical methods which contribute to the development of sustainability competences (European Commission. Joint Research Centre. 2022a):

- Active learning
- Student-centered, project-based and transformative learning
- Gamification
- Role-plays, experimental games and simulations
- Analysing case-studies form the local context
- Blending and online learning
- Outdoor approaches
- Collaborative approaches (with external partners)

GS & Games

"GET UP! – the game" is the output of the eponymous project[14] and an interactive video game designed for the upper secondary level which deals with the preservation of a nature reserve from the point of view of its managing director. The game has two elements which must be controlled and balanced throughout the game. Biodiversity as an indicator for the health of flora and fauna and consensus as the extent of appreciation of the park by the local population. An increasing biodiversity results in a decreasing acceptance of the park and vice versa. The goal is to advance in the game as many months as possible. "GET UP!" fosters the development of sustainability and environmental competencies such as recognizing the importance of biodiversity and natural land protection. According to the developers the game further contributes to the development of soft skills such as: strategic planning, time management, problem-solving, decision making and reflectivity about environmental impacts (GET UP! The Game 2020).

Arising from the GreenComp framework for sustainability competences the GreenComp Game promotes the development of a sustainable future by discussing and evaluating the priorities of such. It is designed as a conversational game which reflects on the SDGs, the competences included in the GreenComp framework as well as the EducationForClimate's innovation areas (Education for Climate 2024).

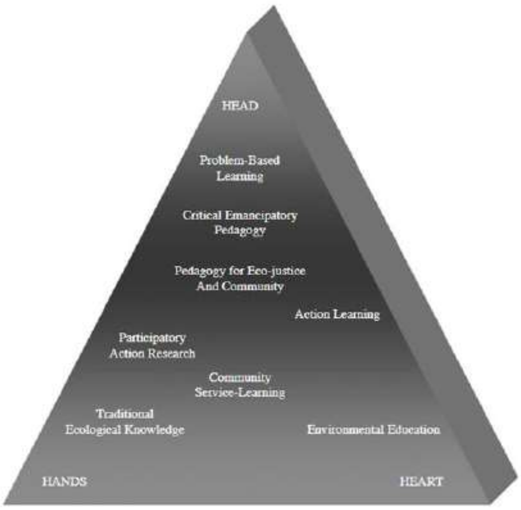
Higher education

In the work of Sipos et al. (2008) a higher education pedagogic framework for transformative sustainability learning organized along the principles of head, hands and heart is presented. The uttermost goal of transformative learning is to enable learners to change their relationship and view of the world with critical reflection being essential for its achievement. Similar to the three dimensions of the European Commission. Directorate General for Education, Youth, Sport and Culture (2021) the principle of ´head´ refers to cognitive engagement with sustainability topics e.g. knowledge about sustainability. The principle ´hands´ relates to the psychomotor area including practical competences and physical activity, whereas ´hearts´ aims at developing pro-sustainable values and attitudes resulting in a behavioural impact.

[14] https://getup.erasmus.site

Furthermore, the authors conducted a literature review on existing pedagogical concepts concerning sustainability education. Additionally, they categorized the pedagogical concepts according to the principles of head, hands and heart which is depicted in Figure 28.

Pedagogical model	Overview of intended learning outcomes
Action learning	A form of experiential learning that enlists peers in helping learners question their assumptions and (optimally) experience a paradigm shift before applying their learning in new situations (McGill and Brockbank, 2004; Revans, 1998)
Community service-learning	An educational approach that integrates service in the community with intentional learning activities. Within effective CSL efforts, members of both educational institutions and community organizations work together toward outcomes that are mutually beneficial (Hayes, 2006, p. 2)
Critical emancipatory pedagogy	An ideology for learning facilitation that arises from an emancipatory tradition, focusing on equity amongst classes, races and genders (Mezirow, 1985; Freire, 1970)
Environmental education	An approach to teaching and learning that provides people with experience and knowledge to care for our environments (Gruenewald, 2004; Orr, 1994)
Participatory action research	A summary of terms in social science that refer to involvement of participants in the research process, commitment to social change, and that include aspects of social learning. There are many ways to define true participation, action and exactly what constitutes true research (Moore, 2005b; Coghlan and Brannick, 2001, Ch. 1; Stringer, 1999)
Pedagogy for eco-justice and community	An ideology for learning facilitation that acknowledges and finds tensions in "industrial mindset," works to replace attitudes with the metaphor of ecology (Bowers, 2001)
Problem-based learning	A framework for learning that is focused, experiential and organized around investigation of real-world problems. Authentic experiences foster active learning, support knowledge construction and integrate school learning and real life (Association for Supervision and Curriculum Development, 2005; Barrows, 1994)
Traditional ecological knowledge	Knowledge bases built by local or traditional resource users, as opposed to "experts"; argues for acknowledgement of more diverse forms of knowledge (as opposed to simply expert western science) (Berkes, 2004; Turner *et al.*, 2000)



Notes: This ternary diagram charts the relatedness amongst these pedagogies to each other and to the foci of Head, Hands and Heart. The pedagogies are not fixed in position; their relative positions will be influenced by their particular practice

Figure 28: Left: Overview and explanation of pedagogical models. Right: pedagogical concepts of sustainability and transformative learning categorized according to head, hands, and heart (Sipos et al. 2008).

In the study of Lozano et al. (2017) the authors come up with a framework of twelve pedagogical approaches for sustainability education in higher education based on a literature review of well-cited references. These pedagogical approaches do not stand alone but can also be used cooperatively. The authors categorized them according to three main pillars and assigned each specific teaching methods (Lozano et al. 2017):

1) **Universal**: pedagogies which can be broadly applied in many disciplines such as case studies, mind and concepts maps, interdisciplinary team teaching and project/problem-based learning.
2) **Community and social justice**: pedagogies which are specifically linked to community-building and social justice including participatory action research, community service learning and jigsaw/interlinked teams.
3) **Environmental education**: pedagogies that emerge from environmental sciences such as eco-justice and community, place-based environmental education, supply chain/life cycle analysis, and traditional ecological knowledge.

Additionally, they provide a matching of pedagogical methods and sustainability competences, which is depicted in Figure 29. The green cells indicate a high probability that the pedagogical approach addresses a specific competence, a yellow cell displays that the competence is likely to be addressed and a white cell does not indicate any contribution of the pedagogical approach to the development of a specific competence.

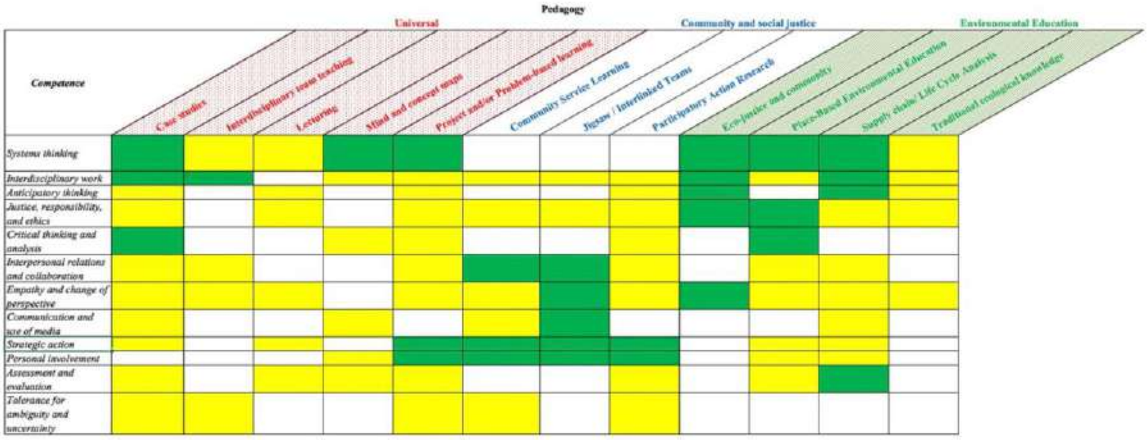


Figure 29: Matching matrix of pedagogical approaches and sustainability competences (Lozano et al. 2017).

Tejedor et al. (2019) reviewed didactic strategies relevant for higher sustainability education and present how these can be implemented in a higher education setting. Table 12 lists five active learning strategies, describes the characteristics and explains how they contribute to the improvement of sustainability education in higher education.

Table 12: Overview of the five learning strategies covered by Tejedor et al. (2019)

Strategy	Explanation
1. Problem-based learning (PBL)	Students actively learn to solve a problem by searching and analysing necessary information in small groups. In the first place is not the solution of the problem but to critically reflect the information obtained by various resources and to learn from dealing with the challenges evolving during the process. PBL should equip students with problem-solving skills for their future professional work. Furthermore, they are trained in critical thinking, to be responsible for their own learning process and to experience the multi- and interdisciplinarity of (sustainability related) problems.
2. Project oriented learning (POL)	Is a constructivist teaching and active learning strategy which connects theory with practice by solving real world challenges and places students the center of POL. Students are trained in applying their knowledge in real situations and in carrying responsibility for their own learning processes by actively steering it.
3. Service learning (S-L)	S-L, or community-based learning, is a learning method that refers to learning by the active engagement in a community. It is an experimental method by which learning takes place through the organisation of projects addressing real needs. It favours the development of personal, social and community competences like solidarity and social responsibility.
4. Case study	Refers to a learning method in which students are given a certain situation containing several problems which must be analysed, discussed and elaborated. Case-studies are conceptualized on real situations relevant to the student´s field of education. The students are trained to develop critical and complex thinking skills as well as putting knowledge into practice. Different levels of difficulty and designs are possible and it is often combined with project- or problem based learning.
5. Simulation	Simulation refers to an experimental learning strategy and includes e.g. role-games or simulation games. It is useful for working on conflicts in an socio-environmental context and promote reflection within it. The learning process takes place within the learner and via discussion and sharing in a group communication and teamwork skills are promoted. It is a suitable method to address the complexity and interrelations between contexts, subjects or institutions of certain problems.

VET

A transition towards a sustainable and green economy will have significant impacts on the employment sector. It is unavoidable to ensure that all citizens become equipped with knowledge, competences and skills to deal with this changes. VET will play an decisive role in qualifying learners with necessary skills to adjust to the changing requirements of the working force. This applies both to young people at the beginning of their careers and to adults who need up- or reskilling (European Commission. Directorate General for Employment, Social Affairs and Inclusion. 2023).

European Commission. Directorate General for Employment, Social Affairs and Inclusion (2023) therefore provides practices and concepts on how VET can contribute and adapt in order to achieve a transition towards a green economy. "New green skills need new ways of teaching and learning" (European Commission. Directorate General for Employment, Social Affairs and Inclusion. 2023): VET finds itself in being in a suitable position to promote and support the development of new teaching and learning strategies. The basis of VET is formed by a combination of theoretical and practical learning which provides a good starting point: learners develop both technical and green key skills such as critical thinking and trainers are already used to switch between different teaching strategies which makes embracing new ways of teaching easier. Table 13 lists and characterizes teaching methods suitable for VET.

Table 13: Teaching methods suitable for VET according to the European Commission. Directorate General for Employment, Social Affairs and Inclusion (2023).

Strategy	Explanation
Digital and blended learning (p.37)	Blended learning is often integrated to projects regarding a green transition in VET. It refers to a learning method which combines online, distance and face-to-face methods to achieve a mix of learning experiences (Caird and Roy 2019). The application of digital technology can expand learning opportunities e.g. through virtual reality. E.g. an output of the LIFE FOSTER project including France, Spain, Malta, and Italy is an app that monitors food waste and its resulting costs which trained the learners view on the effectiveness of saving food.
Project based learning (p.39)	Promotes interdisciplinary learning and problem-solving skills fundamental for the complexity of sustainable and environmental issues. E.g. in Albania sustainability education is obligatory in vocational education, and it incorporates small projects and activities dedicated to the protection of the local environment.
Learning by developing digital products and services for the green transition (p.40)	Digital technologies play a relevant role within the green transition of economy and society. This learning methods focuses on the development of new, beneficial digital tools which foster and provides a learning environment at the intersection of sustainability and digitalisation. E.g. in Latvia VET students created a smart garden in which plant growth and health is monitored by a robot.
Learning for entrepreneurship (p.40)	The transition towards a green economy is often related with entrepreneurship. Teaching methods in entrepreneurship education can foster the green transition e.g., by developing the market for sustainable products and services. E.g., ´the sustainable fashion brand´ in Spain targets the environmental pollution of the fast fashion sector and aims to demonstrate how it can be reduced.
Learning through games (p.41)	Game based learning offers the opportunity to push forward the green transition in VET and is also able to engage learners who are difficult to be motivated by other learning strategies. There already are many such products available like games aiming at building green cities. Among the listed teaching methods game-based learning is the less favoured. Nevertheless e.g. Germany supported the development of two educational games in the context of saving resources e.g., "My World – My Things"

6. OVERVIEW OF COMPETENCE FRAMEWORKS ALIGNED WITH ComeThinkAgain

6.1. DigComp

The Digital Competence Framework for Citizen (DigComp) provides a common understanding of what digital competence is (European Commission: Joint Research Centre et al. 2022).

Figure 30: The DigComp Conceptual reference model.

There are 21 competences that are pertinent to these areas, their titles and descriptors are outlined in Dimension 2. Taken together, Dimension 1 and 2 form the conceptual reference model. Additional Dimensions outline Proficiency levels (Dimension 3), Examples of knowledge, skills and attitudes (Dimension 4) and Use cases (Dimension 5). The latest publication, DigComp 2.2, presents the consolidated framework.

1) **Information and data literacy**

Competences (Dimension 2)

1.1 Browsing, searching and filtering data, information and digital content
To articulate information needs , to search for data, information and content in digital environments, to access them and to navigate between them. To create and update personal search strategies.

1.2 Evaluating data, information and digital content
To analyse, compare and critically evaluate the credibility and reliability of sources of data, information and digital content. To analyse, interpret and critically evaluate the data,

information and digital content.

1.3 Managing data, information and digital content
To organise, store and retrieve data, information and content in digital environments. To organise and process them in a structured environment.

2) **Communication and collaboration**

Competences (Dimension 2)

2.1 Interacting through digital technologies
To interact through a variety of digital technologies and to understand appropriate digital communication means for a given context.

2.2 Sharing through digital technologies
To share data, information and digital content with others through appropriate digital technologies. To act as an intermediary, to know about referencing and attribution practices.

2.3 Engaging in citizenship through digital technologies
To participate in society through the use of public and private digital services. To seek opportunities for self-empowerment and for participatory citizenship through appropriate digital technologies.

2.4 Collaborating through digital technologies
To use digital tools and technologies for collaborative processes, and for co-construction and co-creation of resources and knowledge.

2.5 Netiquette
To be aware of behavioural norms and know-how while using digital technologies and interacting in digital environments. To adapt communication strategies to the specific audience and to be aware of cultural and generational diversity in digital environments.

2.6 Managing digital identity
To create and manage one or multiple digital identities, to be able to protect one's own reputation, to deal with the data that one produces through several digital tools, environments and services.

3) **Digital content creation**

Competences (Dimension 2)

3.1 Developing digital content
To create and edit digital content in different formats, to express oneself through digital means.

3.2 Integrating and re-elaborating digital content
To modify, refine, improve and integrate information and content into an existing body of knowledge to create new, original and relevant content and knowledge.

3.3 Copyright and licences
To understand how copyright and licences apply to data, information and digital content.

3.4 Programming
To plan and develop a sequence of understandable instructions for a computing system to solve a given problem or perform a specific task.

4) **Safety**

Competences (Dimension 2)

4.1 Protecting devices
To protect devices and digital content, and to understand risks and threats in digital environments. To know about safety and security measures and to have due regard to reliability and privacy.

4.2 Protecting personal data and privacy
To protect personal data and privacy in digital environments. To understand how to use and share personally identifiable information while being able to protect oneself and others from damages. To understand that digital services use a "Privacy policy" to inform how personal data is used.

4.3 Protecting health and well-being
To be able to avoid health-risks and threats to physical and psychological well-being while using digital technologies. To be able to protect oneself and others from possible dangers in digital environments (e.g. cyber bullying). To be aware of digital technologies for social well-being and social inclusion.

4.4 Protecting the environment
To be aware of the environmental impact of digital technologies and their use.

5) **Problem-solving**

Competences (Dimension 2)

5.1 Solving technical problems
To identify technical problems when operating devices and using digital environments, and to solve them (from trouble-shooting to solving more complex problems).

5.2 Identifying needs and technological responses
To assess needs and to identify, evaluate, select and use digital tools and possible technological responses to solve them. To adjust and customise digital environments to personal needs (e.g. accessibility).

5.3 Creatively using digital technologies
To use digital tools and technologies to create knowledge and to innovate processes and products. To engage individually and collectively in cognitive processing to understand and resolve conceptual problems and problem situations in digital environments.

5.4 Identifying digital competence gaps
To understand where one's own digital competence needs to be improved or updated. To be able to support others with their digital competence development. To seek opportunities for self-development and to keep up-to-date with the digital evolution.

6.2. EntreComp

The Entrepreneurship Competence Framework, also known as EntreComp Framework, was developed by the European Commission in 2016 to promote entrepreneurial competences as one of the 8 key competences for lifelong learning (European Commission. Joint Research Centre. 2016).

The framework comprises three main competence areas: "Ideas and Opportunities", "Resources" and "Into action". These key competence areas form the first dimension of the EntreComp Conceptual Model, reflecting entrepreneurship as the ability to put ideas into action that create value for someone other than oneself.

The second dimension consists of the 15 specific competences. These are divided into the 3 main competence areas. In Table 14, the competences are summarized including a hint or an exhortation and a descriptor which breaks down the competence into its core aspects.

Table 14: Summary of EntreComp competences.

Areas	Competences	Hints	Descriptors
Ideas & Opportunities	Spotting opportunities	Use your imagination and abilities to identify opportunities for creating value	• Identify and seize opportunities to create value by exploring the social, cultural and economic landscape • Identify needs and challenges that need to be met • Establish new connections and bring together scattered elements of the landscape to create opportunities to create value
	Creativity	Develop creative and purposeful ideas	• Develop several ideas and opportunities to create value, including better solutions to existing and new challenges • Explore and experiment with innovative approaches • Combine knowledge and resources to achieve valuable effects
	Vision	Work towards your vision of the future	• Imagine the future • Develop a vision to turn ideas into action • Visualize future scenarios to help guide effort and action
	Valuing ideas	Make the most of ideas and opportunities	• Judge what value is in social, cultural and economic terms • Recognize the potential an idea has for creating value and identify suitable ways of making the most out of it
	Ethical and sustainable thinking	Assess the consequences and impact of ideas, opportunities and actions	• Assess the consequences of ideas that bring value and the effect of entrepreneurial action on the target community, the market, society and the environment • Reflect on how sustainable long-term social, cultural and economic goals are, and the course of action chosen • Act responsibly
Resources	Self-awareness and self-efficacy	Believe in yourself and keep developing	• Reflect on your needs, aspirations and wants in the short, medium and long term • Identify and assess your individual and group strengths and weaknesses • Believe in your ability to influence the course of events, despite uncertainty, setbacks and temporary failures
	Motivation and perseverance	Stay focused and don't give up	• Be determined to turn ideas into action and satisfy your need to achieve • Be prepared to be patient and keep trying to achieve

			your long-term individual or group aims • Be resilient under pressure, adversity, and temporary failure
	Mobilizing resources	Gather and manage the resources you need	• Get and manage the material, non-material and digital resources needed to turn ideas into action • Make the most of limited resources • Get and manage the competences needed at any stage, including technical, legal, tax and digital competences
	Financial and economic literacy	Develop financial and economic know how	• Estimate the cost of turning an idea into a value-creating activity • Plan, put in place and evaluate financial decisions over time • Manage financing to make sure my value-creating activity can last over the long term
	Mobilizing others	Inspire, enthuse and get others on board	• Inspire and enthuse relevant stakeholders • Get the support needed to achieve valuable outcomes • Demonstrate effective communication, persuasion, negotiation and leadership
Into action	Taking the initiative	Go for it	• Initiate processes that create value • Take up challenges • Act and work independently to achieve goals, stick to intentions and carry out planned tasks
	Planning and management	Prioritize, organize and follow-up	• Set long-, medium- and short-term goals • Define priorities and action plans • Adapt to unforeseen changes
	Coping with uncertainty, ambiguity, and risk	Make decisions dealing with uncertainty, ambiguity and risk	• Make decisions when the result of that decision is uncertain, when the information available is partial or ambiguous, or when there is a risk of unintended outcomes • Within the value-creating process, include structured ways of testing ideas and prototypes from the early stages, to reduce risks of failing • Handle fast-moving situations promptly and flexibly
	Working with others	Team up, collaborate and network	• Work together and co-operate with others to develop ideas and turn them into action • Network • Solve conflicts and face up to competition positively when necessary
	Learning through experience	Learn by doing	• Use any initiative for value creation as a learning opportunity • Learn with others, including peers and mentors • Reflect and learn from both success and failure (your own and other people's)

6.3. GreenComp

The European sustainability competence framework, short GreenComp, provides an EU-wide reference framework for learners and educators and thus a unified concept of what competences in sustainability include (European Commission. Joint Research Centre. 2022a). The framework incorporates 12 competences which are organized in four dimensions: embodying sustainability values, embracing complexity in sustainability, envisioning sustainable futures, and acting for sustainability. Table 15 lists the four dimensions, the competences assigned to them as well as a short characterisation of each.

Table 15: List of dimensions, competences, and descriptors of the GreenComp framework.

AREA	COMPETENCE	DESCRIPTOR
1. Embodying sustainability values	1.1 Valuing sustainability	To reflect on personal values; identify and explain how values vary among people and over time, while critically evaluating how they align with sustainability values.
	1.2 Supporting fairness	To support equity and justice for current and future generations and learn from previous generations for sustainability.
	1.3 Promoting nature	To acknowledge that humans are part of nature; and to respect the needs and rights of other species and of nature itself in order to restore and regenerate healthy and resilient ecosystems.
2. Embracing complexity in sustainability	2.1 Systems thinking	To approach a sustainability problem from all sides; to consider time, space and context in order to understand how elements interact within and between systems.
	2.2 Critical thinking	To assess information and arguments, identify assumptions, challenge the status quo, and reflect on how personal, social and cultural backgrounds influence thinking and conclusions.
	2.3 Problem framing	To formulate current or potential challenges as a sustainability problem in terms of difficulty, people involved, time and geographical scope, in order to identify suitable approaches to anticipating and preventing problems, and to mitigating and adapting to already existing problems.
3. Envisioning sustainable futures	3.1 Futures literacy	To envision alternative sustainable futures by imagining and developing alternative scenarios and identifying the steps needed to achieve a preferred sustainable future.
	3.2 Adaptability	To manage transitions and challenges in complex sustainability situations and make decisions related to the future in the face of uncertainty, ambiguity and risk.
	3.3 Exploratory thinking	To adopt a relational way of thinking by exploring and linking different disciplines, using creativity and experimentation with novel ideas or methods.
4. Acting for sustainability	4.1 Political agency	To navigate the political system, identify political responsibility and accountability for unsustainable behaviour, and demand effective policies for sustainability.
	4.2 Collective action	To act for change in collaboration with others.
	4.3 Individual initiative	To identify own potential for sustainability and to actively contribute to improving prospects for the community and the planet.

7. Competence area cross-analysis

7.1. CT

7.1.1. Correlation of CT and DigComp Competences

The European Union defines digital competences as a "confident, critical and responsible use of, and engagement with, digital technologies for learning, at work, and for participation in society" (European Commission. Directorate General for Education, Youth, Sport and Culture. 2019). According to European Commission: Joint Research Centre et al. (2022) the DigComp framework displays the competences in-depth to be developed to deal with a rapid changing world regarding ongoing digitalisation in nearly all areas of everyday life. These encompass five key competences: "information and data literacy, communication and collaboration, digital content creation, safety and problem-solving". Whereas the first three aspects are referring to specific applications and uses, the key-competences "safety" and "problem-solving" are of general importance when acting with digital technologies independent of a certain kind of activity (European Commission: Joint Research Centre et al. 2022).

The main competence to be focused on by the ComeThinkAgain project concerning CT can be assigned to the "problem-solving" key competence of the DigComps framework. But, because of the generic access of the ComeThinkAgain project, problem-solving is kept in a broader sense and is assumed as a general way of thinking which can also be applied to other disciplines and is not only aimed at technical problems (European Commission: Joint Research Centre et al. 2022). The project therefore as well covers skills necessary to deal with problems from a CT point of view e.g. abstraction or pattern recognition (see 2.2.1). Nevertheless, it has clear overlaps with the DigComp framework by putting a focus on digital technologies to creatively support the acquisition of problem-solving skills in a digital environment and beyond that (European Commission: Joint Research Centre et al. 2022).

We assume problem-solving is of general significance beyond computer sciences and as well affects the other areas of competences addressed by the ComeThinkAgain project, Entrepreneurship Education (EE) and Green Skills (GS).

The overlap between CT and the DigComp framework can be seen particularly in the areas of **information and data literacy, communication and collaboration**, **digital content creation** and **problem-solving** (Table 16).

In pillar 1, **data literacy** serves as a foundational aspect of CT, where individuals not only utilize data but also navigate, assess, and structure it effectively. This higher-level understanding allows for more informed decision-making and enhances the ability to tackle complex problems, ultimately fostering a more profound engagement with technology and data-driven environments.

In pillar 2, Netiquette and Managing Digital Identity, do not align as closely with CT. In contrast, the other competences related to Interacting, Sharing, Engaging, and Collaborating through digital technologies can be seen as facets of CT Participation. They involve utilizing digital tools to co-create and communicate effectively.

In pillar 3, Copyright and Licences does not align with CT because it centres on legal and ethical aspects. **Programming**, developing content and remixing fits well within CT, as it involves planning and developing sequences of instructions to solve problems. It's important for us that the focus is not on specific tools or programming languages, but rather on a general understanding of programming concepts such as data structures, loops, and algorithms.

CT and safety competences (pillar 4) not seamlessly align due to their distinct focuses: CT emphasizes problem-solving and innovation in digital technologies, often pushing the boundaries of what is technologically possible, while safety competences concentrate on risk management, privacy, and preservation, prioritizing caution and regulation. This difference can create a gap where the rapid pace of technological advancement in CT outstrips the development of comprehensive safety standards, leading to potential oversights in risk management and safety protocols, which may be perceived as hindering innovation.

All competences in this pillar (pillar 5) align with Computational Thinking (CT) and can be categorized under **higher-order problem-solving**. This classification emphasizes the ability to not only identify and resolve technical issues but also to assess needs and creatively use digital tools for innovation.

Table 16: Correlation of CT and DigComp Competences

DigComp	CT
1. Information and data literacy	
1.1 Browsing, searching, and filtering data, information, and digital content	X
1.2 Evaluating data, information, and digital content	X
1.3 Managing data, information, and digital content	X
2. Communication and collaboration	
2.1 Interacting through digital technologies	X
2.2 Sharing through digital technologies	X
2.3 Engaging in citizenship through digital technologies	X
2.4 Collaborating through digital technologies	X
2.5 Netiquette	
2.6 Managing digital identity	
3. Digital content creation	
3.1 Developing digital content	X
3.2 Integrating and re-elaborating digital content	X
3.3 Copyright and licences	
3.4 Programming	X
4. Safety	
4.1 Protecting devices	
4.2 Protecting personal data and privacy	
4.3 Protecting health and well-being	
4.4 Protecting the environment	
5. Problem-solving	
5.1 Solving technical problems	X
5.2 Identifying needs and technological responses	X
5.3 Creatively using digital technologies	X
5.4 Identifying digital competence gaps	X

7.1.2. General Competence List

The reviewed literature offers a comprehensive perspective on CT skills. This initial list includes the CT-relevant competencies from the DigComp framework and frequently mentioned competences from the literature (Chapter 3). It makes a first attempt at grouping similar competences, but at the same time it is evident that some competences can be categorised in different ways.

Table 17: General list of competences for CT.

Competence	Sub-Competencies	Resource
Data Literacy	data collection, data analysis, data interpretation, data evaluation, data management, data representation, understanding data structures, data-driven decision-making	(Barr and Stephenson 2011; Brennan and Resnick 2012; European Commission. Joint Research Centre. 2022b; European Commission: Joint Research Centre et al. 2022; Grover and Pea 2013; Kalelioglu, Gulbahar, and Kukul 2016; Seiter and Foreman 2013)
CT Participation	communication, collaboration, collaborative problem-solving and participatory approaches to learning, emphasizing collaboration, reuing, remixing and project-based learning. It includes the ability to work effectively in teams, share ideas, and build on the contributions of others using computational tools and method, developing skills necessary for global digital citizenship.	(Brennan and Resnick 2012; European Commission: Joint Research Centre et al. 2022; Kafai 2016; Partnership for 21st Century Skills 2019)
Computing	creatively using digital technologies, parallelisation, testing and debugging, control structure, automation, event, conditions, data types, functions, iterations, loops (repetitions), modularization, sequencing, threads	(Atmatzidou and Demetriadis 2016, 2017; Barr and Stephenson 2011; Bers et al. 2014; Brennan and Resnick 2012; Dong et al. 2024; European Commission. Joint Research Centre. 2022b; European Commission: Joint Research Centre et al. 2022; Grover and Pea 2013; Kalelioglu et al. 2016; Seiter and Foreman 2013; Shute et al. 2017)
Higher-Order Problem-solving	identify problems, research potential solutions, develop various approaches, select the best option, construct a prototype, test its effectiveness, evaluate the results, and redesign the solution as necessary. ability to solve complex, multifaceted problems that require critical thinking, creativity, and innovation	(Curzon et al. 2019; European Commission: Joint Research Centre et al. 2022; Hermans et al. 2024; Partnership for 21st Century Skills 2019; Yadav et al. 2014)
Algorithmic Thinking (AT)	creating step-by-step solutions, understanding algorithm efficiency, and applying these to both computational and real-world problems, algorithm design, parallelism, efficiency, automation	(Atmatzidou and Demetriadis 2016, 2017; Barr and Stephenson 2011; Brennan and Resnick 2012; European Commission. Joint Research Centre. 2022b; Grover and Pea 2013; Kalelioglu et al. 2016; Looi et al. 2018; Seiter and Foreman 2013; Selby 2012; Shute et al. 2017; Yadav et al. 2014)
Abstraction	focus on the essential information while filtering out irrelevant details, modelling and generalizing solutions, create conceptual models and frameworks, data collection and analysis, pattern recognition, modelling	(Atmatzidou and Demetriadis 2016, 2017; Barr and Stephenson 2011; Brennan and Resnick 2012; European Commission. Joint Research Centre. 2022b; Grover and Pea 2013; Kalelioglu et al. 2016; Looi et al. 2018; Repenning, Basawapatna, and Escherle 2016; Seiter and Foreman 2013;

		Selby 2012; Shute et al. 2017; Wing 2006; Yadav et al. 2014)
Decomposition	break down complex problems or processes into smaller, more manageable parts	(Atmatzidou and Demetriadis 2016, 2017; Barr and Stephenson 2011; Brennan and Resnick 2012; European Commission. Joint Research Centre. 2022b; Grover and Pea 2013; Kalelioglu et al. 2016; Seiter and Foreman 2013; Selby 2012; Shute et al. 2017; Yadav et al. 2014)
Pattern Recognition	recognizing patterns and trends is vital for making predictions and identifying solutions, critical analysis and strategic planning	(Angeli et al. 2016; European Commission. Joint Research Centre. 2022b; Kalelioglu et al. 2016; Selby 2012)
Generalisation	extract common patterns or principles from multiple specific instances and apply them to new situations	(Atmatzidou and Demetriadis 2016, 2017; European Commission. Joint Research Centre. 2022b; Looi et al. 2018; Shute et al. 2017; Yadav et al. 2014)
System Thinking	understanding how different parts of a system interact and influence one another within a whole, analyse complex environmental issues and create practical, eco-friendly solutions	(Brennan and Resnick 2012; European Commission. Joint Research Centre. 2022b; Lo 2024; Shin et al. 2022; Unterfrauner et al. 2021)
Logical Thinking	evaluating conditions and making decisions based on logical flow and facts	(European Commission. Joint Research Centre. 2022b)
Simulation and Modelling	ability to create and use models to simulate complex systems or processes is increasingly important across disciplines, from natural sciences to social sciences	(Barr and Stephenson 2011; European Commission. Joint Research Centre. 2022b; Grover and Pea 2013; ISTE and CSTA 2011; Kalelioglu et al. 2016; Selby 2012; Shin et al. 2022)
AI literacy	CT 2.0, collect data from the intended context, filter and clean data, label data, train a model, evaluate and use the model, inductive reasoning, knowledge of how AI models are trained, evaluated, and deployed, as well as awareness of AI’s capabilities, limitations, and ethical considerations, machine learning techniques, ai knowledge, data science	(Casal-Otero et al. 2023; Tedre et al. 2021)
CT Literacy	ability to read, write, and comprehend computational ideas digital adaptability: ability to continually learn and adapt to new digital tools, technologies, and platforms, ensuring long-term career resilience in rapidly changing environments	(Jacob and Warschauer 2018; Kruse et al. 2011; Lee et al. 2014; Partnership for 21st Century Skills 2019)
CT Empowerment	skills to use computational tools and methods to take action, make decisions,	(Dindler et al. 2022)

	and solve problems independently	
Higher-Order Thinking Skills	include critical thinking, creative thinking, and metacognitive skills that are essential for analysing, evaluating, and creating new knowledge, formulate new questions, explore possibilities, and engage in reflective practice Ability to creatively combine digital and physical tools, manipulating technologies to develop new solutions, and thinking beyond the standard uses of technology.	(Kang and Lee 2020)
Computational Making	design thinking, prototyping, digital fabrication, programming, circuit design, physical computing, creating, designing, building artifacts, iterative design approach, continuous testing and improvement Ability to creatively combine digital and physical tools, manipulating technologies to develop new solutions, and thinking beyond the standard uses of technology.	(Assaf 2019; Brennan and Resnick 2012; Garzi et al. 2019; Rode et al. 2015)
Computational Mathematics	Using mathematical concepts to model real-world scenarios, optimization techniques	(Mathews and Fink 2015)

7.1.3. Skill Gaps in Education & Challenges

As described in Section 2, CT is seen as a multi-faceted interdisciplinary construct composed of numerous sub-competences, which are not adequately addressed in all curricula or training across Europe (Shute et al. 2017). Despite the recognition of CT's importance, its integration remains fragmented, with significant gaps in both primary and secondary education, as well as in VET. In various countries, CT is incorporated into national or regional curricula, either as a standalone subject or integrated within subjects like mathematics and computer science. In VET education its primary application-oriented lessons.

The reviewed literature is emphasizing that data increasingly influences decision-making across various fields, the skills necessary for data analysis and interpretation have become crucial also in connection with the hype of Artificial Intelligence (AI) in 2022 and AI tools such as Chat-GPT, Gemini etc. AI abilities are integral to drawing meaningful conclusions and are vital components of CT literacy and empowerment. Thus, many of these concepts are influencing each other.

Identified Skill Gaps in Primary and Secondary Education

The curricula in primary and secondary education focus mainly on basic programming skills, leaving higher-order CT skills like data analysis, modelling and algorithm optimization underdeveloped. This results in a **lack of comprehensive CT integration** across educational programs. There is also a limited understanding that CT involves thinking strategies that extend beyond computer science. Furthermore, there is a **limited emphasis on core concepts** like problem-solving and critical thinking, which are essential to CT. Students are often not sufficiently taught how to decompose complex problems or grasp foundational CT principles such as algorithmic decision-making, and advanced computational strategies. As a result, their ability to approach technological challenges is underdeveloped. Moreover, CT skills are often not directly connected to real-world applications, which reduces their relevance to both everyday life and professional settings. This **insufficient real-life connection** limits students' ability to face real-world technological challenges, making it more difficult for them to effectively apply CT skills to practical problem-solving situations.

Skill gaps in Vocational Education Training (VET)

In VET, CT is often taught in isolation, with **limited integration into other disciplines**, which restricts the holistic development of CT skills. Additionally, VET curricula tend to **emphasize basic digital literacy rather than more advanced computational skills**. This focus on foundational skills leaves a **gap in preparing students for emerging technological fields** like artificial intelligence, machine learning, and data science, which demand advanced CT abilities. As a result, VET students may not be fully equipped with the critical CT skills necessary to thrive in future workplaces driven by modern technology and innovation.

7.1.4. Challenges in CT-Education

The literature review revealed not only skill gaps in education but also highlighted numerous challenges that must be overcome to facilitate the seamless integration of CT into education.

One of these challenges is that many educators lack confidence in teaching CT due to insufficient training and limited familiarity with advanced CT concepts. Knowing that the existing professional development of teachers in CT is a predictor of teachers' CT-procedural skills, it is crucial to address this challenge (Tagare 2024). Additionally, continuous CT training does not necessarily lead to improved skills if misconceptions are not addressed or if training methodologies do not align with practical teaching needs.

Inadequate technological infrastructure in schools further hampers the effective integration of CT, particularly in regions with limited access to computers and the internet, which makes it essential to explore unplugged teaching methods.

Another significant challenge lies in the current state of curricula, as the integration of CT is inconsistent across different countries, with many educational systems failing to incorporate CT comprehensively, see section above. There is also a general misunderstanding of CT's interdisciplinary nature, which significantly limits the development of critical CT skills among students. This underscores the urgent need for curriculum enhancement, teacher training, and resource allocation to effectively incorporate CT into educational practices.

7.2. Entrepreneurship

7.2.1. Correlation of Entrepreneurship and EntreComp Competences

Our analysis of entrepreneurship competence frameworks has shown that broadly, most of the frameworks promote a very similar set of skills related to entrepreneurship. Given that the EntreComp framework fits well with the goals and context of ComeThinkAgain, our approach to correlating competences is the following: The EntreComp competence framework is taken as the benchmark against which all other frameworks are compared. Table 18 summaries our findings, highlighting if a competence area of a framework is covered by EntreComp in one way or another. The goal of this analysis is not to achieve a 1:1 matching of competence areas between frameworks (which is difficult to achieve), but to identify if a knowledge area is in general covered by EntreComp or not. Furthermore, Table 19 lists those competence areas that are provided by other frameworks, but in our assessment are not addressed by EntreComp. Those competence areas will be evaluated to see if they should be included in the ComeThinkAgain competence list in addition to the EntreComp competence areas.

7.2.2. Skills Gaps in Education

First, it should be mentioned that entrepreneurship is a subject area that has increasingly established itself as a separate subject in education, especially in recent years, and therefore faces different challenges than the other two pillars (CT and Green Skills). Although the importance of entrepreneurship education has been recognized, especially in Europe, there are still considerable deficits in its integration into general education (European Commission: Executive Agency for Small and Medium sized Enterprises. et al. 2021). In the area of general education, there is still no consensus on how exactly entrepreneurship should be integrated into curricula. This problem applies to the development of content and practical activities in the classroom (Henry and Lewis 2018; Johansen 2018).

At the same time, the training and qualification of teachers is a key issue. Teachers themselves often do not have the necessary knowledge and skills to teach entrepreneurship competence. Due to the lack of theoretical understanding, practical experience and resources of many teachers, the implementation of entrepreneurial activities in the classroom is often unrealistic. The lack of examples of classroom activities or best practices that educators can use as role models factors into this as well (European Commission: Executive Agency for Small and Medium sized Enterprises. et al. 2021; Henry and Lewis 2018; Johansen 2018; Ruskovaara and Pihkala 2015).

While some efforts are being made to explore these gaps and provide resources to teachers, the current literature still offers too few concrete tools for teachers to engage students in meaningful entrepreneurial experiences (European Commission: Executive Agency for Small and Medium sized Enterprises. et al. 2021; Henry and Lewis 2018).

Table 18: Correlation analysis of existing competence frameworks to EntreComp.

		The Great Eight	**A Competency-Based Perspective on Entrepreneurship Education: Conceptual and Empirical Insights**	**Consolidating core entrepreneurial competences: toward a meta-competence framework**	**Empretec programme**	**Entrepreneurial competencies: Assessment and predictive valuefor entrepreneurship**	**Entrepreneurship Competence An Overview**	**Exploring the Entrepreneurial Intention-Competency Model**
1. Ideas and opportunities	**1.1 Spotting opportunities**	X	X		X	X	X	X
	1.2 Creativity	X	X		X	X	X	X
	1.3 Vision	X	X	X	X	X	X	X
	1.4 Valuing ideas	X	X			X	X	X
	1.5 Ethical and sustainable thinking	X			X	X		
2. Resources	**2.1 Self-awareness and self-efficacy**	X	X	X	X	X	X	X
	2.2 Motivation	X	X	X	X	X	X	X

	and perseverance							
	2.3 Mobilizing resources	X	X				X	
	2.4 Financial and economic literacy	X		X		X	X	
	2.5 Mobilizing others	X	X	X		X	X	
3. Into action	**3.1 Taking the initiative**	X	X	X		X	X	X
	3.2 Planning and management	X	X	X	X		X	
	3.3 Coping with uncertainty, ambiguity and risk	X	X	X	X		X	
	3.4 Working with others	X	X		X	X	X	X
	3.5 Learning through experience	X	X	X			X	

7.2.3. Challenges in Entrepreneurship-Education

The key challenges in entrepreneurship education involve infrastructure, teaching methods and resources. Many schools do not have the physical and technological infrastructure required to teach practical entrepreneurship skills (Henry and Lewis 2018; Johansen 2018). In addition, as mentioned above, there is a lack of methodological tools and teaching materials tailored to entrepreneurship education (European Commission: Executive Agency for Small and Medium sized Enterprises. et al. 2021; Henry and Lewis 2018). Furthermore, there is limited cooperation between schools and the business community, which is crucial for providing practical experience of entrepreneurship (Henry and Lewis 2018; Ruskovaara and Pihkala 2015).

Overall, there is a need to improve school infrastructures, including solid professional development for teachers and the promotion of closer links between educational institutions and the business community.

Table 19: Topic areas not covered by EntreComp.

A Competency-Based Perspective on Entrepreneurship Education: Conceptual and Empirical Insights	
	8. Guerrilla Skills: the capacity to take advantage of one's surroundings, employ unconventional, low-cost tactics not recognized by others, and do more with less
Empretec Programme	
	Demand for quality and efficiency

7.3. Green Skills

7.3.1. Correlation of Green Skills and GreenComp Competences

Since the GreenComp competence framework largely covers the competences included by the other frameworks mentioned in this literature review it works as a comparative benchmark as it is the case for EE. Table 20 shows an overview of the competences comprised by the six different frameworks in relation to the GreenComp reference framework. The purpose is to emphasise where the competences generally overlap in one way or the other and not to provide a clear 1:1 matching.

Table 20: Matching of sustainability competences from different frameworks with GreenComp.

	Framework					
GreenComp (2022)	**Wiek et al. (2011) Wiek et al. (2016)**	**Brundiers et al. (2021)**	**Redman and Wiek (2021)**	**Juuti et al. (2021)**	**Vesterinen and Ratinen (2024)**	**Kwauk and Casey (2022)**
1.1 Valuing sustainability	x	x	x	x	x	
1.2 Supporting fairness						x
1.3 Promoting Nature					x	
2.1 Systems Thinking	x	x	x	x	x	x
2.2 Critical Thinking	basic academic skills	basic academic skills	x			x
2.3 Problem Framing	problem-solving	problem-solving	problem-solving			problem-solving
3.1 Futures-literacy	x	x	x	x	x	x
3.2 Adaptability						x
3.3 Exploratory Thinking						
4.1 Political Agency	X	X	x	x		x
4.2 Collective Action	x	x	x	x	x	x
4.3 Individual Initiative					x	

Table 20 clearly shows that some of the competences are covered by almost all the analysed frameworks. These include valuing sustainability, systems thinking, futures literacy, political agency and collective action. In some frameworks individual competences are titled differently but cover more or less the same competences. E.g. political agency and collective action somewhat refers to strategic thinking in the frameworks of Brundiers et al. (2021), Redman and Wiek (2021), and Wiek et al. (2011).

Whereas ´critical thinking´ is a stand-alone competence in the GreenComp framework, it belongs to a set of basic academic or general skills for the frameworks of Brundiers et al. (2021) and Wiek et al. (2016, 2011). For Redman and Wiek (2021), ´critical thinking´ goes along with creativity and learning skills summarized as general competences. Four of six frameworks cover ´problem-solving skills´ whereas the GreenComp framework only covers ´problem framing" as a competence which refers ´to the process of identifying actual or potential sustainability problems´ (European Commission. Joint Research Centre. 2022a). Brundiers et al. (2021) and Redman and Wiek (2021) also incorporate implementation skills in their frameworks relating to an active realization process of given solutions. The frameworks which are dealing in an higher education and vocational education setting also cover topic or disciplinary knowledge like engineering, chemistry or environmental sciences, which is not part of the GreenComp framework. Additionally, also not covered by GreenComp but suggested for example by Brundiers et al. (2021) and Kwauk and Casey (2022), are general intrapersonal competences like self-reflectivity or resilience as well as interpersonal/collaborative competences (Kwauk and Casey 2022; Redman and Wiek 2021; Vesterinen and Ratinen 2024).

Competences which are hardly covered by any of the compared frameworks are supporting fairness and promoting nature, adaptability, exploratory thinking as well as individual initiative.

7.3.2. Skill Gaps in Education

In 2008, Sipos et al. (2008) stated that "[e]ducation is at odds with sustainability when modern economies function to damage and destroy the ecological systems that support human and non-human communities" (Sipos et al. 2008). More than 15 years later universities still prioritise fossil fuel studies compared to studies on renewable energies, indicating that education is lagging behind current efforts regarding a sustainable transition (Vakulchuk and Overland 2024). As described in chapter two, until recently there was no clear consensus on what the terms sustainability competences and green skills truly indicate (Brundiers et al. 2021; Redman and Wiek 2021) and not before 2022 the European Commission provided a unified sustainability reference framework – GreenComp. Also, industry is facing difficulties as the requirements for a green transition are rapidly changing resulting in a lack of properly educated workforce (Braun et al. 2024).

It therefore comes as no surprise, that there is a lack of literature concerning skill gaps in education of sustainability, simply, as we assume, sustainability education has not been implemented long enough and basically represents a skill gap in itself. The work of the European Commission. Directorate General for Education, Youth, Sport and Culture (2021) on sustainable education, scanning top-level curricular across European education systems, reports on an "evidence gap" on how European countries are covering sustainability education in their curricular (European Commission. Directorate General for Education, Youth, Sport and Culture. 2021). Additionally, the authors point out on research gaps concerning learning for sustainability on different levels: most research refers to higher education whereas there is only limited knowledge about other education levels, from early childhood on to vocational and adult education (European Commission. Directorate General for Education, Youth, Sport and Culture. 2021).

7.3.3. Challenges in Green Skills-Education

Since sustainability topics are of interdisciplinary nature, they are relevant for all teachers and trainers and not only to those teaching natural scientific subjects. However, according to the European Commission. Directorate General for Education, Youth, Sport and Culture (2021), teachers report that they are facing barriers in teaching sustainability competences. Two are of major significance: a lack of time resources as well as a lack of adequate skills and insufficient knowledge resulting in little confidence to teach sustainability in a multidisciplinary way. It therefore is a necessity that educators are provided with teaching guidelines and methods as well as useful materials.

Although there is increasing consensus on which competences constitute sustainability and green skills as well as which didactic methods contribute to the development of them, strategies and methods on how to assess green skills have received little attention so far. As assessment is very valuable in order to comprehend if what is taught is also being learnt, more efforts must be put into this field of research in order to provide well-developed assessment methods (Bianchi 2020; Redman and Wiek 2021; Tilbury 2023).

As the European Commission. European Education and Culture Executive Agency (2024) reports, specific criteria for the evaluation of learning for sustainability only exist for less than one third of the analysed education systems. In the most countries criteria either do not exist or there simply is no evaluation process at all. In order to effectively integrate sustainability education in school curricular, its implementation needs to be part of the general monitoring and evaluation of education systems, both external as well as school internal.

8. SYNERGY AND INTERSECTION ANALYSIS

8.1. CT & EE

Competences in Entrepreneurship Education (EE) encompass a broad range of skills aimed at recognizing opportunities and transforming ideas into value-creating activities. This value can be financial, cultural, or social (Vestergaard et al. 2012). EE is closely linked to economic growth, innovation, job creation, and productivity improvements (Acs and Audretsch 1988; Birch 1979; Blanchflower 2000; Parker 2009). Modern entrepreneurs are innovators who identify opportunities, turn them into marketable ideas, and manage risks to achieve profits (Kuratko et al. 2012). The core competences of EE include initiative, risk management, decision-making, and the ability to organize resources efficiently (Hisrich, Peters, and Shepherd 2017; Lazear 2005).

CT complements and strengthens EE by providing systematic problem-solving approaches essential for developing and implementing innovative business ideas (Kang and Lee 2020; Nuar and Rozan 2019). For example, through CT, aspiring entrepreneurs learn to break down complex problems into manageable parts, recognize patterns, and make data-driven decisions. These skills enable them to succeed in a dynamic and often uncertain market environment.

In schools, the combination of CT and EE allows students to systematically develop innovative business ideas. By learning to solve problems algorithmically and applying data analysis methods, they can simulate entrepreneurial scenarios in projects and simulations (Moog et al. 2015; Sánchez 2013). Additionally, Maker Education creates a practical bridge (Unterfrauner et al. 2021): it challenges students to develop their own products while addressing key entrepreneurial questions—such as target audiences, data usage, and product features. Students can create names or slogans for their products. In a final step, they pitch their product, answering questions from other students who act as potential investors. This approach allows students to step into the role of entrepreneurs and apply entrepreneurial thinking directly. These activities also train critical thinking, creative problem-solving, and adaptability to change (Eggers et al. 2017; Lazear 2005).

8.2. CT & GS

Knowledge about sustainability and social responsibility, also known as Green Skills (GS), is essential today to ensure the sustainable development of our society. The term GS encompasses the knowledge, skills, motivations, and attitudes necessary to solve environmental problems and shape a sustainable future (Bianchi 2020; Brundiers et al. 2021). These skills are particularly important as they help learners understand the ecological challenges of our time and actively participate in addressing them. GS are not only critical for the future of the workforce but should also be embedded in curricula early on to prepare the next generation to contribute to achieving the global sustainable development goals (United Nations. Department of Economic and Social Affairs, Sustainable Developement 2015).

CT plays a crucial role in developing GS by fostering the ability to understand and process complex ecological data. This contributes to optimizing processes and developing environmentally friendly practices (SOC/636-EESC-2020 European Economic and Social Committee 2022). This combination is particularly important to support the transition to a sustainable society and achieve the goals of the European Green Deal.

The integration of CT and GS in education offers a valuable opportunity to raise students' awareness of sustainability while equipping them with practical tools for active problem-solving. By incorporating CT into subjects like biology, geography, and environmental science, students can, for example, create models, analyse data, and develop sustainable solutions using Industry 4.0 technologies (Bianchi 2020; Brundiers et al. 2021). Maker projects further enhance these approaches by motivating students to develop creative solutions to environmental problems (Hughes and Thompson 2022). These projects can be strategically integrated into curricula to emphasize the importance of sustainable development (Bianchi 2020; CEDEFOP 2019).

8.3. EE & GS

The integration of EE and GS is crucial in fostering an entrepreneurial and sustainable, responsible mindset. In this context, literature proposed the concept of sustainable entrepreneurship (SE), which can be seen as a process that addresses environmental issues while balancing ecological, social and economic aspects (Planck et al. 2024). Generally, in the last decades a shift towards the alignment of EE and GS could be observed (Terán-Yépez et al. 2020). This is also underpinned by certain frameworks and educational programs which combine these two areas. For instance, the European Sustainability Competence Framework (GreenComp) includes competence areas which overlap with entrepreneurial areas (e.g. envisioning sustainable futures, acting for sustainability, exploratory thinking) (Laherto et al. 2023) and complements other frameworks, such as the European Entrepreneurship Competence Framework (EntreComp) (Moon, Walmsley, and Apostolopoulos 2022). Another current example of such a combined approach would be the digital and sustainable entrepreneurship approach within the scope of VET programs (CEDEFOP 2023). The Green4Future project as well promotes the transition towards a green economy and thus combines sustainability and entrepreneurship education. The output of the project presents a revision of the established EntreComp framework and incorporates sustainable and ecological aspects providing support to educators on the vocational education level. Similar to EntreComp the Green EntreComp framework consist of the three dimensions: ´ideas and opportunities´, ´resources´ and ´into action´ to each of which the same five competences are assigned. As an example, Figure 31 visualises the Green EntreComp framework in the context of ´uncovering environmental needs´ for the competence ´1.1 spotting opportunities´.

		Level of proficiency		Foundation		Intermediate		Advanced		Expert	
		Progression		Relying on support from others		Building independence		Taking responsibility		Driving transformation, innovation and growth	
				Under direct supervision.	With reduced support from others, some autonomy and together with my peers.	On my own and together with my peers.	Taking and sharing some responsibilities	With some guidance and together with others.	Taking responsibility for making decisions and working with others.	Taking responsibility for contributing to complex developments in a specific field.	Contributing substantially to the development of a specific field.
				Discover	Explore	Experiment	Dare	Improve	Reinforce	Expand	Transform
Competence	Hint	Descriptor	Thread	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
1: IDEAS AND OPPORTUNITIES											
1.1 Spotting opportunities	Use your imagination and abilities to identify opportunities for creating sustainable value.	Identify and seize opportunities to create sustainable value by exploring the social, cultural and economic landscape. Identify needs and challenges regarding the environment that need to be met. Establish new connections and bring together scattered elements of the landscape to create green opportunities to create value.	**Uncover environmental needs**	I can find examples of groups who have benefited from an eco-friendly solution to a given environmental problem.	I can identify environmental needs in my community and surroundings as well as the environment that have not been met.	I can explain that different groups may have different environmental needs.	I can establish which user group, and which environmental needs, I want to tackle through creating sustainable value.	I can carry out a environmental needs analysis involving relevant stakeholders.	I can identify environmental challenges related to the contrasting environmental needs and interests of different stakeholders.	I can produce a green 'roadmap' which matches the needs with the actions needed to deal with them and helps me create sustainable value.	I can design green projects which aim to anticipate environmental future needs.

Figure 31: Extract from the Green EntreComp framework (green4future.eu).

8.4. CT, EE & GS

A particularly effective approach is the implementation of interdisciplinary projects (Hinterplattner, Sabitzer, and Skogø 2021) in which computational thinking, entrepreneurship thinking, and green skills are combined. Making is one method to achieve such interdisciplinary projects. Maker projects could, for example, involve the development of a sustainable product that is optimised through the use of CT (e.g. with the help of sensors and actuators) and marketed through EE. The students could take on all aspects from the idea to the development and commercialisation themselves and thus acquire a deeper understanding of the connections between technology, the economy and the environment. By applying CT, they can analyze complex environmental issues, such as resource efficiency and waste reduction, and create practical, eco-friendly solutions (Lo 2024). These projects not only promote interdisciplinary learning, but also the ability to view and solve complex economic problems from different perspectives (Kang and Lee 2020; Mets, Holbrook, and Läänelaid 2021).

9. ComeThinkAgain COMPETENCE LIST

The ComeThinkAgain Competence List (Table 21) is the culmination of an extensive investigation into existing literature and established competence frameworks. Through an in-depth review of global and EU-level frameworks, such as DigComp, EntreComp, and GreenComp, this list integrates core competences in Computational Thinking (CT), Entrepreneurship Education (EE), and Green Skills (GS). By aligning closely with these well-established frameworks, the ComeThinkAgain list aims to provide a comprehensive and relevant competence structure that meets the evolving demands of modern education and the job market.

Table 21: ComeThinkAgain competence list

COMPUTATIONAL THINKING	
Algorithmic Thinking (AT)	Decomposition
Pattern Recognition	Abstraction
Modeling & Simulation	Generalisation
Logical Thinking	System Thinking (ST)
CT Empowerment	CT Participation
Higher-Order Thinking Skills	Higher-Order Problem-solving
Digital Literacy	Data Literacy
AI Literacy	Computational Mathematics
Computational Making	Computing (Programming)
ENTREPRENEURSHIP	
Spotting opportunities	Mobilizing others
Creativity	Taking the initiative
Vision	Planning and management
Valuing ideas	Coping with uncertainty, ambiguity and risk
Ethical and sustainable thinking	Working with others
Self-awareness and self-efficacy	Learning through experience
Motivation and perseverance	Guerrilla Skills
Mobilizing resources	Demand for quality and efficiency
Financial and economic literacy	
GREEN SKILLS	
Systems-Thinking	Critical Thinking
Problem-solving	Futures Literacy
Valuing sustainability	Political Agency
Collective Action	Supporting Fairness
Promoting Nature	Adaptability
Exploratory Thinking	Individual Initiative
Interpersonal/collaborative competence	Intrapersonal competences

The competences included in this list are not rigidly prioritized, offering flexibility for institutions and educators to tailor the framework to their specific regional contexts, educational levels, and target groups. This adaptability ensures that the framework can be customized to address diverse needs, from primary to higher education, while maintaining a cohesive and structured approach. In ComeThinkAgain, this list serves as the basis for further developments such as the selection of the topics for the learning content that is developed during this project.

Importantly, the list is designed as a living document and will undergo further refinement throughout the ComeThinkAgain project. This iterative process will ensure that the competences remain aligned with the latest educational and industry trends, guaranteeing the highest quality learning materials and contributing to the development of the ComeThinkAgain Competence-Based Education and Training System (CETS). The goal is to foster a holistic and future-proof set of skills that will equip learners for successful careers and societal contributions in an increasingly interconnected and sustainability-driven world.

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