Come ThinkAgain
Certification based Education Training System

D2.2 - Pedagogical concept for target groups in teacher training and vocational education

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LIST OF ABBREVIATIONS

ACME	Code Animation by Evolved Metaphors
AI	Artificial Intelligence
CoP	Community of practice
CTA	ComeThinkAgain
CTFP	Computational thinking framework pedagogical
CETS	Certification based education training system
CRDs	Centers for research and development
CT	Computational Thinking
DBL	Design-based Learning
EE	Entrepreneurship Education
ESG	Environmental, social and governance
ER	Educational robotics
GBL	Game-based Learning
GS	Green Skills
HEIs	Higher education institutions
ICT	Information and Communication Technology
IDGs	Inner development goals
LLM	Large language model
MOOC	Massive open online course
NGOs	Nongovernmental organisation
OER	Open Educational Resources
PbBL	Problem-based Learning
PjBL	Project-based Learning
PlBL	Play-based Learning
RPS	Role-play Simulations
SDGs	Sustainability Development Goals

STEAM	Science, Technology, Engeneering, Arts and Mathematics
STEM	Science, Technology, Engeneering and Mathematics
TPACK	Technological Pedagogical Content Knowledge
UX	User Experience
VEE	Visual execution environment
VPLs	Visual programming languages
VET	Vocational Education training

EXECUTIVE SUMMARY

This deliverable provides a comprehensive analysis of the latest approaches to didactical concepts, learning strategies and curricular implementations to efficiently address the development of competences in the field of computational thinking (CT), entrepreneurship education (EE) and green skills (GS), the three core competence pillars of the ComeThinkAgain project. Constructionism has emerged as a pivotal learning approach for integrating CT, EE and GS into interdisciplinary education. By emphasizing active learning, hands-on experimentation, and collaborative strategies, constructionist methods effectively foster skill development across these domains, addressing both theoretical understanding and practical application needs.

The curricular implementation of CT, EE and GS is still challenging. The findings emerging from this deliverable show that there is no uniform approach in countries across Europe and the implementation differs according to countries as well as competence area. Most popularly, these competences are either integrated in other subjects e.g., mathematics for CT, economics for EE and natural sciences for GS, or incorporated as cross-curricular topics or as stand-alone subjects.

Moreover from September to December 2024 we conducted nine co-creation workshops with nearly 100 participants from academia, industry and government. The workshops aimed to give important insights concerning CT, EE and GS competences, training methods, assessment and curricula implementation. The findings of these workshops represent a crucial component of this deliverable. The workshops emphasized the important role of interactive and practice-oriented learning approaches. Methods such as design thinking, project-based learning and simulation games emerged as powerful tools for fostering in-depth learning and competence application. Additionally, the workshop served to revise the original competence list derived from D2.1 and competences which are not yet or only partly covered by our original list but emerged from the co-creation workshops as relevant were identified.

Our analysis in this document will serves as a linking point for Task 2.4., the development of the learning modules within the CTA-CETS.

1. INTRODUCTION

1.1. Project Overview

Living in a rapidly changing world, there is a need to prepare future generations for dealing with many aspects concerning modern life (e.g., digitalisation or climate change) by equipping them with 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 (CT), entrepreneurship education (EE), and green skills (GS). 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.

This deliverable is the final result of Task2.2 and Task 2.3. It is based on our submission D2.1 that emerged from Task 2.1 and provides an important foundation for Task 2.4 which addresses the development of pedagogical content.

1.2. Purpose of the document

This document presents a comprehensive literature review of didactical approaches and learning methods as well as curricular implementations suitable for addressing and promoting the three competence pillars of the ComeThinkAgain project, CT, EE and GS, on the target level of primary, secondary and vocational education and aims to provide an important foundation for the development of the ComeThinkAgain learning modules and CETS training system. Furthermore, it includes a detailed report about the nine co-creation workshops conducted in the projects partner countries. The outcomes derived from the workshops are discussed and analysed in relation to the findings of the present document and the consolidated competence list emerged from D2.1. The structure of D2.2 comprises 5 chapters which are briefly presented in the following:

Chapter 1. Introduction gives a short overview the ComeThinkAgain project and outlines the purpose, objectives and structure of this document

Chapter 2. Learning methods presents a literature review on didactical concepts and learning methods to efficiently foster the development of competences in CT, EE and GS. This chapter begins with a comprehensive examination of the methods in general, offering detailed descriptions. Subsequently, it explores the three competence pillars in depth providing specific applications within each respective competence area and target level.

Chapter 3. Curricular implementation of countries provides a concise overview on how CT, EE and GS are addressed in the curricula of different countries across Europe.

Chapter 4. Results from the co-creation workshops includes a detailed outline of the aims, methods and results of the co-creation workshops conducted by the nine partner countries involved in the ComeThinkAgain project.

Chapter 5. Conclusion discusses and illustrates the findings from this document. Furthermore, it summarizes the results from the co-creation workshops and discusses them in relation to the outcomes of the present document and the competence list derived from D2.1 providing valuable output for the further implementation of the learning modules.

2. Learning Methods

This chapter provides a comprehensive literature review on didactic approaches as well as learning strategies to efficiently promote the development of CT, EE and GS competences. Throughout the document, we deliberately use the term "learning methods" rather than "teaching methods" to emphasise the learner-centered approach in developing these competences. The choice of terminology underpins our focus on empowering students to take an active role in their own learning process in contrast to a more traditional teacher-centered instructional approach.

First, the sub-chapter 2.1 addresses common didactic concepts that will serve as the foundation for the CTA-CETS. Second, we will offer an in-depth overview of learning methods suitable for primary, secondary and vocational education providing a general and detailed description in section 2.2. Third, the sub-chapter 2.3 focuses on the three competence pillars CT, EE and GS emphasising specific applications and literature of suitable learning strategies discussed in section 2.2.

2.1. Main didactical concepts used in ComeThinkAgain

2.1.1. E-learning formats

Before looking into different learning methods, it is essential to consider different e-learning formats, as they provide the foundational frameworks that shape how learning methods are applied and adapted in diverse educational contexts. These formats offer different approaches to integrating technology and face-to-face interaction, each with unique benefits and challenges that influence the teaching and learning experience. Therefore, the CETS explicitly aims to blend online and offline formats, leveraging the advantages of both digital and in-person learning environments to create flexible, accessible, and engaging educational experiences.

One of the most widely recognized e-learning formats is **blended learning**. The blended learning format is defined as a combination of instructional methods that integrate online and face-to-face components, creating a flexible learning environment that leverages the strengths of both (Rovai & Jordan, 2004). Another format is **distance learning**, which relies entirely on online platforms and digital tools to deliver instruction, eliminating the need for physical presence in a traditional classroom. Moore et al. (2011) describe distance learning as a form of instruction that occurs between a learner and an instructor at different times and places while relying on various types of instructional materials. An increasingly popular e-learning format is the **flipped classroom**, also called inverted classroom. Activities that are traditionally performed in the classroom, such as content delivery, are shifted to the home through pre-recorded lectures or digital materials. Meanwhile, tasks typically assigned as homework, such as problem-solving and collaborative exercises, are brought into the classroom, allowing for more interactive and hands-on learning experiences during class time (Bergmann & Sams, 2012; Sohrabi & Iraj, 2016). With focus on the student's location, **hybrid learning** is an e-learning format, where one group of students attends the course on campus, while another group participates remotely from a location of their choice, simultaneously engaging in the same lesson (Butz et al., 2016; Hastie et al., 2010). It allows for meaningful interaction with both the teacher and peers, regardless of physical location, ensuring inclusivity and accessibility. In addition, E-learning environments can bring challenges such as decreased focus, motivation, and attention. A format that can address such difficulties is **micro-learning**. Micro-learning can be defined as a technique designed for distance training, delivering small, bite-sized, amounts of content that learners can absorb during brief training sessions interspersed with other activities (Díaz Redondo et al., 2021). **MOOC** stands for "massive open online courses". This format is characterized by its open nature and offering virtual educational opportunities to anyone that wants to participate (Mallon, 2013). MOOCs have gained significant attention because they broaden the access to higher education and enhance the quality of teaching and learning (Jung & Lee, 2018).

The **Open Educational Resources (OER)** refers to teaching and learning resources that are freely accessible on the internet. This includes materials explicitly designed and pedagogically structured for teaching and learning processes, as well as tools, learning objects, and information provided for educational purposes. To define "open" content, the five "Rs" have become established, referring to the rights to retain, reuse, revise, remix, and redistribute material (Wiley, 2015). These resources can include various media products such as videos, images, simulations, audio (podcasts), recordings, electronic textbooks, easily editable PDF/Word documents, or presentation handouts. They range from individual learning objects to MOOCs, blended learning formats, or facilitated online courses.

2.1.2. Constructionism

The Constructionist approach (Papert, 1980) is interested in building knowledge through active engagement and personal experience. Seymour Papert noted that individual learning occurred more effectively when students understood the world around them and were creating something that was meaningful to them. His constructionist approach, deeply rooted in Piaget's constructivist theories, views learning as an iterative and exploratory process, where computers serve as powerful tools for thought. This experiential and discovery learning by challenges should inspire creativity, and project work allows for independent thinking and new ways of constructing information. The iterative process of self-directed learning underlines that humans learn most effectively when they are actively involved in the learning process and build their own structures of knowledge. In this theory, communication between students about the work, and the process of learning with peers, teachers, and collaborators, is seen an indispensable part of a students' learning (Papert, 1993; Papert & Harel, 1991).

> "*The construction of knowledge through experience and the creation of personally relevant products. The theory proposes that whatever the product, e.g. a birdhouse, computer program, or robot, the design and implementation of products are meaningful to those creating and that learning becomes active and self-directed through the construction of artefacts.*" [Papert, 1980, p.2]

Thus, Papert described the huge potential of bringing new technology into the classroom (Papert, 1993). For this reason, he co-invented the LOGO programming language in the late 1960s at MIT. LOGO was designed to have a "low threshold and no ceiling" and was indeed used to help novice programmers, and to support complex explorations and the creation of sophisticated projects (Tinker & Papert, 1989). LOGO set the basis for later visual programming tools, such as Etoys (Kay et al., 1997) and Scratch (Resnick et al., 2009). Such block based visually oriented tools made programming accessible for a large number of people and taught new skills such as engineering, design, and coding (Blikstein & Krannich, 2013). They allow students to recognize blocks instead of recalling syntax. They are broadly integrated in schools, or even at universities all over the world (Meerbaum-Salant et al., 2010).

Recent studies highlight the transformative potential of integrating advanced technologies within constructionist learning environments. For example, Holbert and Blikstein (2023) frame generative AI as a contemporary "Mathland," merging traditional constructionist concepts, such as those introduced by Papert, with the adaptive and creative capabilities of modern AI systems. Similarly, Zheng and Blikstein (2023) illustrate how digital fabrication tools combined with remote-making contexts can democratize access to personalized, culturally relevant, and equitable learning experiences. Collectively, these studies emphasize the critical role technologies such as AI, digital fabrication, and virtual environments play in advancing innovative, inclusive, and individually tailored constructionist education.

2.1.3. Self-regulated learning

Self-regulated learning is defined as a process, where learners personally activate and sustain cognitions, affects and behaviours, while focusing on personal goals. By setting these goals, learners establish self-directed feedback loops, enabling them to monitor their progress and adapt their strategies accordingly (Zimmerman & Schunk, 2011). It is important to highlight, that self-regulated learning is not exclusively an individualized process. It also encompasses self-initiated social learning, where learners actively seek support and guidance from peers, mentors, and teachers (Zimmerman & Schunk, 2011).

Self-regulated learning is fundamental to sustainable education and lifelong learning, as it provides students with the essential tools to engage in continuous learning and develop their skills throughout their lives. In a world characterized by rapid technological advancements and evolving career landscapes, self-regulated learning empowers learners to take ownership of their education, enabling them to succeed in dynamic and digital environments (Taranto & Buchanan, 2020).

2.1.4. Cooperative Learning

Social learning facilitates the acquisition of knowledge and skills through observational processes and interpersonal interaction within a communal context (Kendal et al., 2018). Thus, collaborative and cooperative learning methods are widely recognized as efficient pedagogical approaches and show applicability and benefits across diverse age groups. These benefits include positive effects on cognitive, social and motivational aspects as well as enhanced overall learning outcomes (Baloche & Brody, 2017; R. E. Slavin, 2015).

A characteristic of collaborative learning, though there exist many different types of, is working in small groups or teams to help and benefit from each other during the learning process. Another form of social learning that occurs within groups, both in educational settings and beyond, is the **community of practice.** It facilitates knowledge sharing and the exchange of expertise among individuals connected by common interests or goals (L. C. Li et al., 2009).

2.2. Practical and applied learning methods in Primary, Secondary Education and Vocational Education and Training

Problem-Based Learning (PbBL): PbBL is an instructional method where students learn by solving real-world problems collaboratively (Hung & Amida, 2020; Pilcher, 2014; Yew & Goh, 2016). It emphasizes active learning, critical thinking, and self-directed learning. PbBL helps students develop problem-solving skills, communication skills, and the ability to work in teams. It also promotes higher-order thinking and the application of knowledge in practical contexts. PbBL involves problem-initiated instruction, real-life complex problems, and collaborative small group learning. The teacher acts as a facilitator and coach rather than a traditional lecturer (Hung & Amida, 2020). In short, it enables students to learn while engaging actively with meaningful problems (Yew & Goh, 2016). PBL is effective in various educational settings, including science education, CT, and interdisciplinary courses. It has been shown to improve students' problem-solving skills and attitudes towards learning (Marklin Reynolds & Hancock, 2010; Saad & Zainudin, 2022).

PbBL can be integrated with CT to enhance problem-solving skills in computer science courses (Hsu et al., 2018; Saad & Zainudin, 2022). This combination has been found effective in teaching algorithmic and system design problems. For instance, Hsu et al. (2018) describe using PBL in a science class where students develop models to predict weather patterns, requiring them to apply pattern recognition and data analysis skills. PbBL also encourages an entrepreneurial mindset by engaging students in real-world problem-solving and critical thinking, which are essential for entrepreneurial success (Fassbender et al., 2022; Sousa & Costa, 2022). Furthermore, PbBL can be applied to environmental education, helping students understand and solve complex environmental issues, thereby promoting green skills (Cavadas & Linhares, 2022; Marklin Reynolds & Hancock, 2010).

Project based learning (PjBL): PjBL is a learner-centred pedagogical approach that aligns with the constructionist theory which emphasizes that learning is enhanced through hands-on experiences as well as interaction and collaboration with others. Accordingly, students are active participants within the learning process, not passive recipients of information, and achieve their learning goals through collaborative interaction and exchange of knowledge (Kokotsaki et al., 2016). PjBL enhances student´s critical thinking and problem-solving skills while providing them with practical learning environments to apply these skills to real-world contexts (Genc, 2015).

Design-Based Learning/Thinking (DBL): Design-Based Learning (DBL), sometimes also referred to as Design-Based Science is a pedagogical approach where the goal of designing an artifact contextualizes all curricular activities (Fortus et al., 2004). It is a variant of project- and problem-based learning that integrates design-thinking principles into the learning process (Azizan & Abu Shamsi, 2022; Barak, 2020). Learners engage in iterative design cycles to prototype and refine solutions to real-world challenges, emphasizing creativity and innovation. DBL involves students working on the design of artifacts, systems, or innovative solutions (Oo et al., 2024). It integrates theoretical knowledge with practical design tasks. DBL emphasizes creativity, innovation, and the application of design thinking. It helps students develop skills in problem-solving, critical thinking, and the ability to create and test prototypes (Gómez Puente et al., 2013; Strimel, 2024). DBL includes stages such as idea generation, background research, artifact building, and final product design. It often involves interdisciplinary activities and hands-on learning (Barak, 2020; Fayanto et al., 2024; Oo et al., 2024). DBL is used e.g., in STEM education to enhance student engagement and learning outcomes. It is particularly effective in teaching CT and integrating it with other disciplines (X. Li et al., 2023; Lyon & Magana, 2021; Matere et al., 2023). n

In addition, DBL supports the development of CT by engaging students in designing and building computational models. This approach helps students practice abstraction, algorithmic thinking, and evaluation (Lye & Koh, 2014; Lyon & Magana, 2021). DBL fosters an entrepreneurial mindset by encouraging students to think creatively and develop innovative solutions to real-world problems. It also helps students understand the commercialization of technology (Lynch et al., 2021). DBL can be applied to projects focused on sustainability and environmental design, promoting green skills and awareness among students (Curzon et al., 2019).

Maker-Education Approach: Making is a hands-on, creative approach to learning that emphasizes tinkering, experimenting, and inventing. It involves using a combination of traditional tools and modern digital technologies, such as 3D printers, laser cutters, or microcomputers, to design and create tangible objects (Assaf, 2019). Garzi et al. (2019) describe making as a process of building, disassembling, modifying, and developing objects to bring one's ideas to life. As an example, using microcontroller in classroom projects allows students to build physical computing projects, fostering both CT and engineering skills through hands-on learning (Martinez & Stager, 2013).

This open and flexible approach can be applied across various disciplines, encouraging exploration, creativity, and problem-solving. Making fosters active engagement, collaboration, and innovative thinking, Making it a valuable method for interdisciplinary learning. Becker et al. (2023) link Making directly to DBL by exploring how teachers develop pedagogical and content knowledge through maker activities integrated into design-thinking frameworks. In D2.1 we have already described that Making serves as a great method to apply interdisciplinary projects between CT, EE, and GS. 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.

Hackathons: Hackathons are typically 1-2-day events, where participants work intensively as a team, aiming to develop software to solve a problem or a challenge, and in the end, they present their prototype to a jury (Franco et al., 2022). Hackathons have a competitive element included, as the teams typically compete against each other in some way. From learning perspective, informal learning (Nandi & Mandernach, 2016), learning by doing (Gama, 2017), and learning from peers (Nandi & Mandernach, 2016; Warner & Guo, 2017), have been identified to happen through hackathons (Gama et al., 2018). Hackathons foster teamwork and creativity with time-limited tasks. In entrepreneurial hackathons, teams engage in innovation process while working around a business idea (Franco et al., 2022). Hackathon model of working in form of intensive long days can be a challenge to organize with younger participants, and indeed, hackathon participants are usually adults, e.g. college students (Gama et al., 2018), but modified versions of hackathons have been tried out also with younger students.

Work-Based Learning Models/Simulations: Lee et al. (2014) emphasize the importance of work-based learning models where students spend time in industry placements applying skills to solve actual business challenges, bridging the gap between theoretical knowledge and practical application. Different models for work-based learning exist. Three major models include internships, youth apprenticeships, and school-based enterprises, which support understanding of the entrepreneurial career (Alfeld et al., 2013). Work-based learning is seen to support the learners' cognitive development by engagement with a variety of ideas and things in the practice environment, social/emotional development when engaging the learners in work-related social situations, and career development, through engaging learners in work processes and workplaces (Darche et al., 2009). Work-based learning is often combined with school-based learning. Simulated work environments are one form of work-based learning, where the aim is to offer learners realistic workplace experiences in the context of an educational institution. Specific skills or tasks can be taught by utilizing simulation tools, and workplace expectations and behaviours can be replicated in simulated workplaces, while allowing a safe to space to practice and to make mistakes. School-based enterprises can be used here for offering a holistic understanding of how to run a business (Moyer et al., 2017).

Robotics and AI in an educational context: Robots can be used to encourage students, for instance by developing and programming smart systems to perform specific tasks, such as automated quality control or predictive maintenance, as described by Juškevičienė (2020). This practical approach helps students understand the applications in modern industrial settings. In this context, Educational Robotics (ER) has gained increased importance in recent decades, attracting growing interest from educators and researchers globally. This approach leverages robots as educational tools to spark students' interest and to foster skills across STEM fields as well as enhance their social and cognitive development. By incorporating hands-on robotic activities into the classroom, teachers can create engaging learning experiences that stimulate students' natural curiosity and motivation to learn (Alimisis, 2013; Barker, 2012). Accordingly, Artificial Intelligence (AI) in an educational context can be viewed as Education in/for AI - in terms of teaching the concepts of AI – as well as AI in Education (AIED) - meaning the use of AI as a teaching/training aid, for instance the use of intelligent tutoring systems to enhance or improve learning (Schiff, 2022).

For educational purposes, a broad range of platforms exist, both in terms of educational robots as well as practical tools to teach concepts of AI. The pedagogical foundations trace back to Papert (Papert & Harel, 1991) and his theory of constructionism. Educational platforms and tools differ significantly in their features as well as in the target group addressed. Prominent examples for such platforms are Teachable Machine, Bee-Bot or Ozobot (primary level), Mindstorms, mBot, Thymio or Nao (secondary level), Turtlebot, Baxter as well as Universal Robots, or KUKA robotic arms (vocational, higher education) (Catlin et al., 2018). This list is by no means complete since the variety of available platforms is vast and selecting an appropriate platform can only be done after evaluating specific needs and practical constraints for each specific use-case.

Programming/Computing/Coding: Programming serves as a key element of constructionist approaches to bring active learning and hands-on engagement into the educational process (Monga et al., 2018). To gradually familiarize learners with fundamental programming concepts and simplify the introduction to programming, block-based programming languages are widely used. Block-based programming languages like Scratch, Snap or Pocket Code are considered Visual Programming Languages (VPLs) and serve as an example of a programming learning environment (Tsai, 2019). Block-based programming environments are based on metaphors where programming primitives such as variables, operators, or loops are represented as blocks (Weintrop & Wilensky, 2015). The user interface of VPLs exhibits a high degree of interactivity, as clicking on a block immediately executes the code (Resnick et al., 2009). The process of directly and continuously testing code blocks can reduce feelings of uncertainty regarding abstract programming concepts (Tsai, 2019). Furthermore, various studies have shown that learning programming skills with block-based programming languages can increase students' motivation (Jatzlau & Romeike, 2017; Tsai, 2019).

Educational **Field Trips:** Educational field trips have been recognized for a long time as an effective approach to enhance learning outcomes. Usually, field trips are organized by schools and take place in stimulating, interactive and authentic environments. These include trips to museums, zoos and nature parks but also to cultural institutions and historical sites (Greene et al., 2014) or to business enterprises (Ruskovaara & Pihkala, 2015). Field trips offer learners the opportunity to connect theoretical knowledge with practical experiences and enhance their understanding of complex ideas. Thus, field trips represent a powerful method to provide a contextualized learning environment and enhance students' motivation and interests (Morag & Tal, 2012).

CS Unplugged Activities: Unplugged tasks, often completed using simple materials like pen and paper, demonstrate that computer science is not solely tied to the use of computers (Looi et al., 2018). By employing metaphors and hands-on approaches, unplugged activities make complex computer science concepts more tangible and foster a constructionist, action-oriented learning experience. While unplugged tasks can be used in many different subjects and disciplines, it remains a common teaching method in computer science and therefore for fostering CT skills.

Teachers can use scaffolding techniques, as described by Dillenbourg (1999), to help students build foundational skills. For instance, introducing algorithmic thinking with unplugged activities (such as sorting exercises) before moving to more complex programming tasks.

Game-Based Learning (GBL): The game-based learning (GBL) method applies core gaming principles such as competition, points, rewards and feedback loops to real-life contexts in order to engage users (Pho & Dinscore, 2015; Trybus, 2015). The motivational psychology behind the game-based learning approach enables students to engage with educational content dynamically (Pho & Dinscore, 2015). Game-based learning involves designing activities that continuously introduce new concepts while guiding the learners to achieve a certain goal (Pho & Dinscore, 2015). Various arguments support the effectiveness of games as learning environments. Plass et al. (2015) mention motivation, player engagement, adaptivity, and graceful failure as the key arguments for GBL. Digital GBL is particularly valuable in interdisciplinary fields that prioritize skills like critical thinking, communication, debate, and decision-making. Those games enable learners to apply knowledge, learn flexibly, and gain virtual experiences that shape their behaviour and enhance reflective thinking (Pivec, 2007).

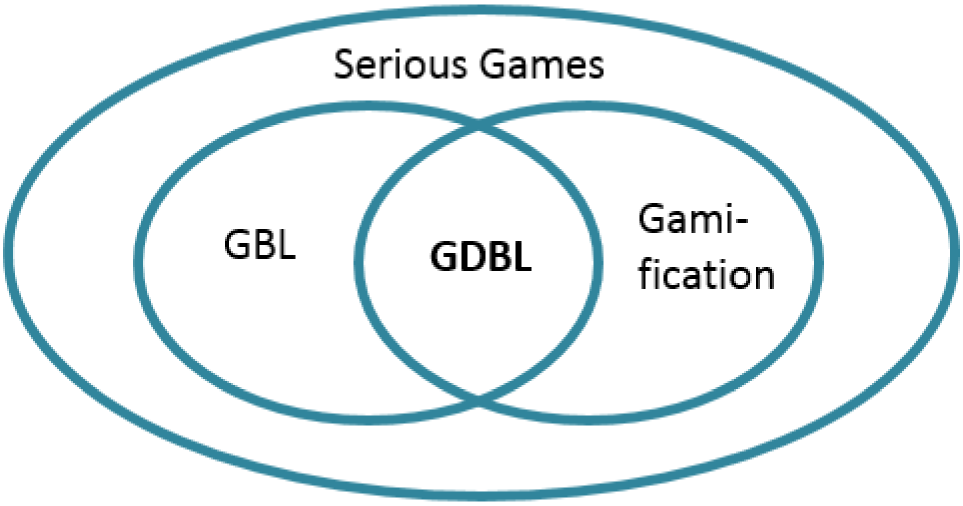

Figure 1: Classification of game-based learning methods (own creation)

Figure 1 illustrates the relationship between different game-based learning concepts, positioning them within the broader category of serious games.

Game Development-based Learning (GDBL): Game creation challenges in schools potentially provide engaging, goal-oriented, and interactive tasks in classes, thereby supporting the transfer of knowledge in a fun and pedagogic manner (Romero, 2012). This process requires them to apply computational concepts like algorithms, debugging, and user experience design, promoting deeper understanding through practical application (Hsu et al., 2018). By leveraging the interactive and immersive nature of games, GBL transforms traditional educational practices into dynamic experiences that foster critical thinking, problem-solving, and collaboration among learners (Wu & Wang, 2012). In addition, it guides students through iterative cycles of problem identification, idea generation, prototyping, testing, and reflection. GDBL emphasizes scaffolding student inquiry and creativity, encouraging learners to actively construct knowledge through hands-on exploration and iterative improvement.

Gamification: Using a gamification approach involves leveraging game design elements to enhance motivation and engagement in non-game contexts, such as education. This strategy integrates components like points, badges, and leaderboards to sustain user activity and promote learning outcomes. Research shows that gamification can significantly boost student motivation and engagement by creating interactive and immersive experiences. For instance, studies highlight the positive effects of gamified elements on intrinsic and extrinsic motivation, with features like badges fostering recognition and self-regulation while leaderboards encourage competitiveness (Sailer et al., 2017; Alsawaier, 2018). The ultimate goal of gamification is to improve user experience (UX) and engagement by addressing users' needs. For example, progress-tracking tools like those used by Udemy allow learners to visualize their achievements, while platforms like Kahoot incorporate competitive quizzes to stimulate active participation (Alsadoon, 2023;Bicen & Kocakoyun, 2018).

Serious Games: Serious games describe a category of video games designed to go beyond entertainment, with the aim of achieving specific, purposeful outcomes. They offer unique pedagogical benefits, particularly in fostering motivation and engagement in the learning process (Mouaheb et al., 2012).Moreover, serious games encourage students to immerse themselves personally, emotionally, and cognitively, making learning more interactive and impactful (Anastasiadis et al., 2018). Serious games can be implemented in a variety of educational settings. For example, in primary school, they can support the training of basic mathematical competences or new vocabulary in a foreign language (De Gloria et al., 2014). In higher grades, such as secondary school, serious games can be used to enhance problem-solving skills through interactive simulations.

Play-Based Learning (PlBL): Play-based learning describes a learning method which is based on the belief, that play is a natural and essential part of learning. PlBL leverages student's inherent curiosity and interests to foster exploration, creativity, and problem-solving (Taylor & Boyer, 2020). Nolan & Paatsch, (2018) define PlBL as a purposeful, co-construction of knowledge with peers within the student's social and cultural worlds. Especially in the field of early childhood education, PlBL is seen as a foundational approach. It enables young children to develop problem-solving abilities, self-regulation, and communication skills in an engaging and natural way (Suhonen et al., 2015).

Play-based learning is not limited to children engaging independently as it also involves the active participation of adults who provide guidance and structure to support meaningful learning and skill development. Educators scaffold learning objectives to enhance the developmental and educational value of play (Weisberg et al., 2013).

Competition-based Learning: Some students enjoy such learning methods where competition is a central element, although it needs to be noted that for some students competition can be also very unmotivating. In EE, 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 & Rahman, 2018). A business idea can also be presented to a simulated group of investors ("shark tank"), where the investors comment and ask questions from the student entrepreneur team. Teams can then compete who the investors decide to give the largest imaginary investments.

Competitions can also be turned upside down, like in Hebocon robot competitions where participants build robots and competition winners are the ones who fail the worst with their robots, see (Durall et al., 2024). This kind of competitions that celebrate the lack of technical competence and failure can be used to increase engagement and enjoyment in learning as well as toleration of failure and understanding of iteration when constructing something (Durall et al., 2024).

Competitive elements can be added to learning also through games and gamification. Some students are motivated by achievements: completing all the given tasks as fast or as well as possible and seeing their names at the leaderboard.

Guest Lectures and (Hands-on) workshops: Guest lectures are commonly used particularly in entrepreneurship education but fit well with other subjects too. Expert visits from the economy and workshops with them in particular offer students valuable insights into the business world (Block et al., 2023; Samuel & Rahman, 2018). They are seen as having potential to promote student engagement and creating a positive learning environment (Nakano, 2009). Guest lectures are probably more engaging when organized face-to-face with students, but they can also be organized online, which makes it possible to have a wider variety of guests, for example from a different city or even country. Students are often passive learners in guest lectures, but more active models have been proposed as well, such as student-centered guest lecturing. To facilitate student engagement, this type of a guest lecture is organized in interview style, where students present questions to the expert guest speaker. The questions have been prepared beforehand, and after the guest lecture, students continue their work e.g. in form of discussions and writing term papers (L. Li & Guo, 2015). Various workshops can also be organized where guests act as external experts, supporting students in their learning process. A practical example from entrepreneurship education is development of a business plan for a new business idea, where entrepreneurs can support the students with the overall plan writing, or technical experts can support particularly with the technical elements of the business idea. Guest lectures and workshops can be used with any topic or any age group, as long as the guest speaker is well chosen.

Reflective and Theory-based Learning / Case Studies: Reflective and theory-based methods are a traditional yet powerful tool in EE. 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 & Hamburg, 2019; Samuel & Rahman, 2018).

Storytelling: Stories serve as a foundational way for processing experiences in daily life. Using storytelling in an educational setting offers the opportunity to provide knowledge content in relation to a context which is especially important as learners can immediately connect the acquired information to their personal experiences whereas content which is delivered without any relevant context more likely passes by (Hofman-Bergholm, 2022; McNett, 2016). According to McNett (2016) incorporating storytelling elements into lessons promotes better understanding and facilitates learning by more actively engaging the learner's brain. Furthermore, storytelling offers a versatile learning methodology adaptable to various educational goals such as entertaining and capturing the learner's attention, providing a comfortable atmosphere, make information easily accessible or connecting a new concept to a memorable story.

A story can also be utilized for instructional purposes and encapsulate information. McNett (2016) (after Andrews et al. (2009)) suggest four different types of story-based instructions: case-based, scenario-based, narrative-based and problem-based. For example, problem-based instructions include stories with badly structured problems to encourage learner-driven problem-solving. In the case-based instruction, the learner acts as an observer outside of a story with a pre-defined problem and solution. A scenario-based instruction involves interactive elements and various solutions, which are not yet fixed, the learner is positioned within the story. The latter also applies for a narrative-based instruction but the story has a given problem and solution.

Mentoring: Mentoring plays a crucial role in education, particularly in EE, where practical guidance and real-world insights are invaluable. A mentor, typically an expert with extensive experience and understanding, supports younger entrepreneurs in building a business. By giving advice and emotional support, sharing knowledge and promoting connections with business networks, the development of entrepreneurial skills and mindsets are fostered, from business idea conception to product development (Memon et al., 2015; Prastyaningtyas et al., 2023).

Arts-based learning: Arts-based learning is an innovative and cross-disciplinary pedagogical approach that integrates artistic thinking and creativity into the learning process (Marshall, 2014, 2016). This approach can include different creative practices such as painting, drama, creative writing (Papavasileiou et al., 2020) or puppetry (Okwara & Henrik Pretorius, 2023). For example, building upon arts-based learning, the STEAM approach integrates STEAM into a transdisciplinary educational framework. By combining STEM with arts and creative expression, critical thinking and problem-solving skills are enhanced allowing deeper understanding of complex concepts (Okwara & Henrik Pretorius, 2023).

2.3. Methods applied to CT, EE, and GS

This section provides a comprehensive analysis of the learning methods presented in chapter 2.2 with a particular emphasis on three competence pillars of the project. It aims to offer a thorough understanding of techniques to promote CT, EE and GS competences on the level of primary, secondary and vocational education.

2.3.1. Computational Thinking

As described in D2.1 for CT, various learning methods have proven helpful. Most of them are general in nature and can be used in different contexts (e.g., storytelling, game-based learning). Some tools or resources, such as Scratch or CS Unplugged, are specifically designed to strengthen CT. Therefore, these are mentioned again explicitly for CT in the following section.

Primary Education

Integrating CT into primary education is essential for developing young learners' problem-solving and critical thinking skills. Various learning methods have been effectively employed to introduce CT concepts to this age group. Below are practical examples from the literature demonstrating the application of these methods in primary education:

Unplugged activities provide foundational CT skills without the need for technology, making learning accessible and inclusive. Supporting this idea, Del Olmo-Muñoz et al. (2020) highlight the benefits of integrating unplugged activities into the learning process of younger learners. The study with 84 second year primary students found that primary school pupils achieve better outcomes when they begin with unplugged CT tasks to build a strong conceptual foundation before transitioning to computer-based CT exercises, compared to starting directly with plugged activities (Del Olmo-Muñoz et al., 2020).

In addition, a multiple-case study in Spain examined the implementation of unplugged tasks across different school settings, focusing on developing CT skills in K-6 students. The researchers conducted a qualitative case study in three different schools. In total, 94 lessons were observed. The study found that these activities effectively enhanced students' understanding of CT concepts through hands-on learning experiences (Tsortanidou et al., 2023)

The study by Futschek & Moschitz (2011) found that introducing algorithmic concepts to young children through tangible, hands-on activities, such as the "Tim the Train" scenario, effectively enhances their understanding of basic computational principles. This approach not only makes learning engaging but also facilitates a smoother transition to virtual programming environments like Scratch, thereby improving their grasp of programming concepts.

List of examples for unplugged activities in primary education:

- **The Bebras Challenge** - an international, game-based competition that introduces students to CT through engaging, logic-based puzzles and problem-solving tasks, without requiring prior programming knowledge.
- **CS Unplugged** – Free resources with unplugged activities covering sorting, binary numbers, graph traversal, and more.
- **Barefoot Computing** – UK-based platform with unplugged CT activities like logic puzzles, decomposition tasks, and pattern recognition.
- **Code.org Unplugged** – Interactive, offline lessons on algorithms, debugging, loops, and conditionals.
- **Google CS First** – Free computer science resources with some unplugged activities related to storytelling and problem-solving.
- **CS for All Teachers** – Community-driven resource with unplugged CT lesson plans for various age groups.
- **Thinkersmith's Unplugged Lessons** – Hands-on, screen-free activities like "My Robotic Friends" to teach programming fundamentals.
- **Turing Tumble** – Physical logic puzzles using marble-powered mechanical computers to teach programming concepts.
- **Hour of Code – Unplugged** – A collection of unplugged coding activities, including logic-based games and storytelling exercises.
- **Bee-Bot Unplugged Activities** – Unplugged exercises for introducing sequencing and algorithmic thinking using movement-based challenges.
- **Kodable Unplugged** – Printable unplugged coding activities focused on early CT skills for primary learners.

In addition, board and card games can be used to teach CT concepts, particularly to develop algorithmic thinking. Games like **Robot Turtles** or **Code Master** are specifically designed for young children to introduce logical thinking and algorithmic processes through playful challenges.

Play-based learning (PBL) is a teaching method grounded in the belief that play is a natural and vital component of learning especially in young learners. In a case study from Lisbon, educators collaborated with an inclusive public school to integrate CT into early education. In the first phase, IT teachers and specialized educators for visually impaired children were interviewed to determine their opinions, needs, as well as perceived barriers and opportunities in teaching CT. Various robots and programming tools were introduced, ranging from traditional graphical interfaces to tactile user interfaces with auditory feedback. The results show, that through playful, hands-on activities, students engaged with foundational CT principles, demonstrating improved problem-solving skills and enthusiasm for learning (Pires et al., 2024).

Alawajee & Delafield-Butt (2021) examine the educational benefits of Minecraft, focusing on its impact on learning and social engagement. Their study highlights how Minecraft supports collaborative learning, problem-solving, and creativity, making it a valuable tool for both individual and group activities. They emphasize the game's potential to enhance student motivation, engagement, and digital literacy, particularly in STEM and language learning. Additionally, the authors explore how Minecraft fosters social interaction and communication skills, making it especially beneficial for students with diverse learning needs.

Resources for PBL in primary education:

- **LEGO Education** – Hands-on learning kits like **LEGO SPIKE** and **LEGO WeDo** to introduce CT and problem-solving through play.
- **Minecraft Education Edition** – Game-based learning environment where students can explore CT concepts through building and problem-solving.

Storytelling can contextualize CT concepts, making them relatable for young learners. Stories can introduce core CT principles such as sequencing, decomposition, pattern recognition, and debugging through relatable characters and problem-solving situations (Kordaki & Kakavas, 2017). This method taps into young learners' natural inclination for imagination and play, fostering curiosity and motivation. Moreover, storytelling promotes collaboration and discussion as students share ideas and reflect on the problem-solving process, creating a dynamic and inclusive learning environment.

In a study by Zeng et al. (2023) conducted in China, an early childhood teacher developed and implemented an unplugged programming and CT curriculum that incorporated storytelling elements. This approach helped children grasp abstract CT ideas by connecting them to familiar narratives, enhancing both engagement and comprehension.

Another study by Curzon et al. (2014) found that using unplugged storytelling as a method to introduce CT to primary school teachers was an effective and engaging approach. The study aimed to address the challenge of teachers lacking computing backgrounds by designing 90-minute workshops that incorporated interactive, kinesthetic activities without computers. The findings showed that teachers gained a better understanding of CT, felt more confident in teaching it, and were motivated to integrate these methods into their classrooms (Curzon et al., 2014).

Resources or examples to introduce storytelling:

- **Using stories to support CT** - Breaking down stories into elements like characters, plot, and sequence helps students develop logical thinking and sequencing skills. This method supports an understanding of algorithms and program structures.
- **StoryCoder** - A Language-Based App for Early Coding.
- **Scratch** - Create own story's using Scratch.
- **Hello Ruby** – A book and activity set that teaches CT through storytelling and offline games.

Making activities, particularly for younger students, can include hands-on projects such as simple circuits, nonsense machines, and chain reactions that encourage exploration and problem-solving. By creating digital fabrications or artifacts through hands-on making, young learners can deepen their understanding of CT concepts, connecting the learning experience to their personal interests (Iwata et al., 2020). More examples for Making activities are rapid prototyping challenges, design thinking iterations, user-centered problem solving, STEM-inspired maker missions, inquiry-based engineering tasks, hands-on experimentation, material exploration and testing, tinkering with everyday objects, open-ended making challenges, creative construction tasks, and collaborative maker projects. Additionally, students can engage in reverse engineering activities, redesigning and improving a product, inventing and prototyping solutions, story-based making challenges, building working models, exploring digital fabrication and smart wearables, hacking and modifying existing objects, integrating art and science in making, and designing interactive installations.

Maker education has shown promising results in enhancing CT skills among primary school students. The systematic literature review by Kakavas & Ugolini (2019), which analysed 53 studies published between 2006 and 2018, highlighted several key outcomes of integrating maker education with CT learning. For example, maker education significantly improved core CT skills such as abstraction, algorithmic thinking, and problem decomposition. Additionally, maker education can increase motivation and engagement in students, close the gender gap and support students with diverse learning styles.

In addition, Bower et al. (2018) explore the impact of makerspaces on primary students, highlighting their role in fostering creativity, collaboration, and problem-solving skills. The study emphasizes how hands-on, project-based learning in makerspaces enhances student engagement and develops critical thinking and STEM competencies. The authors also discuss how makerspaces promote experiential learning, helping students build confidence in technology use and innovation.

Tools that are often used in combination with primary education and Making are:

- **Makey Makey** – A creative invention kit that allows children to turn everyday objects into interactive circuits.
- **MakeDo** - A construction kit that encourages creativity and hands-on learning by enabling users to build models and structures using cardboard, plastic connectors, and simple tools.
- **LittleBits** - A platform of modular electronic building blocks that snap together with magnets, allowing beginners to create and prototype interactive projects without soldering or programming.

In addition in Making, *Microcontrollers*, such as micro:bit, provide a hands-on, engaging teaching method for primary school students (Fidai et al., 2020), fostering creativity, problem-solving, and CT. By programming microcontrollers to interact with sensors, lights, or motors, students can explore real-world applications of coding and electronics in projects like building weather stations or simple robots.

The study of Kalogiannakis et al. (2021) systematically reviews the use of the BBC micro:bit in primary schools, based on twelve empirical studies. The findings indicate that students and teachers have positive experiences, finding the device easy to use and engaging. Students report enhanced creativity and problem-solving skills, while teachers value its motivational impact. However, challenges include technical issues and teachers' limited knowledge of coding. Despite this, micro:bit's integration into STEM education has shown potential for fostering computational thinking and skills development.

Tools for physical computing:

- **Micro:bit** - A pocket-sized programmable microcontroller designed to teach coding and electronics to beginners through easy-to-use hardware and software.
- **Calliope** - A microcontroller designed for educational use, enabling beginners, especially schoolchildren, to learn programming and electronics through simple coding projects and built-in sensors.

- **CodeBug** - A wearable, beginner-friendly microcontroller with an LED grid, designed to teach programming and electronics through simple, interactive projects.
- **Chibitronics** - Chibitronics combines paper and electronics using peel-and-stick circuit stickers, enabling beginners to learn and create interactive projects by drawing circuits with conductive tape.

Robotics provides an effective introduction to CT by allowing students to systematically break down tasks and create step-by-step coding commands to program a robot (Chalmers, 2018).

A study by Körber et al. (2021) explored introducing programming to primary school children using Ozobot robots across eight schools in Germany and Austria. Workshops involved both unplugged (pen-and-paper) and digital programming with the OzoBlockly app. Participants responded positively, showing enthusiasm and engagement, especially with the pen-and-paper mode. Challenges included managing hardware and supporting teachers. Overall, the study suggests that Ozobots effectively bridge unplugged activities and computer-based programming.

Another study by Chevalier et al. (2020) involved 111 primary school students aged 10–12. The study presents a model for using educational robotics to develop CT skills in primary school students, focusing on problem-solving beyond trial-and-error approaches. Two groups used the Thymio robot: one with unrestricted programming access and another with scheduled constraints. Results show that limiting access promotes deeper problem understanding and strategic thinking. The study suggests that structured ER activities can effectively enhance CT skills.

Robots suitable for primary education:

- **Bee-Bot** – A programmable floor robot for young learners to practice sequencing and problem-solving.
- **Ozobot** – A small robot that introduces CT through color-coded commands and hands-on play.
- **KIBO Robot** – A hands-on, screen-free robot that teaches CT through physical play.
- **Thymio** – An educational robot designed for teaching programming and robotics, featuring various sensors and programmable actions that help students learn through interactive, hands-on experiences.

Gamification/GBL is based on the idea, that learning can be both enjoyable and effective. For gamification game elements such as challenges, rewards, and competition can be integrated into the school day to stimulate students' intrinsic motivation and encourage active participation (Pho & Dinscore, 2015). Another way to support the development of CT skills in primary education is learning through engaging in gameplay (Turchi et al., 2019).

The study by Holenko Dlab et al. (2020) involved primary school students in Croatia, aged 8–12, who participated in activities using digital games to develop CT and programming skills. Results indicated that games effectively enhanced skills like decomposition, pattern recognition, and algorithm design. The structured use of educational games promoted engagement and learning of basic programming concepts.

An example for a Game-based learning tool is **Lightbot** – a puzzle game that introduces sequencing, loops, and conditionals through programming a robot.

Coding/computing or programming serve as an effective method for formalizing and teaching concepts related to CT (Çakiroğlu & Çevik, 2022). Especially visual programming languages (VPL's) support younger learners in their development of CT skills such as problem-solving or decomposition, while minimizing concerns about programming syntax (Grover & Pea, 2013; Lye & Koh, 2014).

A study exploring the perspectives of primary school teachers on programming education revealed that, despite initial challenges, educators recognized the value of coding in developing students' logical thinking and problem-solving abilities. The research emphasized the importance of adequate teacher training and resources to successfully implement coding curricula in primary education (Greifenstein et al., 2021).

Fagerlund et al. (2021) provides a systematic review of how Scratch is used to developing CT in primary schools. This study synthesizes findings from multiple research papers, identifying key teaching strategies, challenges, and learning outcomes related to programming with Scratch. The authors highlight that block-based coding environments like Scratch help young learners develop problem-solving skills, logical reasoning, and algorithmic thinking. Additionally, they discuss the role of scaffolding, teacher guidance, and assessment methods in supporting computational thinking. The study serves as a comprehensive resource for understanding how programming can be effectively integrated into primary education and how it benefits students' cognitive development.

Tools for coding in primary education:

- **ScratchJr** – A visual programming app designed for young learners to create animations through play.
- **CodeSpark Academy** – A game-based coding platform for kids aged 5-9 with interactive puzzles and storytelling.
- **MakeCode Arcade** – A game-building platform where students can create retro-style games using block or JavaScript coding.
- **Twine** – A tool for creating interactive, text-based adventure games that introduce logical thinking and branching structures.
- **Construct 3** – A game development tool that teaches event-driven programming.
- **Scratch** - A visual, block-based programming language designed to introduce beginners, especially children, to coding.
- **XLogo -** Is an educational programming environment based on the Logo language, using turtle graphics to help beginners learn programming concepts through simple commands and visual patterns.
- **Pocket Code** - a mobile app that allows users to create and share interactive stories, games, and animations by programming with visual, block-based coding, similar to Scratch.

Many approaches to fostering CT overlap, as coding activities often incorporate game-based learning, playful exploration, and problem-solving challenges, while Making integrates robots, microcontroller and coding, allowing students to engage in hands-on problem-solving, engineering design, and creative computational exploration simultaneously.

Secondary Education

To implement CT in secondary education, educators and researchers often incorporate various tools, hands-on activities, methods, and pedagogical strategies. These approaches not only help teachers understand and apply CT concepts in classroom settings but also provide creative ways for students to engage while developing their CT skills.

Various models and **frameworks** have been proposed to integrate CT into teacher training. As already described in D2.1, the Computational Thinking Framework Pedagogical (CTFP) model, for example, structures CT integration through four key pedagogical experiences: unplugged, tinkering, making, and remixing (Kotsopoulos et al., 2017). Unplugged experiences involve CT activities without computers, while tinkering focuses on deconstructing and modifying existing objects. Making emphasises constructing new artefacts, whereas remixing involves repurposing components for new applications (Kotsopoulos et al., 2017; Orl & Villalba-Condori, 2019).

The Technological pedagogical content knowledge (TPACK) by Neira et al. (2021), incorporates a visual execution environment (VEE) and Scratch project as a means to teach and assess CT among secondary school students (Neira et al., 2021). While the CT for an Inclusive World framework integration including foundational CT (Abstract, Algorithmic, Debugging, Decomposition, Pattern Recognition, and Selecting tools), applied computational practices (Automation, Computational modelling, and Data practices) and inclusive pedagogies (see Figure 2) (Mills et al., 2021)

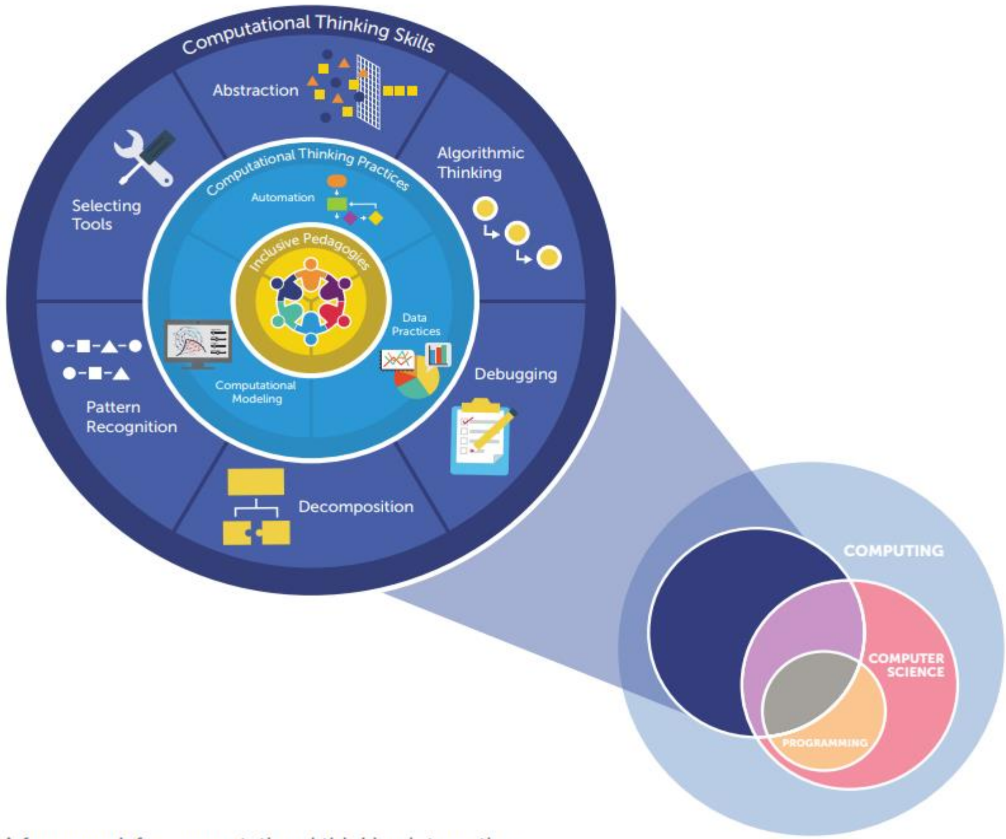

Figure 2. A framework for computational thinking integration.

Figure 2: CT for an Inclusive World framework (Mills et al., 2021)

Graphical programming environments allow students to develop CT through visual programming interfaces. Scratch, a widely used block-based programming language helps to foster creativity, problem-solving, and interdisciplinary (Basogain et al., 2018; Fields et al., 2014; Sarro et al., 2024; Yildiz Durak, 2020). Similarly, Alice is a visual programming environment designed to helps introduce core CT concepts through storytelling and interactive animations (Basogain et al., 2018; Yildiz Durak, 2020). Other initiatives, such as the Hour of Code [https://hourofcode.com/], provide accessible, short-format coding experiences to engage students in programming and computational thinking (Yauney et al., 2023).

Project-based learning has proven to be an effective method for cultivating CT by engaging students in real-world problem-solving. Project-based learning pair programming can effectively improve students' CT ability and CT self-efficacy (Liu et al., 2023) and can support them in engaging with CT through computational modelling (Shin et al., 2021). Project-based learning could also enhance students' practical CT skills such as innovation, algorithmic thinking, collaboration, critical thinking, and problem-solving (Zhang et al., 2024).

Integrating **robotics** into the curriculum allows students to apply CT principles in tangible ways, enhancing problem-solving and programming skills. Project-based learning robotics programs can incorporate block-based programming platforms such as Scratch™ and LEGO® Mindstorms® (Zhang et al., 2024) alongside web resources like Blockly Games and Kahoot (Díaz-Lauzurica & Moreno-Salinas, 2019). Kibotics is another tool that has been designed for CT and educational robotics (ER) in primary and secondary education (Martín et al., 2024). It features an online 3D robot simulator that supports common physical robots, including LEGO EV3, Makeblock Mbot, and Tello Drone.

With focus on older students, Thymio and LEGO Mindstorms are educational robots and robotic kits designed to support the development of CT skills at the secondary level. Both tools offer students opportunities to engage with programming, engineering, and problem-solving in a hands-on and collaborative manner. By integrating them into secondary education, teachers can introduce more complex concepts and scenarios, fostering deeper learning in STEM and computational thinking.

Unplugged activities develop CT skills without requiring electronic devices, making them an accessible, and low-cost approach. They have shown potential in improving CT skills, especially in upper secondary education (Benavides-Escola et al., 2024). Researchers have developed various offline and interactive methods, such as flowblocks - a visual and programming tool, delivered in the form of game-based learning which includes a series of game missions to develop programming concepts to teach secondary students (Threekunprapa & Yasri, 2020). Another example is the CS Unplugged project [csunplugged.org], which engage students through games and puzzles using cards, string, crayons and physical activities (Bell & Vahrenhold, 2018; Benavides-Escola et al., 2024). Additionally, a literature review of 49 studies from 2006 to 2022 found that board and card games were the most common unplugged activities, particularly in computer science and STEM education (Chen et al., 2023).

Code visualization tools enhance students' understanding of abstract programming concepts by providing interactive and visual representations of code execution. ACME (Code Animation by Evolved Metaphors) is a scalable visualization tool that uses consistent metaphors to teach procedural and object-oriented programming (Mecca et al., 2021). Other tools that support algorithm understanding, debugging, and learning advanced programming concepts, particularly text-based languages, include Python Tutor (Guo, 2013), VB2ALGO (Almadhun et al., 2019), Jeliot 3 (Moreno & Joy, 2007) and several others (Giordano & Carlisle, 2006).

VET

In our previous Deliverable (D2.1), we provided an overview of teaching methods, tools, and literature related to CT in VET. For instance, problem-based, project-based, and design-based learning approaches were discussed, drawing on sources such as Kruse et al. (2011) and Lee et al. (2014), as well as insights from the Partnership for 21st Century Skills (2019). However, when it comes to VET organisations, research and established frameworks remain less prevalent. Given this gap, the current deliverable shifts the focus towards practical examples from our project partners in the VET sector (Mercantec, libs, VHS). By showcasing concrete implementations and experiences, we provide insights into how CT can be meaningfully integrated into vocational training, highlighting both the opportunities and challenges from real-world applications.

In addition, in practice, CT is often not labelled as such especially in VET; instead, the relevant skills are embedded within job roles or as a cross-curricular competence that demand problem-solving, algorithmic thinking, and data analysis. These skills manifest in everyday tasks in industries where digital tools, automation and project work are integral.

Libs (CH): libs offers a variety of technical and commercial apprenticeships. Some of the available training programs include:

- Automation Technician: Experts in developing and building control and automation systems.
- IT Specialist: Experts in application development or system engineering.
- Design Engineer: Professionals in developing and designing technical products and systems.

A full list of available apprenticeships can be found on the official libs website: libs.ch.

VHS Vienna (AT): VHS Vienna offers for their target group beginner courses for Python programming and Design Thinking, also addressing certain (but not all) aspects of CT implicitly.

As part of their internal education program (only available for VHS trainers), additional courses are offered in the area of Python programming, prompting, Markdown as well as mathematical foundations of AI – all under the umbrella of CT.

2.3.2. Entrepreneurship Education

Entrepreneurship is considered to be a continuous learning process (García-Rodríguez et al., 2019) and EE to teach entrepreneurial skills but also attitudes and mindset needed by entrepreneurs (Fayolle et al., 2006). The presented learning methods in chapter 2.2 are almost all adaptable to all age groups with no inherent limitation based on age. The primary difference lies in the choice of materials, the depth of subject exploration and the preference of the learners rather than in the principles of the methods themselves.

Primary & Secondary Education

A general consensus exists that it is beneficial to start EE from an early age, thus EE can be started already in primary education. EE of young children can help children to adopt an entrepreneurial mindset from a young age and helps them to gain understanding of the possibilities entrepreneurship offers as a career choice. It is suggested that for young children, it is more beneficial for EE to focus particularly on practical aspects, while with older age groups there is a need to focus on entrepreneurship as a viable and interesting career choice as well (García-Rodríguez et al., 2019).

One form of **Problem based learning** is working with business ideating and business idea development, ideating solutions for customer needs. Through that, students of different ages learn a structured way to approach different problems that need to be solved in new business development. Business idea development can be adapted to serve various purposes, as seen e.g. in Kinnula et al. (2024) who used it for ideating and developing sustainable artificial intelligence applications with 14-15-year-olds. It can also teach systems thinking (Kinnula et al., 2024), which is useful for a profitable and sustainable business, and is generally needed in the increasingly complex world, to solve wicked problems such as climate change (Grewatsch et al., 2023). This happens e.g. when identifying customer need and planning for value creation to the customer, and when considering who would be suitable partners to support the business idea, which are all part of the work in business idea development (Kinnula et al., 2024). Adapted versions of the business model canvas (Osterwalder & Pigneur, 2010) can be used for that purpose, fitted to serve the age group. A simplified version of a textual business plan can also be used, with guiding questions to support the work (Kinnula et al., 2024). As an approach for EE, business ideating can serve any age group.

Project-based learning can also be effectively linked with EE. For example, most of the business development work can be framed as a project with a schedule and milestones, resources available, and goals set for the project.

Entrepreneurial hackathons where teams engage in an innovation process while working around a business idea (Franco et al., 2022) are an intensive way of developing a business idea. They are often partly framed as **competitive** situations, where teams compete against each other on whose business idea is best and which team is able to present their business plan in the best way to potential investors in the end of the entrepreneurial hackathon in a "shark tank". Use of this kind of competition in education of children can be questioned, but it has also been shown to work well with 14-15-year-olds (Hartikainen et al., 2023; Kinnula et al., 2024). Generally, hackathons are more suitable for older students due to their intensive way of working, but they can be adapted to younger students by e.g. shortening the time used for the hackathon.

Design-based learning and **maker education** can be used also in EE as they complement well the business ideating and business idea development. They bring a more concrete element to learning, when the learners not only ideate their business but also start creating something tangible related to their business idea, such as product design or even a prototype. A combination of design and making and business idea development is not that commonly used yet, but the tangible outcomes created by making and digital fabrication can help children to understand the concrete and practical problems in new product creation and learn the skills and tools useful for developing new business in the digital world (Geser et al., 2019).

Various **work-based learning models** can be used for EE. **Providing role models** by meeting with entrepreneurs or discussing case studies with students (Kuckertz, 2013) can increase interest in the entrepreneurship career and understanding of it etc. For example, Kinnula et al. (2024) collaborated with entrepreneurs who told of their own story about how they became entrepreneurs and what was their motivation to start their entrepreneurship career. This can also be combined with **mentoring** (Memon et al., 2015) where entrepreneurs for example support the business ideating process of students.

Guest lectures and workshops can be used in EE with any topic or any age group, as long as the guest speaker is well chosen. A practical example is development of a business plan for a new business idea, where entrepreneurs can support the students with the overall plan writing, or technical experts can support particularly with the technical elements of the business idea. These learning methods can be linked with learning by doing, where for example internships in start-ups can be used to support learning. Internships naturally suit better for somewhat older students, and the purpose and goals for their use needs to be carefully considered and discussed with workplace mentors (Alfeld et al., 2013). Mini-enterprises set up by learners, working with the programme for a whole school year, are one way to make EE more concrete. For that purpose, students need to ideate new business and consider marketing and making profit with their business, supported by adult mentoring (Riese, 2013).

Materials, models and practices for EE:

- **The Entrepreneurial School** – Material produced by a European Commission co-funded EE **initiative for supporting teachers in applying** entrepreneurial learning in several subjects and learning environments (primary, secondary, upper secondary and vocational schools). This large material base includes examples and best practices for EE tried out across Europe.
- **JA Europe** – a non-profit for EE from primary school to higher education, providing EE education, material, and events.
- **Entrepreneurial Kids** – a European Union funded programme for teaching 6-10-year-olds entrepreneurial skills through interactive workshops, company visits, and creative activities.

A number of commercial programmes and materials also exist for teaching children entrepreneurial skills; the following are examples of those:

- **Kidpreneurs** – books and online programs for 6-12-year-olds.
- **Kidspreneurship** – learning resources, curricula, and products for educators teaching 5-14-year-olds.

VET

In Deliverable 2.1, we explored theoretical insights for VET and EE. In the realm of EE, practice-oriented strategies were emphasised, including project-based learning, simulations, design thinking, competitions, guest lectures, workshops, and reflective case studies, as supported by the EntreComp Framework (European Commission. Joint Research Centre., 2016) and reports from the European Commission. Joint Research Centre. Institute for Prospective Technological Studies. (2015). Building on these foundations, we now present practical examples from our VET project partners that demonstrate how EE can be integrated in real-world VET and EE settings.

Mercantec (DK): "Subject-Specific Course" - In our business department, students completed their basic course with a project where they either worked with an existing company or created their own. Students were allowed to develop the concept, work on marketing, etc., culminating in a fair where they presented their businesses to other students in the school.

The structure of the project was as follows: Students were introduced to the assignment, including the theories within the commercial area that they were required to incorporate into their work. Following this, students worked in small groups of 2-3 to create their businesses. Teachers acted as advisors throughout the process, but the students were responsible of reaching out to relevant companies and partners for information and if necessary, borrow materials for the fair.

After the fair, students were required to take an exam where they presented their business concept, budget, marketing strategies, etc., and explained the theories behind their choices.

Libs (CH): libs offers structured entrepreneurship programs through its "Unternehmerhaus" initiative, providing apprentices with essential business skills. The 101 course (mandatory) introduces fundamental entrepreneurial methods, business modelling, and pitching. The 201 course (optional) allows top learners to develop and implement start-up or intrapreneurship ideas, covering topics such as financing, growth hacking, and agile product development. These programs aim to cultivate an entrepreneurial mindset and prepare learners for innovative careers.

VHS Vienna (AT): VHS Vienna offers a comprehensive range of courses on business and management for their target group. The course program is designed for anyone looking to further their education both professionally and personally. The courses and events address topics like understanding economics as well as career orientation and the job market. Additional courses comprise key areas such as accounting and financial management, labour law, project management, and marketing. The entire program can be found at https://www.vhs.at/de/k/wirtschaft-und-management.

In contrast to the VHS Vienna courses in the area of CT, no such internal training courses for VHS trainers in the area of EE exist.

2.3.3. Green Skills

The presented learning methods in this section are mostly adaptable to all age groups with no inherent limitation based on age. The primary difference lies in the choice of materials, the depth of subject exploration and the preference of the learners rather than in the principles of the methods themselves.

Primary & Secondary Education

Storytelling presents a powerful method for deepening comprehension of environmental concerns when considered in the context of green skills and education for environmental sustainability. For example, storytelling makes sustainability topics better accessible (Hofman-Bergholm, 2022). It also offers the opportunity to combine it with other e.g. hands-on activities as shown in the study of Andriopoulou et al. (2021) conducted with learners at the age of 13 to 15. The authors reported on positive benefits as an increased environmental literacy and an enhanced learning motivation and creativity concerning the ability to solve problems. Furthermore, storytelling promotes and makes behavioural changes easier. Also, Ebersbach & Brandenburger (2020) report on positive benefits of storytelling on pro-sustainability behaviour for students at the age of 10.

Project-based learning has many positive benefits on the development of green competences. For example, project-based learning methods foster and facilitate crucial GS such as critical thinking as well as problem solving- and collaborative competences (Bramwell-Lalor et al., 2020). Furthermore, as the study of Genc (2015) reveals, it positively influences the attitude towards and the awareness of environmental concerns which is fundamental to advance behavioural change critical for a green transition of society. A practical example how project-based learning can foster the development of ecologic, social and economic sustainability competences, the three dimension of sustainable development, is pointed out in Del Cueto Lopez (2021). The project is about setting up a fictional village somewhere deep in nature. The students (grade five to eight, middle-school) are supposed to draw their fantasy village keeping in mind various aspects of daily life including which climate zone they choose, dietary habits, housing conditions, infrastructure or clothing choices and social norms. By informative input sessions about interdisciplinary topics such as circular economy, sustainable farming, balanced diet or aspects of different climate zones the learners are enabled to integrate knowledge directly into their practical work. By doing so, it empowers the students to envision compelling and inspiring scenarios for the future.

Problem-based learning represents a promising teaching method to foster environmental knowledge and attitudes as well as sustainable behaviour by working on real-life issues. Moreover, students take accountability for their own learning processes (Ural & Dadli, 2020; Vasconcelos, 2012). Ural & Dadli (2020) investigated the effect of problem-based learning on the environmental attitudes of 7th grade students and could prove it to be significant. The authors also present scenarios on how problem-based learning can possibly look like.

Game-based learning in environmental and sustainability education provides a useful tool to engage learners across all educational levels and can be adapted to various topics and learning objectives. Often named as "**serious games**" (SGs) their purpose goes beyond mere entertainment but defines learning outcomes. SGs can support the development of e.g. system-thinking and collaborative competences as well as sustainability awareness (Scurati et al., 2023). A GBL approach can also be combined with other learning methods such as **problem-based learning** (Scurati et al., 2023; Toprac, 2011) as well as cover interdisciplinary topics simultaneously e.g. sustainability and economics by balancing green activities and economic impact throughout the game (Peña Miguel et al., 2020). In Table 1 examples for SGs for different levels are listed:

Table 1: Examples for serious games in the field of GS

Game	Level of education	Link
GET UP!	Secondary	GET UP! – The game – GetUP
Wild Kratts	Elementary/ Primary	https://www.wildkratts.com/play-learn-wild-kratts/wild-kratts-games/ (Rossano et al., 2018)
GreenComp Game	All	The GreenComp game - Publications Office of the EU
Stop disasters!	All	https://www.stopdisastersgame.org/ (Katsaliaki & Mustafee, 2015)
Climate Fresk	All	Climate Fresk (world) – Climate Fresk

As a component of serious games, simulated role-plays (RPS) demonstrate significant potential in fostering environmental knowledge and skills. Rumore et al. (2016) show an example on how RPS can promote climate adaptive action by providing a platform to learn and discuss about climate adaptation strategies. Furthermore, RPS create an engaging environment where players can explore complex environmental issues and discuss potential solutions.

Competition-based learning can positively influence sustainability and pro-social behaviour e.g. by overcoming conflicts between collective and self-interests (Van Horen et al., 2018). An example for a competition in the context of sustainability is provided by the "CircularCityChallenge", a competition addressing learners aged 14-18 and encourages them to propose their ideas for promoting circularity and sustainability in their environments. The competition aims at promoting systemic and critical thinking, problem-solving and social skills as well as providing basic knowledge on circular economies (Ataol & Meacham, 2023).

Reflective-methods can be used to appropriately teach environmental and sustainability behaviour since reflective thinking is an essential prerequisite for creating sustainability values. In their study, Gopinath & Kumar (2024), stimulated reflective thinking by thought diaries and used empathy-generating stories on topics such as environmental degradation, water scarcity or online shopping to enhance the development of pro-environmental attitudes. The study was conducted with learners aged 11-12 years and results demonstrated that reflective thinking methods foster the development of environmental values. Reflection also is an important tool when it comes to the development of environmental identities necessary for individuals to act as environmental and social change agents. During the "Trash to Treasure" project conducted by Simms & Shanahan (2019) with 10 to 12 years old students, the garbage collection activity was enhanced by incorporation journaling components. This component included reflective questions on their thoughts and experiences throughout the process. The results show that the collection activity triggered diverse emotional responses and a subsequent reflection demonstrated the potential to increase the learner's engagement.

Making and design-based learning can contribute in a positive way to the development of GS such as systems-thinking or collaborative and problem-solving competences. Furthermore, it is not limited to a certain age group or learning experience which makes it highly flexible (Brown, 2024). A popular approach, as shown by Kinnula et al. (2022), is the combination of innovation and GS (sustainable innovation) to leverage innovation as a means of addressing environmental challenges and to critically reflect on the impacts of existing technologies. Also, the DOIT research project (DOIT) combines entrepreneurship education in the context of sustainability and societal topics using making approaches. It creates space for children and teenagers between 6 and 16 to find creative and sustainable solutions to local environmental or social issues using a practice-based approach. Examples include upcycling workshops ("from waste to inventions") or the creation of a granola bar in the context of health and food, including a complete product concept (Geser et al., 2019).

Field trips are often discussed within the context of outdoor education (Morag & Tal, 2012). **Outdoor education** is a general term referring to educational approaches which take place outside of classical classroom-settings in an authentic and/or natural environment. This offers students the opportunity to connect theoretical knowledge with practical experiences in real nature. Outdoor education includes various approaches and activities e.g. fieldwork and field trips (Jeronen et al., 2016), hiking and adventure activities (Palmberg & Kuru, 2000), farm education (Smeds et al., n.d.) or learning in school gardens (Papadopoulou et al., 2020). Learning in an outdoor setting helps students to improve their ecological literacy/thinking (e.g. understanding how ecological systems work and their connection to society) and to develop a deeper connection to nature which is essential for driving sustainability thinking (Jeronen et al., 2016). Many authors point out to the positive effects and outcomes of outdoor education not only on a cognitive but also on an affective, social, behavioural and physical level (Morag & Tal, 2012). These include: environmental consciousness and positive attitude towards the environment (Jeronen et al., 2016), improved personal and social skills (Morag & Tal, 2012) motoric skills (Lavie Alon & Tal, 2015) as well as critical thinking (Papadopoulou et al., 2020).

Arts-based and creative learning methods like painting, music, creative writing, comics or dramatization promote the development of an emotional relationship and deeper connection with nature which is essential for fostering environmental awareness and encouraging individuals to take responsibility for their own actions. Creative processes can help children to reflect on their environmental values and attitudes, express their emotions and solving problems in a creative way. Moreover, learning experiences that engage emotions tend to be more captivating and memorable, thus enhancing long-term retention of information (Papavasileiou et al., 2020). Häikiö (2020) report that sustainability education combined with aesthetic learning approaches can help children on pre-primary and primary level to adopt different perspectives and creates valuable learning environments to deal with complex issues.

VET

In D2.1, we identified several learning methods for integrating GS into VET. For example, active, experiential approaches such as project-based learning or learning through the development of digital products and services were highlighted as effective in fostering green, problem-solving and critical thinking skills among the learners. Additionally, innovative strategies such as game-based learning as well as blended and digital learning were discussed to enhance learner engagement and interdisciplinarity (European Commission. Directorate General for Employment, Social Affairs and Inclusion., 2023). Building on these foundations, the current deliverable will again present practical case studies from our pilot VET projects to illustrate how these methods can effectively nurture GS in sustainable, industry-relevant contexts.

Mercantec (DK): Green Friday – We have worked with the three sustainability principles – social, economic, and environmental sustainability in our basic course. Students participated in a theme day with workshops such as making insect hotels, establishing a wild garden, creating a café with sustainable snacks, and a communication workshop on nudging for environmental care. How students work on a theme day:

1. Learning goals: Students should understand and apply the three sustainability principles in their projects. By the end of the day, they should present their work and reflect on their learning process.
2. Materials available: Students have access to tools and resources for building insect hotels, materials for a wild garden, ingredients for sustainable snacks, and communication tools for nudging. The teacher provides printed examples for inspiration.
3. Deadline: Projects must be completed by the end of the day, followed by a presentation round for feedback from peers and the teacher.

After the introduction, students independently seek inspiration and manage the process, with the teacher guiding on the sidelines. This requires independence and engagement, with printed task examples available to help all students participate.

Sustainable building – In the Construction & Building class, students learned about old craftsmanship, visited museums to see half-timbered houses, and worked on timber joints and climate-friendly materials in the workshop. Review of the Sustainable Building course: Students start by reading about half-timbered houses to learn technical terms and techniques. They visit the open-air museum Hjerl Hede to find examples of technical terms for a documentation task. Upon return, they present their knowledge through a mini- book or presentation and work on timber joints in the workshop. The school year ends with a field trip to Den Gamle By, where a guided tour by the museum's carpenter enhances their technical vocabulary.

Room for everyone – think before you speak – A course in basic course 1 focusing on social sustainability, emphasizing equality, respect, communication, relationships, and diversity. Description of the course: Students read articles about work culture in their industry, answer related questions, and discuss various issues in class. This prepares them to participate in a work community with respect for differences and the opportunity to change old-fashioned workplace cultures.

libs (CH): libs integrate GS into its training programs by focusing on waste management and energy awareness. In collaboration with the City of Zurich's waste disposal guidelines and management concept, learners are educated on proper waste disposal and sustainability practices. Additionally, the energy awareness module covers key topics such as energy consumption at work and home, climate change, and future scenarios. A hands-on Innovation Project encourages apprentices to develop and implement energy, planning, or awareness initiatives in small groups.

VHS Vienna (AT): VHS Vienna does not offer specific courses on GS, but integrates green aspects into various other activities, workshops and courses (for instance, the workshop energy transition addresses certain aspects of GS, among other topics such as CT and EE).

3. Curricula Implementation of Countries

The following subsection serves to provide a concise overview of how CT, EE and GS are implemented in the curricula of countries across Europe.

3.1. Curricula Implementation of CT

In recent years there has been 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 (European Commission. Joint Research Centre., 2022). To get an overview of how CT is currently integrated in curricula, we analysed the curricula of all nine partner countries of the ComeThinkAgain project. The curricula review showed, that the integration of CT into curricula varies significantly across countries, reflecting diverse educational priorities and structures (European Commission. Joint Research Centre., 2022). In many nations, CT is embedded within broader initiatives for digital competence and media literacy, often introduced as part of programming, computer science, or mathematics education. For example, Finland integrates CT across subjects like mathematics and crafts, while in Switzerland, CT is a key component of the "Media&Informatics" curriculum. Other countries, such as Denmark, are in the process of formalizing national strategies for CT, building on pilot projects like "Technology Comprehension." In regions like Spain and Belgium, CT is addressed through cross-curricular approaches or dedicated coding and robotics courses. Despite the differences, there is a common trend towards embedding CT within digital education initiatives, equipping students with problem-solving and algorithmic thinking skills essential for the digital age.

3.2. Curricula Implementation of EE

The integration of entrepreneurship into education is becoming increasingly important around the world. In many countries, entrepreneurship is seen as a key competence for promoting innovation, economic growth and employment. Different countries take different approaches to integrating entrepreneurship into their curricula.

The 'Youth Wiki' of the European Commission provides valuable insights into the development of entrepreneurial competences in 34 different European countries. Chapter 3, 'Employment & Entrepreneurship', examines how entrepreneurship is embedded in national education systems. It shows how curricula are designed and implemented to promote entrepreneurial thinking and behaviour. However, the integration of entrepreneurship into the curricula varies significantly between countries. In some countries, a holistic approach is taken that includes both theoretical and practical elements.

Here, students not only learn business basics, but also apply them in practical projects. In other countries, however, the integration is less effective. For example, entrepreneurship content may only be taught in theory, without practical applications or the necessary support for teachers. To summarise, the integration of entrepreneurship into curricula is an ongoing challenge. Successful models incorporate theoretical knowledge alongside practical experience and close collaboration with the business community to equip students with the skills they need to successfully grasp entrepreneurship (*Youth Wiki: Europe´s Encyclopedia of National Youth Politics*, n.d.) .

3.3. Curricula Implementation of GS

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 competence frameworks in sustainability education (Bianchi, 2020; European Commission. European Education and Culture Executive Agency, 2024; Redman et al., 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 et al., 2008).

There exist different strategies in implementing sustainability education in school curricula, the most common ones are cross-curricular (integrating sustainability into all subjects), project-based or as a stand-alone subject. In the work of the European Commission. European Education and Culture Executive Agency (2024) school curricula are analysed according to how sustainability education in schools on primary and secondary level in 39 European countries are covered. The overall results reveal that all of the examined European countries cover sustainability topics in the curriculum which are in most cases incorporated in the subjects of natural sciences, citizenship education and geography. In addition, most education systems treat sustainability competences in a cross-curricular way.

4. Results from the Co-creation workshops

4.1. Objectives

The ComeThinkAgain project has organized nine co-creation workshops across Europe, engaging 102 participants from higher education institutions (HEIs), vocational education and training (VET) providers, the public sector, and the private sector. These workshops aimed to establish a collaborative dialogue among stakeholders, identify synergies, and address skill gaps and learning demands crucial for the development and implementation of the ComeThinkAgain CETS. Below are the detailed objectives of these workshops:

Stakeholder engagement: The goal is to involve stakeholders in the co-creation process of the ComeThinkAgain CETS. This includes fostering collaboration in the development of learning content and increasing stakeholder interest in aligning their work with the implementation of the CETS.

Mapping stakeholder needs and expectations: This objective focuses on identifying the needs and expectations of stakeholders across the three competence pillars. The pillars include:

- Computational Thinking skills (C1): Aimed at enhancing logical reasoning, problem-solving, and digital literacy.
- Entrepreneurship and Innovation skills (C2): Encouraging entrepreneurial mindsets, innovative practices, and adaptability.
- Green Skills (C3): Promoting environmental and social responsibility, along with sustainable development.

Curriculum requirements and career pathways: This objective addresses curriculum requirements to improve employability, creativity, and career opportunities. It also emphasizes integrating industry perspectives to foster innovation and problem-solving that align with various economic sectors.

Validation and expansion of competences: The objective is to validate previously identified fundamental learning competences and expand the competences list within the three resilience-related pillars (C1, C2, and C3).

Tools and learning methods: This involves defining and confirming new tools and methods for teaching computational thinking, entrepreneurship, and environmental sustainability. It also aims to establish didactic approaches and teaching requirements, including simulations and methodologies that emphasize the development of transversal skills.

Knowledge sharing and stakeholder feedback: The objective here is to facilitate knowledge sharing among HEIs, VET institutions, the public sector, and the business sector. Additionally, it aims to gather participant feedback and encourage their involvement in pilot-testing phases.

Community of practice (CoP) development: The final objective is to lay the groundwork for the ComeThinkAgain Community of Practice, encouraging broader discussions and ensuring the sustainability of project outcomes.

4.2. Methodology used at the workshops

The methodology employed for conducting the co-creation workshops integrates a variety of collaborative and innovative techniques. These approaches aimed to actively engage diverse stakeholders in discussions and ideation processes, ensuring the generation of meaningful and actionable outcomes. The choice of methodologies has been tailored to suit the conditions of each workshop and the composition of participants, allowing for flexibility and inclusivity in the facilitation process.

The project outlines four primary methodologies as part of the workshop framework selected for their effectiveness in fostering engagement and promoting creativity. The four methodologies outlined in the guide are the following:

1. **World Café** facilitates dynamic discussions on key topics through small group rotations, encouraging diverse perspectives.
2. **SOAR Analysis** focuses on identifying strengths, opportunities, aspirations, and results, providing a structured approach to exploring the project's key pillars.
3. **Design Thinking** employs a human-centred process to empathise, define, ideate, prototype, and test innovative solutions tailored to stakeholders' needs.
4. **Plus/Delta Feedback** gathers constructive feedback on workshop experiences to enhance future iterations.

Across the workshops conducted, a mix of the proposed methodologies listed above was frequently utilized to maximize engagement and outcomes. Given the small number of participants, they were often divided into smaller groups to discuss the three core pillars: Computational Thinking, Entrepreneurial Thinking, and Sustainable Futures. Discussions commonly began with the World Café format to capture a wide range of ideas. Participants then moved into SOAR Analysis sessions, which highlighted key strengths and weaknesses, providing a deeper exploration of the topics. The workshops concluded with Plus/Delta Feedback, where participants shared insights on what worked well and areas for improvement. This iterative feedback loop ensured the refinement of workshop formats, contributing to their ongoing success.

4.3. Workshops Calendar and Audience Profile

The nine workshops engaged a total of 102 participants across various stakeholder groups. These groups, as outlined in Table 3, include High Education Institutions (HEIs)/ Vocational Education and Trainings (VETs), the public sector, the private sector, and multipliers.

Table 2 provides a comprehensive overview of the nine workshops schedule, including details of each on the format (online or onsite), number of participants, their language preferences, and their respective stakeholder group.

Table 2: Description of target audiences and stakeholder groups

HEIs/VETs	Public sector	Private sector	Multipliers
HEIs	Public organisations	Influential and representative organisations	Business development organisations
VETs	Public authorities	Local businesses, start-ups, SMEs	Accelerators, Incubators
Private long-life learning organisations	Municipalities	Key industry players, consultancy firms	Non-profit organisations

Table 3: Co-Creation Workshops Calendar and participants information

Country	WS Lead	Online / Onsite	Language	Nº of participants	Workshops date	Stakeholder Group			
						HEIs/VETS	Public Sector	Private Sector	Multipliers
Austria	PHST/OCG	Online	DE	21	7/11/24	11	4	3	3
Finland	UOULU	Onsite	FI	13	12/12/24	8	3	0	2
Estonia	UTARTU	Onsite	EE	14	25/9/24	12	1	1	0
Denmark	MERCANTEC	Onsite	DK	2	27/10/24	0	2	0	0
Germany	GI	Onsite/Online	DE	13	25/11/24 & 13/12/2024	5	2	4	2

Spain	INMARK	Onsite	ES	11	22/11/24	2	2	5	2
Ireland	KONNEKTABLE	Online	EN	4	27/11/24	1	0	1	2
Belgium	SQUARED OT	Onsite	EN	10	27/9/24	4	1	2	3
Switzerland	PHZH	Onsite	DE	14	29/10/24	9	1	3	1
			TOTAL	**102**		**52**	**16**	**19**	**15**

4.4. Main takeaways

The nine co-creative workshops resulted in several key takeaways, including evaluation strategies, learning methods, challenges encountered, recommendations, approaches to cross-sector collaboration, and general observations for future directions. These takeaways were as follows:

Selected competences

Table 4, Table 5 and Table 6 outline the selected key competences per pillar gathered from the nine co-creation workshops required in the labour market and for future professionals.

Table 4: Key competences for CT emerged from the co-creation workshop

C1: Computational Thinking Skills
AI literacy • Understanding AI basics and how to work with it effectively • Awareness of biases, data handling, and ethical implications
Date literacy • Understanding data visualization • Knowledge of data organization, standardization, and protection frameworks • Basic statistical knowledge
Critical Thinking • Evaluating information critically, including models like LLMs (Large Language Models) and their outputs. • Applying logical and analytical thinking • Identifying and addressing the core problem (problem setting) • Breaking down complex issues into manageable parts (problem decomposition) • Recognizing patterns and potential solutions

- Evaluating solutions critically in relation to the problem
- Goal setting and impact analysis
- Combining insights with contextual background influences

Systems Thinking

- Understanding how different components of a system interact
- Network thinking and making connections
- Holistic and multidisciplinary approaches

Algorithmic Thinking

- Designing and applying algorithms systematically
- Basic programming skills (e.g., Python, R, Java)
- Evaluating and interacting with algorithms

Collaborative Tools

- Hands-on experience with tools like GitHub and Kaggle

Digital Competence

- Proficiency with digital tools and infrastructure integration
- Understanding blockchain and decentralized systems

Exploration and Discovery

- Approaching problems creatively and innovatively
- Trying out different solutions

Process knowledge

- Defining problems and objectives systematically.
- Debugging and testing processes

Accessible and inclusive design

- Designing UX with inclusivity in mind

Agile methodologies

- Project management and dynamic service/product design

Cross-cultural collaboration

- Collaborating effectively across diverse cultural and professional backgrounds

Communication Skills

- Assertive and effective communication
- Listening, presentation, and collaboration skills
- Social interaction skills

Ethical Awareness in technology • Understanding intellectual property rights and ethical considerations • Moral reasoning and ethical thinking
Attitude / mindset • Active, reflective, and critical approach to digital technology • Courage and human-centric thinking
Abstract understanding • Understanding information flows and recognizing patterns

Table 5: Key competences for EE emerged from the co-creation workshop

C2: Entrepreneurship and Innovation Skills
Creativity and Innovation • Creativity • Out-of-the-box thinking • Ideation and innovation competence • Design thinking • Service design • Prototyping and product development • Valuing ideas • Vision • Spotting needs and opportunities
Strategic and entrepreneurial thinking • Strategic thinking for opportunity identification and growth • Entrepreneurial thinking (understanding economic relationships, calculations) • Business model generation • Solution-driven approaches • Ethical and sustainable thinking • Implementing sustainability strategies and measures in business • Transforming challenges into assets • Marketing • Acquiring funding for new business • Integrating values and ethics into innovation processes (sustainable development) • Understanding immaterial value (not only monetary)

• Business idea identification and critical reflection (competitors, markets, value)
Teamwork and leadership • Leadership and teamwork skills for inspiring and guiding teams • Collaboration skills • Building high-performing teams • Understanding team roles • Networking • Mobilizing others • Empathy • Listening skills • Presentation skills
Adaptability and Resilience • Problem-solving and critical thinking • Critical Thinking • Human-centered design • Problem identification and innovative problem-solving approaches • Prioritization and task management • Resource planning • Ability to combine things together with background influences
Communication and stakeholder engagement • Good communication skills • Customer discovery • Stakeholder analysis • Value proposition and proposal validation • Translational skills (e.g., making complex concepts understandable)
Entrepreneurial execution and practical skills • Hands-on skills • Practical connections between theory and practice • Actionable thinking (courage, belief, responsibility) • Guerrilla skills (effectuation and bricolage) • Spotting opportunities and engaging with others
Technical and financial literacy • Basic knowledge (general understanding across fields) • Financial thinking (budgeting, projections, cash flow management)

• Assessing and utilizing technological trends • Technology regulation
Personal growth and lifelong learning • Inner Development Goals (IDG) • Long-life learning • Learning through experience • Creating value for others ("Product Market Fit") • Demand for quality and efficiency as part of entrepreneurial mindset

Table 6: Key competences for GS emerged from the co-creation workshop

C3: Green skills, environmental and social responsibility and sustainable development
Knowledge and awareness • Eco-literacy: Understanding ecological systems, cycles, and the impact of human activities on the environment • Green/basic knowledge (know-how) and knowledge of green legislation (e.g., European Green Deal) • Awareness of resource consumption and Interpretation of relevant sustainability data • Climate change mitigation strategies and long-term sustainability thinking and planning • Circular economy principles and Responsible value chain • Sustainable development and systems thinking: Considering all stakeholders, different views to sustainability (ecological, social, economic, etc.), sustainability as subjective and contextual, ecocentric vs. technocentric thinking • Ethics and morals: Ethical reasoning, ethical thinking, moral reasoning, and sharing responsibility over the planet and others • Sustainability impact evaluation from the viewpoint of ecological, social, and economic dimensions • Understanding immaterial value beyond monetary (sustainability, ethics)
Practical and technical skills • Resource optimization (practical knowledge of resource efficiency in one’s field of work) • Waste management (e.g., 9R framework) • Eco-design expertise and promoting sustainability in agriculture, construction, and transportation • Renewable energy solutions and calculating carbon footprint • Second-hand sales systems and product lifecycle management

- Measuring and mitigating carbon and water impacts of technology
- Implementation of sustainability strategies and measures in business
- Artificial intelligence and data analytics for sustainability purposes

Strategic and analytical thinking

- Critical thinking from a sustainability viewpoint
- Futures literacy: Anticipating and preparing for future challenges
- Transformative agency: Ability to make change, analysing current states, and pushing for transformation
- Systems thinking

Leadership and advocacy

- Ethical leadership: Skills in ethical decision-making, transparency, and fairness
- Stakeholder engagement: Ability to engage and communicate with diverse groups (e.g., communities, NGOs, governments)
- Political advocacy for sustainable policies and business sustainability practices
- Entrepreneurial skills for sustainable innovation

Interpersonal and collaborative competences

- Collaborative competence (Interpersonal and team collaboration)
- Communication and collaboration: Listening skills, presentation skills, fostering interdisciplinary solutions, working with more traditional partners
- Empathy: Awareness of societal and environmental challenges, promoting sustainability and adaptability through soft skills

Personal and self-regulation competence

- Intrapersonal competences: Self-supervision for consumer behaviour, rational saving, and resource-efficient decisions
- Adaptability and perception of pain points in sustainability contexts
- Valuing sustainability as a guiding principle in personal and collective actions

Research and development

- Research, Development, and Innovation (R+D+i) for sustainability
- Environmental, Social, and Governance (ESG) criteria

Subject knowledge and methods

- Juridical knowledge: Understanding the legal aspects related to sustainability
- Scenario working, facilitation methods, and collaborative development to integrate ethics and values into the innovation process
- Democracy skills: Understanding how individuals and groups can influence sustainability policies and practices

Additionally, some examples of transversal skills and competences adapted to the three pillars:

Lifelong learning and personal development

- Openness to lifelong learning
- Independent learning
- Self-responsibility
- Self-regulation as a basic skill in an ever-changing world
- Self-motivation to learn
- Personal resilience (e.g., dealing with conflicts)
- Self-knowledge: Awareness of one's own abilities and perspective.
- Flexibility (e.g., adapting to new technologies and experimenting)
- Soft skills: flexibility, resilience, adaptability
- Digital literacy and adaptability in today's job market
- Creative thinking: Creativity and out-of-the-box thinking

Problem-solving and decision-making

- Understanding and analyzing problems
- Critical thinking (part of 4C Future Skills)
- Making decisions under uncertainty
- Dealing with areas of tension and conflicting goals
- Ability to think in cases and contexts
- Generalization of solutions
- Interpretation and evaluation of data

Interpersonal and social skills

- Teamwork skills
- Social skills (e.g., communication, collaboration)
- 4C Future Skills: creativity, cooperation, communication, and critical thinking
- Digital collaboration
- Finding lines of argument to convince stakeholders (e.g., advocating for resource-efficient processes)

Multidisciplinary and strategic thinking

- Interdisciplinary thinking and acting
- Research and evaluation of sources correctly

4.5. Strategies for evaluation and assessing

The assessment strategies combine traditional and innovative approaches, emphasizing real-world applications, process-oriented evaluations, and the integration of soft and technical skills. By aligning with industry needs and leveraging interactive tools, these methods ensure a holistic evaluation of competences across computational thinking, entrepreneurship, and green skills.

Assessment approaches

Before-after comparison: Self-assessment or external evaluation to measure growth in competences over time.

Project-based assessment

- Participants work on individualized solutions to pre-designed problems and objectives.
- Evaluated against predefined characteristics such as sustainability or affordability.
- Includes real-world applications through case studies and practical challenges.

Problem-based assessment: Practical problem-solving tasks as part of projects to showcase application of learned competences.

Quizzes and interactive tasks: Module-based quizzes using single-choice, multiple-choice, and open-ended questions to reinforce learning.

Interactive simulations and games: Tools like Charles Games, Green New Deal Simulator, or Climate Interactive assess decision-making and knowledge application in simulated environments.

Case studies and practical applications: Teams address real-world challenges, evaluated on solution quality and applicability.

Situational personal interviews: Assess soft skills, decision-making under uncertainty, and adaptability.

Process-oriented evaluations

Focus on teamwork, collaboration, and adaptability through: Hackathons, role-playing simulations, and interactive games testing group dynamics and problem-solving.

Competence development through experiential learning, such as business model canvases or concept creation.

Learning methods and learning experiences

Simulation games and interactive tools: Immersive platforms like Kaggle, Scratch, and Green New Deal Simulator.

Project-based learning:

- Practical projects involving concept or campaign development with companies.
- Design Thinking exercises tackling real-world cases.

Living labs and nature-based learning: Real-world environments to test and evaluate competences in action.

Blended learning: Combining MOOCs, online tools, and face-to-face workshops to integrate technical and soft skills.

Case Studies and practical scenarios: Workshops addressing concrete, industry-relevant case studies.

Competence-oriented teaching: Approaches like PERKA, mentoring, and networking events to foster critical thinking, adaptability, and ethical considerations.

Certification and recognition: Micro-Credentials and Open Badges to digitally certify skill mastery and performance-based competencies.

School and university contexts

School initiatives:

- Prepare CT competences in analogue formats before translating to digital spaces.
- Integration of charity projects and entrepreneurial activities into the curriculum.

Higher education:

- Compulsory modules combining technical competences with critical judgment and ethical considerations.
- Practical projects involving partnerships with companies and mentoring for career and training guidance.

Tools and platforms

- Utilize existing platforms like Google for Education and AI Campus to integrate curricula.
- Employ hands-on, competence-focused tools such as business model canvases, escape rooms, and mentoring programs.

Challenges in assessment

- Difficulties in effectively assessing soft skills.
- Bureaucratic and funding barriers to implementing competence-based assessments.
- Resistance to change within educational systems.

Proposed solutions

- Develop standardized tools to measure competences.
- Establish feedback loops between educators and industry professionals to refine assessment methods.
- Shift toward practical evaluations such as:
    - Team-based assessments.
    - Case studies.
    - Intrapreneurship projects.

4.6. Implementing competences in the curriculum/ training programs and strategies

General strategies for curriculum integration

Flexibility and adaptability

- Adapt curricula to evolving job market demands and diverse learner needs.
- Integrate meaningful tasks aligned with real-world contexts to enhance engagement and relevance.
- Embed modular and adaptable learning pathways (e.g., micro-credentials, blended learning).

Project-based learning

- Emphasize hands-on, experiential, and project-based approaches.
- Include charity projects, challenges, and case studies to encourage practical applications.

Collaborations

- Partner with industries, businesses, start-ups, and communities to provide relevant learning opportunities.
- Use mentoring programs (e.g., IHK Berlin) and company-led workshops to align curricula with industry needs.

Interactive and innovative learning methods

- Employ game-based learning, simulation games (e.g., Climate Interactive, En-ROADS), and flipped classrooms.
- Use MOOCs, Barcamps, and other innovative methods for diverse and engaging learning experiences.

Computational Thinking

Early and progressive learning

- Start with analogue CT competences in school contexts, transitioning to digital skills as students progress.
- Address the heterogeneity in didactic approaches for digital education.

Higher education approaches

- Introduce compulsory modules across degree programs combining liberal arts, critical judgment, technologies, and ethics.
- Foster self-motivation through project-oriented learning on concrete issues.

Digital tools and platforms

- Use tools like Scratch, Blockly, Kaggle, and AI Campus to enhance CT learning.
- Equip teachers with coding skills and adequate resources to deliver CT education effectively.

Teaching and learning innovations

- Encourage problem-solving, independent responsibility, and innovative thinking through coding and computational problem-solving.
- Incorporate activities like Biber/Bebras and CS unplugged.

Ethical dimensions: Address topics such as data biases, AI literacy, and ethical considerations in CT.

Entrepreneurship and innovation

Role models and mentorship: Invite entrepreneurs to serve as role models and mentors, showcasing real-world applications.

Industry partnerships

- Collaborate with businesses to design projects, case studies, and workshops reflecting entrepreneurial realities.
- Promote initiatives like the WU Changemaker Program.

Practical application

- Include exercises in designing business models, pitching, and starting companies.

- Use challenge-based learning and innovation-based strategies to simulate entrepreneurial environments.

Green Skills

Alignment with SDGs

- Use the Sustainable Development Goals (SDGs) as a framework for curriculum design.
- Encourage projects aligned with specific SDGs, such as sustainability in agriculture or renewable energy.

Practice-based learning

- Focus on project-, practice-, and experience-based methods to teach green skills.
- Facilitate peer-to-peer learning and community collaborations for practical sustainability education.

University-level integration

- Use lecture series, expert talks, and elective subjects to promote green skills.
- Engage students in practical projects with companies and sustainability campaigns.

Teaching innovations

- Integrate nature-based learning and tools like Sustainicum, Green New Deal Simulator, and sustainability dashboards.

Institutional strategies

- Embed sustainability and ethics across technical and vocational programs.
- Transition educational programs to circular economy models focusing on eco-design and waste management.

Tools, platforms, and resources

Existing platforms

- Use platforms like Google for Education, KI Campus, Sustainicum, and Climate Interactive to streamline competence delivery.

Innovative materials and guides: Leverage resources such as the Guidebook SustainabALE, Klimadashboard, and entrepreneurship guides by Johannes Linder.

Community integration: Collaborate with communities and create protected spaces for hands-on learning and innovation.

Barriers and considerations

Teacher training and support

- Address gaps in teacher capabilities, especially in coding and digital education.
- Provide structured teacher training and standardize concepts for delivering competences.

Assessment and responsibility

- Shift examination culture toward fostering student responsibility and independence.
- Ensure institutions select tools and platforms that meet diverse educational needs.

Needs-oriented approaches: Design curriculum content that aligns with learners' needs and emphasizes practical, impactful outcomes.

Specific recommendations by competence area

Computational Thinking

- Combine theoretical knowledge with practical skills through layered curricula.
- Use tools like Scratch, Blockly, Kaggle, and Git to enhance CT learning.

Entrepreneurship and Innovation

- Promote challenge-based learning, hackathons, and open innovation sessions.
- Use business model canvases and personal projects to foster entrepreneurial thinking.

Green Skills

- Align projects with SDGs to emphasize sustainability.
- Incorporate community sustainability projects and energy efficiency practices.
- Offer specialized training for public officials on green legislation and impact measurement.

4.7. Practice, expectations and requirements

Practical applications of competences

Real-world problem solving:

- Problem-based learning: Students and employees address real-world challenges provided by companies.
- Large, long-running projects where individuals identify problems, form groups, and develop solutions collaboratively.
- Use of design sprints, legal/tech sprints, and digital simulations (e.g., Green New Deal Simulator) to tackle domain-specific issues.

Digital and technological integration:

- AI tools for efficient work (e.g., company-specific chatbots for onboarding and project familiarization).
- Smart devices and digital technologies to track and optimize energy consumption.
- Sharing reusable solutions for office management, such as partial automation of tasks (e.g., file management, booking systems).

Sustainability in practice:

- Bottom-up sustainability initiatives, such as staff-led working groups identifying and addressing environmental challenges.
- Positive incentives for sustainable behaviours (e.g., subsidized public transport tickets, food waste reduction programs, car-sharing apps).
- Schools partnering with local businesses to apply project outcomes in real-world contexts.

Collaborative learning and networking:

- Mentoring, peer groups, and structured networks to transfer competences and build resilience.
- Group activities to strengthen teamwork and self-responsibility (e.g., weekly plans, tasks in teams or individually).
- Competitions and events where dedicated time is provided to work on projects.

Expectations and requirements from companies

Collaboration and engagement:

- Provide real-world cases and problems for learners to address.
- Offer internships, apprenticeships, and industry partnerships to enhance practical learning.

Skill development focus:

- Prioritize transferable skills such as teamwork, independent learning, and adaptability.
- Develop learners' ability to conceptualize and implement projects, including entrepreneurial initiatives.

Flexible learning environments:

- Modular learning pathways, including flipped classrooms and e-learning options, to accommodate varying schedules.
- Tailored content to meet the specific needs of businesses and different learner groups.

Interactive and hands-on approaches:

- Use of case studies, design thinking, and hands-on learning to ensure practical skill application.
- Encouraging employee-led initiatives and innovation through bottom-up processes.

<u>Successful practices and models</u>

Cross-sectoral initiatives:

- Marie Curie Internships: Real-world research opportunities for PhD students to collaborate with industry.
- Quadruple Helix Model: Partnerships between academia, industry, government, and civil society to foster innovation.
- Microsoft AI-Focused Programs: Practical, cutting-edge AI skills training.
- Centers for Research and Development (CRDs): Collaborative projects bridging academic and industry expertise.

Educational institutions:

- Schools leveraging networking and partnerships with local businesses/start-ups.
- University initiatives such as lecture series, expert talks, and interdisciplinary workshops.

Incentive-based learning:

- Rewards for ideas and innovations from employees or students.
- Time allocated during work or school for participation in sustainability projects.

<u>Recommendations for long-term success</u>

Promote flexibility: Embed modular, adaptable learning pathways (e.g., micro-credentials, blended learning) to align with evolving skill demands.

Encourage commitment: Develop incentives and emphasize mutual benefits to attract active participation from enterprises.

Foster interdisciplinary approaches: Design programs that merge academic rigor with practical application for a holistic learning experience.

Leverage proven models: Scale successful initiatives (e.g., internships, quadruple helix collaborations) to other sectors and regions.

Real-world applications:

- Promote project-based learning where students work on real-world problems provided by companies.
- Encourage the use of digital tools like AI-based chatbots and smart devices for energy optimization and task automation.
- Leverage bottom-up processes, such as staff-led initiatives, to promote sustainability in organizations.

Industry expectations: align academic training with industry needs by teaching:

- Big data analysis for marketing and decision-making.
- Cross-platform software skills to foster adaptability.
- Holistic service design and user-centric UX approaches.

Collaboration models:

- Use Living Labs and incubators to foster innovation through interdisciplinary partnerships.
- Encourage partnerships between academia, industry, and government (e.g., Quadruple Helix Model).

4.8. Challenges, Barriers, and Assessment of Competences and Skills

One of the primary challenges in the development and assessment of competences is bridging the gap between academic programs and the practical needs of the workforce. This disconnect often leaves graduates underprepared for real-world demands. A lack of resources for teaching critical skills such as CT and sustainability further limits the ability of education systems to prepare learners effectively. Additionally, inequitable access to upskilling and professional development opportunities exacerbates inequalities, preventing many individuals from reaching their potential. Bureaucratic hurdles, such as rigid administrative systems, also slow the adoption of competence-based assessment frameworks.

To overcome these barriers, ongoing support for educators and students is essential. Educators require tailored training, particularly in sustainability and multidisciplinary teaching, to ensure they can deliver relevant and impactful education. At the same time, inclusive frameworks must be developed to provide equitable access to learning opportunities for all, particularly underrepresented groups.

Strategically, fostering cross-sector collaboration through models like the Quadruple Helix can align educational objectives with real-world needs by integrating insights from academia, industry, government, and civil society. Mentoring networks and peer support groups are also valuable for helping learners develop both technical and interpersonal skills. Additionally, prioritizing multidisciplinary projects can encourage holistic problem-solving and prepare learners to address complex challenges.

4.9. Co-Creation Workshops photos

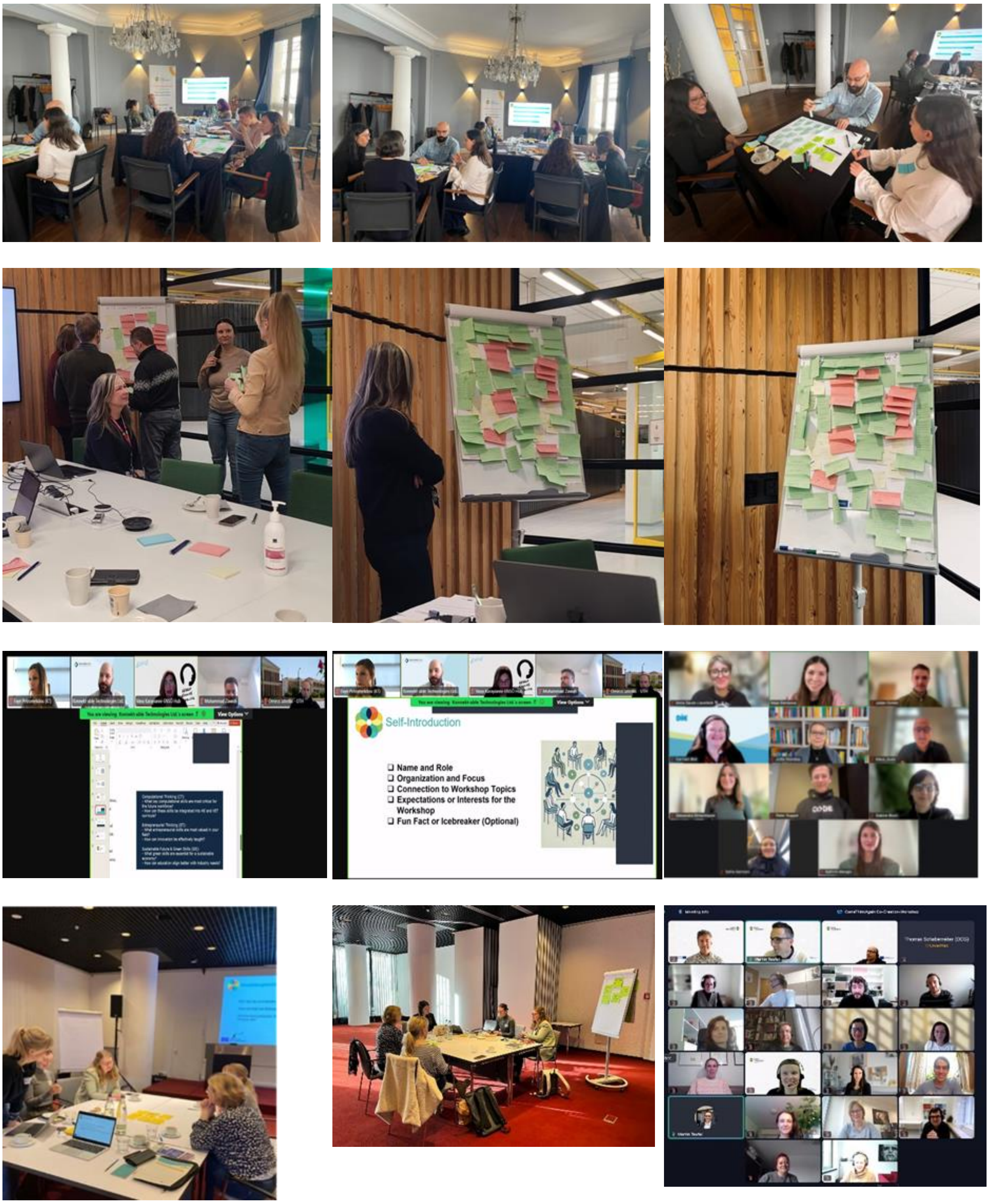
Self-Introduction
Name and Role
Organization and Focus
Connection to Workshop Topics
Expectations or Interests for the Workshop
Fun Fact or Icebreaker (Optional)

Figure 3: Workshop photos

5. Conclusion

5.1. List of learning methods

Upon closer examination, the three competence pillars and their relating learning methods reveal shared common practices. From our analysis, a constructionist approach emerged as an appropriate didactical concept to address CT, EE and GS in interdisciplinary education. Thus, by emphasising learning by doing and active engagement, the discussed learning methods bridge the gap between theory and practice. Common learning methods across all three pillars include project- and problem-based learning, game-based learning, storytelling, making, design thinking and reflective practices. These methods promote hands-on engagement, creativity and critical thinking to ensure the development of relevant skills in meaningful and applied context. Furthermore, the outcomes of the co-creation workshops align well with our findings providing further validations of our conclusion. In Table 7 the methods which will build the foundation for the learning modules of the CTA-CETS are listed. The learning methods are categorized into up to four groups, with some methods potentially fitting multiple categories: constructionist and experiential learning methods, game- and competition-based methods, social and collaborative methods and reflective and theory-driven methods.

Table 7: List of learning methods grouped into up to four categories

Learning method	Constructionist and Experiential Learning Methods	Game- and Competition-Based Methods	Social and Collaborative Learning Methods	Reflective and Theory-Driven Methods
Problem-Based Learning (PBL)	✔		✔	✔

Project based learning	✔	✔	✔	
Work-based learning	✔		✔	
Design-Based Learning/Thinking (DBL)	✔	✔	✔	
Maker-Education Approach	✔	✔	✔	
Hackathons	✔	✔	✔	
Robotics and AI in an educational context	✔	✔	✔	
Programming/Computing/Coding	✔	✔	✔	
Game-Based Learning (GBL)	✔	✔	✔	
Game development-based learning	✔	✔	✔	
Gamification	✔	✔	✔	
Play-Based Learning		✔		
Competition-based methods	✔	✔	✔	
Guest lectures and (hands-on) workshops			✔	
Cross-Disciplinary Projects	✔		✔	
Reflective and theory-based methods / case studies	✔			✔

Storytelling		✔	✔	✔
Mentoring	✔		✔	
Arts-based learning	✔	✔	✔	✔
CS Unplugged	✔	✔	✔	
Field Trips	✔		✔	

5.2. Update of competence list

During the co-creation workshops, the consolidated list of competences emerged from D2.1 was evaluated and validated, yielding valuable suggestions for further refinement. For the analysis a comparative assessment was conducted between the consolidated competence list and the competences identified during the co-creation workshops. Following competences and suggestions have been identified as relevant but are currently only partly (indicated by *) or not included in our original list:

- **Computational Thinking**: Collaborative tools, exploration and discovery, agile methodologies, cross-cultural collaboration, communication skills, ethical awareness and technology, attitude and mindset.
- **Entrepreneurship Education**: Technical and financial literacy, personal growth and life-long learning, strategic and entrepreneurial thinking (*), problem-solving and critical thinking (*), entrepreneurial execution and practical skills (*).
- **Green Skills**: Practical and technical skills, leadership and advocacy, research and development, knowledge and awareness (*).

The decision regarding the extent to which the original competence list will be revised and expanded or reduced by competences will be made at a later stage within the T2.4 of the ComeThinkAgain project as the list represents a living document.

5.3. Curricula Implementation

The integration of CT, EE and GS into educational curricula remains a challenging task across Europe. Our findings reveal a diverse landscape of implementation strategies, varying significantly between countries and competence areas. The most common approaches are:

- **Computational Thinking:** Integrated in other subjects (e.g. mathematics, programming, media & informatics) or cross-curricular implementation.
- **Entrepreneurship Education:** Holistic approach including theoretical and practical projects or included on a theoretical level only.
- **Green Skills:** Cross-curricular, project-based, stand-alone subject or integration in other subjects (e.g. natural sciences or geography).

5.4. Results from Co-Creation Workshops

The ComeThinkAgain project held nine co-creation workshops across Europe. Their objective was to identify skill gaps, define curriculum requirements, and develop the ComeThinkAgain CETS, focusing on three core competences: CT, EE, and GS.

Computational Thinking skills identified emphasized the integration of advanced digital tools and real-world applications. Key areas included AI literacy (e.g., using AI-powered chatbots for onboarding and workflow automation), blockchain (for secure transactions and digital identity verification), and data visualization (e.g., using Kaggle for data analysis and decision-making). Practical learning involved platforms like GitHub for collaborative coding and simulations such as CS Unplugged for problem-solving.

Entrepreneurship Education identified on the workshops focused on fostering entrepreneurial mindsets through hands-on exercises. Examples included business model generation (e.g., using the Lean Canvas method), startup incubation programs, and stakeholder engagement through Living Labs. Challenge-based learning activities such as hackathons, pitch competitions, and industry-sponsored case studies provided learners with direct exposure to real-world business problems. Ethical entrepreneurship was reinforced through sustainability-driven business strategies and initiatives like the WU Changemaker Program.

Green Skills identified underscored the importance of sustainability through practical applications. Participants explored eco-design (e.g., sustainable product lifecycle assessment), resource optimization (e.g., energy efficiency audits in smart buildings), and renewable energy solutions (e.g., solar panel implementation projects). Schools partnered with local businesses to apply sustainability principles in real-world contexts, such as urban gardening projects, food waste reduction programs, and circular economy workshops that promote waste minimization and material reuse.

The co-creation workshops emphasized the need for interactive, practice-oriented learning methods. Effective strategies included design thinking, project-based learning, and co-creation methods like Innovation Jams, participatory roadmaps, and sustainability hackathons. Industry collaborations and digital tools were seen as crucial for aligning education with workforce demands, ensuring that students gain hands-on experience through internships, case studies, and mentorship programs. Successful models like Marie Curie Internships and the Quadruple Helix Approach demonstrated the benefits of cross-sector partnerships.

Key challenges identified included bridging the gap between academic training and industry needs, limited resources for teaching critical skills, and inequitable access to upskilling opportunities. Solutions involve providing tailored teacher training in digital literacy and sustainability, developing inclusive learning frameworks, and fostering stronger collaboration between academia, industry, government, and civil society. Ultimately, the workshops highlighted the need for flexible, industry-aligned curricula that equip learners with the interdisciplinary and future-ready skills necessary for an evolving job market.

5.5. Community of Practice (CoP)

The ComeThinkAgain Community of Practice emerges as a direct outcome of the co-creation workshops, marking a significant milestone in our project's development. These workshops served as the foundation for establishing meaningful connections between VET institutions, higher education representatives, and business sectors. The collaborative dynamics and knowledge-sharing practices developed during these sessions naturally evolve into our formal CoP structure, which will continue fostering sustainable cooperation across sectors. The CoP builds upon the workshop participants' engagement and expands it into a broader network focused on computational thinking, entrepreneurship, and green skills development. This organic transition from workshop activities to a structured community ensures continuity in our efforts to bridge educational gaps and promote innovation in vocational and higher education across Europe. The CTA-CoP holds currently around 80 participants, including members of the external advisory board of the project.

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