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Cream

Report

PR1

State of the Art analysis on STEAM creative teaching approaches and initiatives

Summary

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1 Introduction: summary of the project, summary of PR1, results achieved

1.1 Introduction to CREAM

The CREAM project aims at stimulating the interest of school students in STEAM disciplines and will achieve this result by elaborating and testing a new model for teaching STEAM disciplines through the Creative Writing Laboratory (CWL) technique, by providing daily-life problems to be solved with a creative thinking approach and STEAM notions.

The general objective of the CREAM project is to contribute to:

- Expanding opportunities for the promotion of learning activities that focus on STEAM disciplines and help children learn through trial and error, by experimenting and problem solving;
- Acquiring scientific knowledge and actively participating in the innovation process of local communities;
- Developing an integrative and collaborative approach (CWLs) to link STEAM to daily-life problems and enhance collaboration between formal, non-formal and informal science education providers, enterprises and civil society to integrate the concept of open schooling.

The specific objectives (SO) of CREAM are:

- SO1: explore what we know about STEAM innovative teaching approaches and initiatives using creative writing methodologies within the school environment. This research activity will produce PR1 "State of the Art analysis on STEAM creative teaching approaches and initiatives".
- SO2: Codesign of CWLs concept. This will ensure the development of CREAM CWLs model (PR2).
- SO3: Test and validate the CWLs model with the implementation of pilots in four countries in PR3: Italy, Slovenia, Greece and Poland . Pilots will involve all

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actors necessary for the implementation of the model: schools, companies, social enterprises and NGOs, universities and other education providers.

- SO4: Storytelling (PR4). At the end of each pilot, participants will be able to share stories on lessons learnt, short video documentaries of the pilot experiences, successful stories of scientists and innovative company founders within their communities and society. Experience in CWLs pilots will have a direct impact on participants in making them "scientifically aware" or, for the younger ones, make them consider a scientific career. Students will be invited to explore different channels and means of artistic expression to propose their STEAM based solutions to problems of public concern.
- SO5: Set a sound exploitation and sustainability strategy tailored to end beneficiaries of the project, i.e. schools. The aim is to provide a guide to replicate the CREAM experience and adopt, adapt and tailor the CWLs model.
- SO6: Policy Paper. The aim is to address policy makers at EU and national level in order to foster specific programmes to help the implementation of the CWLs model, as well as to use results and knowledge created within the project in defining education policies.

SO5 and SO6 will be achieved thanks to PR5 "Development of guidelines for CREAM CWLs model for replication".

1.2 State of the Art analysis on STEAM creative teaching approaches and initiatives - PR1

Within PR1, partners explored the state of the art about the adoption of innovative approaches to teach STEAM disciplines and initiatives using creative methodologies like creative writing within the school environment. This research activity aimed to produce the report of PR1 "State of the Art analysis on STEAM creative teaching approaches and initiatives" in partner countries, in the EU and world-wide.

This resulted in a summary of literature with a reasoned collection of case studies and best practices on STEAM innovative teaching methods and examples of initiatives

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using creative methodologies within the school environment. The result was reached in two stages:

1. Parallel field research (collection of stories and inspiring practices) and desk research (scenario analysis and collection of insights on practical experiences and feedback of involved actors) have been conducted through surveys and interviews in order to gather data directly from the relevant stakeholders. This document summarises and analyses the collection of stories that partners have provided. As part of the first stage, a context analysis was also carried out in order to understand who are the different actors that play a role in STEAM teaching and to obtain a full picture of scenarios: personas, users' journeys, ecosystem maps.
2. After matching between experimental data from field research and literature data from desk research, the final report was developed and will contribute to the definition of the CWL model of CREAM project (PR2).

PR1 thus consists of a multidisciplinary evidence-based state-of-the-art presented in the form of a report that includes the guidelines for the project's framework, but also as a transferable product to any learning environment. PR1 leader (WUT) outlined an appropriate research framework and oversaw the management of required research.

The research is attempting to address the following key areas:

- The main innovative STEAM teaching methodologies;
- Existing resources that could be used or re-designed for use within CWLs to avoid duplication;
- The most appropriate media formats for learning content for target groups (schools' staff and students);
- Type of assessment framework that is most appropriate to facilitate the measurement of attainment;
- Types of pedagogic support needed to facilitate the involvement of participants into the CWLs;
- The most appropriate teaching and learning methodologies to adopt.

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1.3 The Core of the Research: Creative Writing Laboratories - Storytelling

The term "Creative Writing Laboratory" (which is not commonly used nowadays) in the CREAM context stands for "Storytelling" for science education.

The "story" is typically composed of the following (not necessarily all) elements:

- A scientific or technical topic (e.g. a rechargeable battery);
- A use case (e.g. the battery could power a car, an electric bicycle, or be applied for energy storage);
- Personas (e.g. a teacher, a science promotor, a salesman who want to sell an electric car);
- Scenarios, meaning the situation when a given topic and use case/s are presented in a specific context by a persona (e.g. a teacher introduces a project to the students);
- And finally, a story that may use specifically adopted elements of one or more teaching methodologies.

The stories provided by the CREAM partners are analysed along these lines on the next pages.

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2 Outcome of desk research

2.1 Goal and methodology of Desk Research

This chapter describes what we know about STEAM's innovative teaching approaches and initiatives in general, and in particular about STEAM education practices that use storytelling and creative writing methodology within the school environment and beyond. To a large extent, the chapter was compiled based on the consortium collective effort comprising:

- Desk Research, that includes identification and analysis of best practices (scenarios and collection of insights on practical experiences and feedback from actors involved) described in several sources (project/initiative webpages, reports, publications, books, interviews, etc.). The Desk Knowledge starts from the investigation of general STEAM educational concepts and then focuses on more specific project-relevant techniques.
- Survey within the consortium on the partner's experience and opinions on innovative STEAM initiatives in their countries and beyond. The survey asked about the existing most common STEAM educational practices and learning methodologies, the main barriers blocking the wider introduction of interactive, student-centred teaching methods, and finally about the most feasible scenarios of STEAM teaching evolution at schools.

As Desk Research was not limited to any specific learning methodology, it resulted in the creation of a very versatile collection of documents and information pertaining mostly to national and international STEAM education initiatives. Thanks to Desk and Field Research, the consortium has preliminarily identified a number of candidate STEAM scenarios that can be elaborated and adjusted to the requirement of the next project phases.

The survey also allowed us to identify the most relevant learning methodologies for STEAM education, as well as to prioritise the topics to be developed in the projects.

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2.2 Evolution of education in historical context

To better understand how the educational system is currently organised and the reasonable basis behind solutions implemented, in this paragraph we will describe how the system worked and evolved in the past and which objectives it served.

Needless to say that education as an organised (or semi-organised) process has existed in societies for a very long time, at least since ancient civilizations emerged. In the past, education enclosed only a small part of society, usually civil servants, priests and some ruling class members. In ancient China, education was already centrally organised and produced a large group of civil servants to administrate the country on behalf of the Emperor. In Rome, education mostly included children of the Roman citizens, at least the richer ones, and usually took place at the child's home being visited by a teacher [Roszkowski W., 2016]. Regardless of a particular culture, common (but still limited to the noble social groups) education in antiquity and the early Middle Ages focused mostly on practical skills development: writing, linguistics, law, and public affairs. Science and technology, usually associated with philosophy, rather did not earn societal respect and were limited to selected schools/academies led by a distinguished scientist/philosopher. Despite apparent practical applications (like siege machines), science and technical knowledge have long been mostly the domain of amateurs and volunteers and rather were not regarded as a career advancement investment for the noble class members. Nevertheless, the achievements of the ancient world regarding not only scientific progress in many areas, but also science education practices are still impressive, and surprisingly some of the concepts are even applicable in our education systems.

The second strong factor which drove the education during centuries was religion. Jewish religious schools (in Antiquity), and Muslim and Christian schools (in the Middle Ages), significantly elevated the level of education in the world of the time. Although in principle the school's mission was studying religious texts, the schools as a by-product provided often basic education to wider groups including children from poorer families.

The characteristic feature of the ancient and Middle Ages higher education systems was an innately holistic approach (which is currently re-discovered): students studied bases of all scientific disciplines, which was feasible given the rather modest scope of the knowledge available at the time.

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European universities started to be funded in the late Middle Ages, significantly contributing to the development of modern science and scientific methodology as well as to education methods.

The final step toward the formation of the modern educational systems was the concept of universal compulsory primary education introduced as one of the first in Prussia in the 19th century [Origin of Prussian Education System] and then gradually implemented in other developed countries. Despite many advantages, such systems were often criticised as being highly oppressive and serving only the particular interests of the rulers. The end of the 19th and the beginning of the 20th century was the time when alternative education formulas were proposed and introduced in selected schools, notably in Italy. They were based on a more flexible learning curriculum, holistic approach, and closer cooperation between students and teachers. One of such a school, located in the village of Aarau, was attended by the keen opponent of restrictive education - Albert Einstein [Isaacson W., 2007].

One of many, but perhaps the most known alternative approach to education, is credited to Maria Montessori [Montessori M., 1917] who had not only published a number of papers, but also managed to organise and promote internationally her school network, which still operates in many counties at primary level.

The STEM (Science, Technology, Engineering and Mathematics) and, corresponding to this acronym, the renaissance of the concept of holistic education was introduced in 1990 [Georgette Y.; "STEAM Education"] and sprung from blurring the borders between traditional disciplines, as the world entered the post-industrial era [Toffler A., 1980]. The new epoch, in which all of us are currently living now, is characterised by a huge domination of globalisation and the service-based economy, which in turn deeply transformed the labour market. More advanced and personalised products offered today necessitate interdisciplinary education and creativity. Ambient ICT infrastructure demands some bases of technical skills virtually on every working position nowadays.

Further evolution of the STEM concept associating science and technology with Art was manifested in the form of the STEAM acronym adopted around 2007 [Elaine Perignat, Jen Katz-Buonincontro, 2019]. Unlike STEM, which in principle and in its objectives is widely similarly understood, there are a lot of different interpretations of what STEAM is and how this concept should impact teaching. Regarding the divergent

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opinions, there is however a common consensus that Art is closely associated with creativity, and creativity is highly needed to address the current societal and economic challenges [Huser, Joyce et al, 2020].

2.3 Recent technological, social and business trends

Technology and society have always slowly evolved over centuries, but the speed of these changes has dramatically increased during the last decades. There is a common consensus that the current education does not well prepare young people to face the challenges of our time. However, the problem with these commonly agreed opinions is that many people, especially young ones, beside mere acceptance, do not necessarily understand the nature of these latest changes and the mechanisms which led to them. So some processes need to be explained more in detail, to understand what has happened and how to deal with the current situation.

In the 1980s and 1990s, the IT revolution impacted virtually all business areas in the developed world (from big corporations to small offices). Some computer literacy and generally logical thinking to deal with specialised software platforms at work made traditional, often boring office jobs, more complex, challenging and creative.

Further IT progress, in particular the emergence of wide area networks and common data communication infrastructure in the form of the Internet, allowed the establishment of large, often international, corporations and other types of organisations.

To manage such gigantic entities, special procedures, processes and organisational structures were implemented, but again all these management tools intensively used IT communication infrastructure and dedicated computer applications.

New technologies for information storing, processing, exchanging and publication exert a tremendous impact both on our work and private life. The majority of information we had to memorise before is now easily publically accessible. The information, often intentionally false or biassed, first filtered by searching machines, and tuned to the person's marketing profile and political opinions, is then commonly used as a base for business and private decisions. Searching, identification, processing and creating information and knowledge has become a key people activity

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at work and at home. This task required not only digital literacy, but also the ability to assess the information reliability.

With the corporation (main working place provider nowaday) are often associated two important notions:

- The “process”, implemented on a massive scale in the auto industry by Henry Ford in the beginning of 20th century, and then popularised in the corporate environment a. o. by Thomas Davenport [Thomas H. Davenport,1993]
- The “project”, which already existed in Antiquity (as a tool to build pyramids, cathedral, ships and cities), became dominant in corporations in the early 2000s.

While the process is often associated with tedious, repetitive, standardised tasks, the project sets out a brand new work landscape: an employee working in a project-based organisation, is usually assigned to a few (3-4) projects at the same time. An average project lasts typically a few months, after which a person begins a new project. A new project often requires new knowledge, or solving new problems. The project team is not a fixed one, so a person works with many people, quite often in an international team and contacts colleagues remotely. In addition to domain specific knowledge (which typically also includes technology), communication skills and even cultural awareness are very important.

Agile project management methodologies (SCRUM) further transformed the working environment in the last years. To briefly characterise, SCRUM is also a project-based methodology, but the project team must include people with different roles and positions (a manager, a problem owner, a technology expert, marketing specialist, and some other depending on the particular project area).

An organisational invention commonly adopted nowadays is so-called a matrix management structure. In a nutshell: instead of one boss, an employee has two or sometimes more direct bosses. These and other changes impose on an employee more responsibility, require new soft skills, but give broader decision-making freedom, even if not in management positions. The corporate work scenario in the 21st century was accurately foreseen by the father of modern management - Peter F. Drucker [1999]. The author, beheld the fact that the technology and new work organisation also profoundly impact the boss-subordinate relation. Due to a huge

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amount of domain specific know-how, the boss often is no longer able to solve the problem her/his subordinates deal with and to provide them meaningful help, which in turn increases the subordinate's value and his position in the company. On the contrary the role of the boss often diminishes and migrates to that of a coach, a leader, relation facilitator, conflict resolution and teamwork reporter.

The more efficient and flexible management structure allows the creation of more complex products (not only technical devices, but also financial, insurance and medical products, to just name a few categories), and all the same, requires higher qualification from the project team.

According to some studies, people in the 21st century will change their professions a few times during their lifetime and their employers a dozen times. As a result, lifelong learning becomes a necessity stemming from an increasing number of jobs and employers.

Art is incorporated in the majority of nowaday professions, but rarely in a traditional form (e.g. painting, sculpture, music, etc). More often creativity is manifested in non standard business ideas, and/or in problem-solving techniques. Due to the technological and organisational revolution which impacts both business and society, nowadays many jobs have become increasingly innovative, challenging and creative. However, unless someone has first-hand experience, people usually are not aware of how the jobs have recently evolved. Therefore, in the following paragraphs we will provide a few examples of old and new jobs, by characterising their innovative and creative aspects:

- **Project manager**: actually an old job, which gained a huge popularity in the last decades. What made this job notably challenging are the advanced technology, products and services the current project manager deals with. Likewise, the number of subcontractors, vendors and stakeholders contribute to the project complexity. Finally, project managers may benefit from a great number of project management support tools like: Trello, Asana, Click Up, JIRA, Basecamp and many others.
- **Software tester**: a relatively new job which, surprisingly, usually does not require advanced IT competences strictly linked to STEM educational background. To a large degree the tester tasks are based on logical thinking, problem solving skills and unconventional use of IT tools.

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- **Lawyer**: depending on the specialisation, this old job was technically reshaped by the support of dedicated IT systems, which facilitate navigation between legal regulations, hierarchy of legal provision and documents. Moreover, the demand for lawyers with specific qualifications has significantly increased due to globalisation, long added value supplier chains, IPR protection and cooperation of organisations under different legal regimes.
- **Surveyor**: the job was deeply modified due to the introduction of digital maps, precise GPS measurements and finally application of drones as a cheaper and widely available technology to do status monitoring.
- **Salesperson**: although traditionally associated with soft skills the job got support from Customer Relation Management systems. Moreover, the increasingly complex technology and products motivate the sales people to constantly upgrade their knowledge and qualifications.
- **Medical Doctor/Medical Staff**: health care related occupations are good examples of activities which underwent profound changes: new technical diagnostic and therapeutic infrastructure, new drugs and healing procedures. Additionally, thanks to telecommunication technologies and open clinical trial data, doctors may find it easier to get information on a particular illness and to consult with their colleagues worldwide.
- **Librarian:** the job was completely redefined by migration of virtually all information resources on digital platforms. Likewise new technology reorganised publications channels. Finally a primary skill/activity of a librarian, information searching, was to a large degree entrusted to computer databases and searching engines.

This job list is of course much longer, in fact the technological progress has impacted, or transformed to a greater or lesser extent virtually every jobs and people activity. Generally, the common denominators of these changes are:

- At least basic knowledge of information and communication technology, which is actually necessary in almost every work.
- The ability of employees to search information in large public and private sources and use dedicated applications on a daily basis.
- Hardware, applications, dominant tools, standards and practices, which evolve quite quickly. The same concerns key business player positions on the market.

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2.4 Skills and competences needed in the 21st century

People in the 21st century need different skills than even a few dozen years ago. This constitutes a necessity for a deep change in the current education system, which is not designed to develop these skills, thus constituting a major challenge for modern education. Technological advances and globalisation make interdisciplinary learning necessary, especially in the case of science technology (STEM). In [Tsupros, Kohler, and Hallinen, 2009] authors claim: "STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy".

In order to thrive well in the 21st century society, the young generation must be equipped with new skills such as creativity, communication, entrepreneurship and teamwork. Science, technology, engineering and mathematics (STEM) are not enough. In order to develop creativity, Art is also needed, which is directly related to the emergence of many new creative professions (and transformation of existing ones), and to the emergence of complex problems the workers are dealing with on a daily basis. This is how STEM turns into STEAM (Science, Technology, Engineering, Art and Mathematics). According to Liao "One of the strongest arguments for STEAM derives from the view that creativity is the most important ability in the 21st century" [Liao, C. (2016).].

Over the last years, a few documents have been published (reports, recommendations, publications) that researched the skills and expertise needed in the current and future labour market, or made recommendations on how to transform the current education system to address the above-mentioned needs.

The report "Science Education for Responsible Citizenship" (2015), prepared for the EC, underlines the role of education to shape the modern, sensitive and responsive citizen, while at the same time formulates strategic recommendations on how to develop the required skills.

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One of the most recent documents defining the education priority is the Recommendation of the Council of the European Union of 22 May 2018 on key competencies for lifelong learning (Text with EEA relevance) (2018/C 189/01).

The Reference Framework sets out eight key competences for lifelong learning, which are important for school education as well:

- Literacy competence;
- Multilingual competence;
- Mathematical competence and competence in science, technology, and engineering;
- Digital competence;
- Personal, social and learning to learn competence;
- Citizenship competence;
- Entrepreneurship competence;
- Cultural awareness and expression competence.

Amongst others, the document outlines the use of a variety of learning approaches and contexts to develop the above-mentioned competencies.

The Council of the European Union identified certain examples of good practices:

- Cross-discipline learning, partnerships between different education levels, training and learning actors, including from the labour market, as well as concepts such as whole-school approaches with its emphasis on collaborative teaching and learning and active participation and decision-making of learners can enrich learning. Cross-discipline learning also allows for strengthening the connectivity between the different subjects in the curriculum, as well as establishing a firm link between what is being taught and societal change and relevance. Cross-sectoral cooperation between education and training institutions and external actors from business, arts, sport and youth community, higher education or research institutions, can be key to effective competence development.
- Acquisition of basic skills as well as broader competence development can be fostered by systematically complementing academic learning with social and emotional learning, arts, health-enhancing physical activities supporting health conscious, future-oriented and physically active lifestyles. Strengthening

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personal, social and learning competences from an early age can provide a foundation for development of basic skills.

2.5 Main education concepts and methodologies

The chapter characterises main ideas and educational methodologies relevant to our project and finally describes Creative Writing. The following concepts are introduced:

1. Constructionism
2. Project based learning
3. Inquiry based learning
4. Games-based learning
5. Citizen science
6. Storytelling and creative writing (in science education)

2.5.1 Constructionism - learning by creating

Constructionism, and idea formulated by Seymour Papert [Papert's Constructionism Theory] and then further developed by Mitchel Resnick [Mitchel Resnick, 1996], activates active learning and independent attempts to solve problems. Instead of the teacher solving a problem and then letting a student remember the knowledge, the student learns by oneself problems-solving, creating solutions, and also correcting errors. It focuses on the subjectivity of the student, who is not only the recipient of knowledge, but rather an active creator.

Such a learning system is more attractive for students, as it allows them not only to expand knowledge but also to develop their skills [Ki-Cheon Hong and Young-Sang Cho, 2019] .

Constructionism emphasises three fundamental aspects in the teaching process:

- Mental: the process of shaping the student's knowledge;
- Social: operating in the system;
- Material: designing, constructing, building,

Dr. Andrzej Walat writes: "Construction, like any variety of constructivism, proclaims that 'Children don't get ideas, they make ideas', but "learning children create new ideas especially effective when they are actively involved in the construction of various types of artefacts - it could be a robot, a poem, a sand castle, a computer program or

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anything else that can be shared with others and that could be an object joint analysis and reflection.

In his work, Dr. Walat lists 8 rules:

1. Learning by doing
2. Use of technology as a building material
3. Fun
4. *Learning to learn*
5. Take your time
6. We learn from mistakes (*you can't get it right without getting it wrong*) - working with the method of design thinking
7. Be the first (*do unto ourselves what we would have students do*)
8. The use of digitalization

2.5.2 Project-Based Learning

Project-Based Learning (PBL) - also known as the project method - is a method of didactic work in which students carry out a project based on assumptions agreed with the teacher. These assumptions include goals and methods of work, but also deadlines for completing tasks.

In the traditional way of education, students learn individually thematic blocks by participating in lectures, exercises, laboratories or projects. Most often they perform the tasks on their own. PBL enriches the teaching process with elements such as team work and work on a specific project. These two new elements make students acquire practical skills related to teamwork and learn how to solve specific problems defined in the project. These skills are important in the 21st century.

PBL involves teaching by defining goals, conveying content based on standards and developing skills, including critical thinking, problem solving, cooperation and self-organisation. During the project, the student solves a difficult problem that is adapted to its level. This problem concerns the real world or even refers to the personal interests and problems in the lives of students. The project is also characterised by a specific problem-solving time. In this way, students engage in the process of asking questions and seeking information. Students and teachers analyse the way they work, discuss the problems that have arisen and how to solve them. As

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research shows, PBL is perceived by students as a pleasant and effective method. The use of this method in the teaching process increases the level of students' involvement in learning. In the PBL method, students are involved not only rationally but also emotionally, which translates into the internalisation of knowledge, thus PBL influences the effectiveness of the teaching process.

After completing the project, the student understands the acquired knowledge better and remembers it longer than in the case of the traditional method. This means that the student acquiring knowledge through the PBL method is better adapted to apply it to a new situation in the future. In the 21st century, the labour market requires more than basic skills. Working on a project teaches how to take initiative and responsibility, build trust, solve problems, communicate ideas, work in a group and self-organise more effectively. PBL thus shapes the skills that are most needed in the real world. Such skills include problem-solving, critical thinking, communication with the use of various technologies, presentation of ideas and results of work, working within a specific time frame.

However, this method poses new challenges for teachers, who do not just impart knowledge to the students, but are supposed to be a guide for the students by making them acquire knowledge independently, help them choose the right sources of knowledge and organise information from various sources. It also requires the teacher to be able to use computers, the Internet, programs and educational portals efficiently.

2.5.3 Inquiry-based learning (IBL)

Inquiry is the search for truth, information, or knowledge by asking questions. The process of transforming information and data into useful knowledge is complex, but extremely important and useful.

In IBL, the role of leader is played by students who start with their own questions and doubts, which are at the centre of their educational path. It is an approach to learning that emphasises the students' questions, ideas and natural curiosity.

IBL is a student-centred approach in which the teacher guides students through the questions they ask themselves, the research methods they design, and the data they interpret. Through inquiry, students actively discover information that supports their

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research. Inquiry in education should lead to a better understanding of the world in which people live, learn, communicate and work.

The content of particular subjects or disciplines is very important, but as a means to an end, not as an end in itself. The knowledge base in each discipline is constantly expanding and changing. Everything can never be learned, but everyone can better develop their skills and shape the inquiring attitudes necessary for lifelong learning.

Here are the individual steps students go through in the IBL model:

- The formulation of questions;
- Designing the way of researching the issue included in the question;
- Identifying and gathering appropriate resources / sources;
- Developing explanations based on evidence and scientific knowledge;
- Sharing audit procedures and results;
- Reflection on the learning process and outcomes.

2.5.4 Games-based learning and Gamification

- **Game-based learning** refers to borrowing certain rules of the game and using them to increase the involvement of students working on solving real problems. According to psychologists, the use of the game (*Games based learning*) increases the student's motivation and to get involved. Educational material is provided in a fun and dynamic way. Learning through games is not only about creating games dedicated to students, it is designing educational activities which can gradually introduce game concepts. Traditional games will use rivalry, competition, points, prizes, and feedback loops. These concepts have become increasingly popular in education. They allow students to be better involved in learning.
- **Gamification** refers to the learning process which uses an educational game, board or computer, and is designed as a separate, autonomous, closed environment. If we bring the game to the classroom, the game itself will be clearly separated from the "normal" part of the class. The game begins and ends with single lessons. On the other hand, gamification of teaching consists in the reorganisation of these phenomena and processes (didactic measures, measurement and evaluation of results, student work), which are already present and constitute integral elements of the education process. Gamification

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puts them in a similar system that is inextricably intertwined with everyday teaching.

2.5.5 Citizen Science (CS)

According to the Google high level definition "Citizen Science and crowdsourcing projects enable the public – young and old, student and teacher, amateur and expert – to participate in scientific data collection and research". Citizen Science is notably popular in the US and it contributes to educational, scientific and social goals. The term CS has multiple origins and different concepts and was first defined in the mid-1990s. Although, CS has a large potential and a significant educational and awareness arising impact on the involved amateurs and professionals, the CS projects must be carefully designed to maximise the project results. In addition to some niche areas like bird observation, meteor hunting, pollution detection where a common effort may lead to mindful scientific results, CS is a highly effective scientific method in sociology and psychology as a means of social experiments carried out at a large scale. Elements of the CS methodology are commonly applied in STEM education as CS incorporate other learning methodologies [Olia E. Tsivitanidou and Andri Ioannou, 2020]

2.5.6 Storytelling

Storytelling is a way of teaching through narrative, and it is a natural way of communicating and collecting information based on people's experiences. Skilful use of narration makes the conveyed content engaging for the recipients. Storytelling is a tool that allows the presentation of story facts in a logical and orderly manner. The effect of creating interesting stories reaches the students and involves them emotionally. Storytelling, by arousing interest, activates more areas in the brain than in the case of presenting dry facts and figures only, thanks to which stories allow to achieve the intended educational results more effectively.
A properly constructed narrative should be simple, emotional and understandable for the student, it should provoke reflection and inspire to independently acquire knowledge. Storytelling is characterised by creativity, audience engagement and dynamic messages.

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Storytelling is available for the students, and its use in education offers an opportunity to present the facts in a more convenient way. The advantage of storytelling is the fact that this method does not require any particular financial outlays. It can also be used when we do not have more funds.

2.6 Results of a survey on STEAM education in the consortium

As a part of PR1A1, research partners were asked to answer 8 questions aimed at collecting information on innovative educational practices in their countries. The list of questions and short summary of the most frequent ideas are listed below.

Which methodologies, ideas and solutions related to student teaching does your organisation use / you think are the most effective in the process of creative STEAM education? Which learning methodologies are the most popular in your country?

The practices described by the partners characterise active student involvement in the learning process (group work, hands-on activities) and intensive utilisation of IT tools. A number of learning methodologies commonly recommended for STEAM teaching (like playful learning, inquiry-based learning, project-based learning and gamification) were mentioned. Also the role of students' soft skills (communication, presentation, asking questions, leadership) development and participation in variety of events/engagement in different activities were underlined.

From the perspective of your organisation and/or your personal experience: what are the main barriers which block wider introduction of non-standard, more inspirational STEAM teaching methods? (e.g.: organisational, financial, lack of time, insufficient staff competences, necessity to follow the learning curriculum, lack of student motivation etc.)

The obstacle frequently listed are:

- Formal inflexible, centralised learning curriculum not really compliant with more creative STEAM teaching methodology;
- Lack of teacher motivation;
- Insufficient teacher knowledge of methodology and digital skills;
- Teacher overwhelmed by extensive school formalities and lack of time.

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Supposing that some barriers are overcome: what new STEAM teaching ideas would be worth to implement, notably in high schools? (taking into account the feasibility a particular idea would be accepted).

Answering this question, partners put forward a few different ideas without one dominant common theme. Most often, partners proposed wider usage of available digital open educational resources (notably videos) and digital tools (including online games). Also the Makers movement was proposed as an impactful method to engage young people in STEAM. Finally the necessity to reduce the assessment of the students' work was stressed as well.

What necessary conditions must be met in order to implement certain creative STEAM teaching methodologies (e.g.: staff qualification, student motivation, student background and skills, equipment etc.).

Also, partners do not have a coherent opinion on what must be done in order to more widely introduce STEAM teaching methodologies. A change of the students' and teachers' motivation was recognized as a crucial factor as well as a closer cooperation between the education process stakeholders (teachers, parents, students, non-formal providers and communities). Access to supporting materials both for students and teachers is also regarded as important.

What type and format would be the most appropriate for STEAM creative educational content? (e.g.: videos, comics, presentations, interactive documents, quizzes, simulations etc.).

Partners do not prioritise any types of content: videos, comics, quizzes, simulation, games, comics are seen as appropriate given that the content type addresses a particular educational problem. Generally the resources should also be interactive.

Which advantages and disadvantages do the creative STEAM teaching approaches have? (e.g.: in terms of student perception, teachers effort, organisational arrangement, additional costs etc.). Do you have any suggestions on a STEM lessons organisation? E.g.:

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type (workshop, project, lecture, seminar, discussion), form (physical, online, hybrid), number of students, room, lesson duration, room arrangement.

Creative STEM teaching methods are widely regarded by the partners as advantageous to the traditional ones on many accounts. However, what was also often noticed is that the implementation of these methods in a traditional school environment requires a lot of effort put in the teachers' training and reorganisation of the school processes. Furthermore, not all methods are suitable for all students and teachers. Suggestions on STEM lesson organisation include more interactive activities and usage of digital tools.

Which facilities, equipment and educational aids may be useful for creative STEAM lesson organisation (e.g.: computer, tablets, specific software, interactive tables).

The partners recommend a variety of digital tools which support different stages of educational activities (planning, idea creation, collaboration, sharing, assessment, providing feedback). Similarly, there are plenty of assembly toolkits and digital platform to develop management software for specific hardware assembly kits for hand-on activities. The currently available (usually at affordable prices) hardware and software allow students guided by teachers to engage in inspiring activities in many schools. The primary challenge is to promote these activities and train the teacher to be more digitally literate.

Which additional information important for the next project phases should also PR1-A1 desk research investigate?

Balance between online and offline as well as blended STEAM methods were underlined.

2.7 STEAM innovative education ideas

To complete this section each project partner has identified a few examples of ideas related to STEAM education. The search was not constrained by any pre-requisite requirements, so ideas gathered here characterise a variety of forms and formats:

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STEAM lesson scenarios, use cases, inspiring topics, educational portals, TV programs, books, comics etc. Contributions provided by partners are included in Attachment 1.

The ideas collected under this section could be roughly categorised into 4 groups:

1. Specific topics for the STEAM activities with suggestions on how to arrange and conduct the lessons as well as links to more detailed descriptions/ content the teacher may use to prepare her/his own educational materials. Descriptions of the topics provide also justifications for why a given idea is relevant and the context of the idea may be presented in a class. Along with the topic introduction, some digital tools/ platforms supporting the topic exploration are also often recommended. Although the topics selected by partners are usually not associated yet with full-fledged educational materials ready to be used by teachers, based on information provided, such materials may be quickly prepared. Furthermore, the lessons scenarios/content development itself may contribute to the teacher's qualification enhancing and the changing in the teacher mind-set.
2. STEAM educational concepts developed around digital platforms, which facilitate study of various topics and foster students' creativity. This category refers mostly to programming environments (like SCRATCH) designed for education purposes and specialised software packets (like GeoGebra) which support a given concept implementation or learning certain disciplines (like geometry). Programming platforms usually allow some hardware sets (like robot assembly kits) configuration and management, which in turn makes the programming less abstract and more engaging. Usually, the digital educational environments are associated with learning communities, in which members share their projects, consult each other, help to identify programming bugs, and allow group working. Finally, there are plenty of projects and digital resources ready to be reused by teachers and students, so using these digital tools during the lesson actually requires a teacher mostly to learn the tool itself.
3. Project results, free of charge of commercial educational portals which publish learning content, and methodology and describe/promote certain educational methodology. The category comprises quite diverse materials in terms of their detailedness, readiness for exploitation, and the way how a given concept may be applicable in a school environment. Many of the ideas in this category refer

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to the storytelling, and exemplify how STEM topics may be introduced in a non-standard way. The ideas' resources falling into this category are usually interactive and contain the elements of Art in the form of music, visualisation or narratives.

4. The last category of resources the consortium has identified as suitable for STEAM education are selected TV programs, science promotion books, comics and other usually not interactive content. This category characterises a number of materials explaining its pedagogical concept and potential impact on a student. The majority of the content here is dedicated rather to self-study and could be often suitable for people at all ages, who have only rudimentary knowledge about STEM.

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3 Outcome of field research

3.1 Aims of the current Field Research

The aim of the field research was taking stock of experiences on STEAM initiatives. The collection of stories and their analysis took place in the first 6 months of the CREAM project and was led by the European School Heads Association (ESHA). This activity aimed to foresee the development of scenario analysis with a collection of insights on real experiences and feedback of actors involved in STEM/STEAM education and who had experiences with non-traditional methods, including storytelling in STEM/STEAM.

As the first step of this exploration phase, partners collected stories representing the point of view of different actors such as students, teachers, school leaders, open schooling and extracurricular activities providers, popular scientists, university researchers and professors, trainers, and company owners, or professionals. Partners have used different methods from direct, unstructured interviews to online searching. While most material found online or based on previous personal or literature experiences has fed into desk research, these also cross-pollinated the field research.

Although field research was primarily based on the storytelling method itself, it followed an evidence-based approach, thus all stories are supported by evidence and references for being included. The original objective was to collect around 40 stories, equally representing the involved countries and the different categories of actors identified as potential "users" of the CWLs model. The current chapter is based on the summary and analysis of 34 stories from the partner countries and beyond as ESHA has brought in stories from its European and international network beyond the partnership.

3.2 Field Research Methodology

A Field Research Protocol was provided by ESHA is part of PR1A2 and aimed to guide CREAM partners in the collection of stories in the field in their respective countries (Greece, Italy, Poland, Slovenia, and other EU countries covered by ESHA) that were prepared by all partners. ESHA collected the stories (in English) and developed a comparative analysis titled "Field research on the State of the Art on STEAM creative teaching approaches and initiatives".

3.2.1 Identification of examples

The aim of the field research was to highlight positive inspiration from various European countries as well as identify barriers, red flags, and challenges – the general experiences with STEAM initiatives. When identifying the examples, partners were asked to consider that failure and challenges are just as valuable for the current project as success stories.

The stories were to address one or more of the above-mentioned research areas:

1. What the main innovative STEAM teaching methodologies are;
2. What existing resources could be used or re-designed for use within CWLs to avoid duplication;
3. What the most appropriate media formats for learning content for target groups (schools' staff and students) are;
4. What type of assessment framework would be most appropriate to facilitate the measurement of attainment;
5. What types of pedagogic support are needed to facilitate the involvement of participants into the CWLs;
6. What the most appropriate teaching and learning methodologies to be adopted are.

When partners identified their (minimum) 5 stories, they were encouraged to rely on a variety of sources.

Primary sources

Primary data is original and unique data collected by the researchers directly from the first-hand source or study object.

In CREAM the following primary sources were identified:

- School leaders;

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- Teachers;
- Pre-service teachers;
- Teacher trainers;
- Parents;
- Students;
- Science centres, libraries, children's universities and similar non-formal education providers;
- Blogs, media articles, mass media reports.

Secondary sources

Secondary data is data that have been already collected by and readily available from other sources. In the CREAM case, this can mean recently published research, scientific articles, outcomes of other projects or similar, evidence-based sources.

3.2.2 Providing the stories

Partners provided the stories with a cover page including basic data and the stories were provided in English.

In case the story was told by one or more people directly, they signed a consent form. If the story was based on literature only, it was indicated on the cover and there was no consent form included. However, it was preferred to rely on first-hand experience, so personal interviews or written testimonials were incentivised.

Partners were to bear in mind that the research is based on stories, and if the story is told in less structured, freer format, it enriches the content by information the interviewer may not intend to solicit. Thus, full transcripts and free written input were preferred to structured interviews.

It was preferable to aim for multiple voices in the form of parallel stories or group interviews. One example could be illustrated through the lenses of e.g. a teacher implementing it, a student being part of it, a school head promoting it, a non-formal education institution, scientist or artist involved in it, and/or a parent engaged in the activity or being informed about it.

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Partners were asked to guide the stories in a way that made it possible to see as many of the following aspects in the example, as possible, in line with the aim of the research:

- Motivation or need - Why did you start this?
- Overall design and aims – Tell us how this is done – preparation, implementation, evaluation
- Stakeholders engaged – Who are the educators and who are the learners?
- Is it based on any specific framework or theory?
- Which STEM domains are addressed?
- What is the arts element in it?
- Is it curricular or extracurricular?
- What resources are used?
- Were there any challenges? If yes, which ones?
- Is it a success? If not, why did it fail?
- Is it ongoing? If not, why did it end?
- Why do students like it? Why do teachers like it?
- Does it help to engage students who are less enthusiastic about STEM?

The reports could be submitted in an un-edited format, but they should have been understandable in English.

3.3 Our collection

Most partners collected stories from their own national context, thus – given the composition of the CREAM consortium – nearly half of the 34 examples are from Italy (15). There are 5 stories from Greece, 5 that have been collected in Slovenia or the Balkans, 4 from Poland, 2 from Hungary and the United Kingdom respectively, and 1 from the United States. In the analysis that follows, this disproportionate selection was counterbalanced to offer a proper international outlook.

The overwhelming majority of storytellers, about 20 of them come from the non-formal education sector (in some cases the storyteller is labelled as a teacher, but from the interview, they appear to be non-formal educators). Some of the storytellers are teachers or school leaders working in formal education, and the voice of the

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learner is also represented in 8 of the stories, while there is only one policy maker and one parent among them.

The age group of learners engaged in the activities introduced in our stories is very diverse. While over half of them specifically target students at ISCED Levels 2 and 3, there are some initiatives that include ISCED 0 and 1. A couple of initiatives also aim at young adults.

In the collection, one EU funded project is introduced. Five separate interviews were made with students and a parent from the same school, operating with a project-based learning approach. A few other examples also showed methods that linked storytelling and STEM/STEAM learning within the curricular teaching framework, but the overwhelming majority was still extracurricular learning at school or non-formal education provision.

With regards to the STEM/STEAM domains covered, most stories cover more than one subtopic or area. The largest number of stories are about initiatives that use robotics as a means or as a goal. 8 stories mention arts and humanities specifically, 14 stories include mathematics, 8 of them chemistry, 6 biology, 3 astronomy, 9 physics, 8 information technology, 11 mention science in general and 3 technology or engineering.

3.4 Inspiring ideas

In most contexts, the idea of STEM, to collectively tackle the various aspects of science, technology, engineering and mathematics is relatively new, and the introduction of arts (and humanities) into the equation is even less mainstream. While it seems to be relatively widespread to have a more holistic approach to science, the engineering element is the rarest – even though it is considered to be a natural way of linking education and learning to real life situations, making learning by experience possible. It looks obvious from the collection, that technology, especially digital technology – including virtual reality - is a major trigger and accelerator of implementing a STEM/STEAM approach.

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One important feature mentioned by many storytellers is that STEM/STEAM programmes introduced through their voices support students in developing their creativity, curiosity and imagination.

One of the interviewees shared a very important consideration for promoting storytelling related to STE(A)M education, namely that children develop two modes of thinking to make sense of the world. One is the "socio-logico" mode, which processes information by abstracting it from context. The other is the narrative mode, which is context-dependent and relies on situation-based evidence. Research widely recognizes that the narrative mode of thinking represents the default mode of human thought, providing structure to reality and serving as the underlying foundation for memory. Therefore, in the context of science learning, presenting new information in the form of stories about scientists and scientific discoveries further supports a natural way of information processing for many learners.

Scratch is one of the best-known examples that offers such a learning opportunity by linking coding and storytelling. One interviewee emphasised that "students love to express themselves, to create, to collaborate, to discover and share. Storytelling and coding help students understand a subject (they gain knowledge and skills), present it with characters and dialogues (showing their understanding, practising critical thinking and writing skills), and animate it (using coding skills and computational thinking). Depending on the scenario that they code, they explore several aspects of STEAM. Programming and digital literacy skills are among those". The challenge of managing multiple teams in the classroom requires the teacher to develop their teaching skills, and students also need to learn time management to find a balance between the artistic element (designing their characters) and actual coding.

When it comes to visual presentation, peer reviewing and peer support are mentioned by several storytellers. The examples of virtual and real galleries, collections of written stories are listed. All storytellers mentioning such methods emphasised the importance of sharing the artefacts or other creations with others as a crucial and especially satisfying element. Some also mentioned the necessity to implement a code of conduct or netiquette to avoid unhelpful comments.

Some catchphrases are mentioned by storytellers that are often associated with creative storytelling activities in STE(A)M. With most of such activities still taking place outside of school, many consider these activities as "informal edutainment" ones. At

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the same time, some of the stories show how such approaches are not necessarily restricted to informal or non-formal education.

As for the edutainment element, the importance of playful learning approaches that foster creativity is often mentioned as something that should be mainstreamed in formal education. A number of storytellers emphasised this combined with the need to introduce the STEAM approach and engage as many learners as possible from a very early age. As one storyteller has put it, “you cannot start early enough to make children catch the [chemistry] bug”. This approach underlines the importance of introducing STE(A)M in a non-frightening way and environment – and for this, kindergarten with no grading is ideal.

For early engagement – as well as STE(A)M engagement later on - the exploration approach is proposed by some. In many cases it happens in outdoors settings, but not necessarily so. However, the exploration approach helps to bring STE(A)M closer to students by linking it to real life problems, and incentivising them to find solutions for real life via various STEM domains.

In these activities, art mostly acts as a vehicle that supports understanding, and as mentioned before, also helps the knowledge gained to become more deeply rooted in one’s memory.

Apart from outdoors, various forms of makerspaces are mentioned by the storytellers. Most of the makerspaces mentioned are either outside of school or – if inside – they are used for afterschool activities mostly. Many of the makerspaces the stories are about are robotics labs. Some of them offer other possibilities for creative expressions (eg. tinkering), some robotics only.

One interesting approach mentioned by two storytellers independently is the inspiration that students may get by learning about or researching the life stories of successful, famous scientists, often coming from disadvantaged or very challenging family backgrounds. It highlights the potential of role models, and can support students in understanding that science is for everybody.

Another storyteller reminds us that “a good story captures the mind and the heart”, making learning deeper and more meaningful. However, another interviewee also shared a word of warning about the framework of reference used in stories. It is of

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crucial importance to consider the context the audience comes from, their prior knowledge, and also possible misconceptions.

It is not only the quality of the story, but also the formulation that must be carefully created. It is emphasised that it is much easier to remember knowledge crumbles or even full curricular topics when there is a pun or riddle, or a relatable anecdotal type of story related to it.

One important notion that is worth mentioning, and that also leads us to the next segment, the implementation of such programmes within curricular frameworks, is science capital. Science capital is the sum of all science-related knowledge, skills and competences that a person – in this case a learner – gathers in all venues of learning. While schools often only consider the science learning related to curriculum, not considering learning outside of school and not recognising its achievements can lead to disengagement with science. A relatively large number of universities are promoting this approach as part of their "third mission" activities, and their recognised position within the science field helps the recognition of science capital.

What is an important fact for CREAM is that a student's aspiration to choose STE(A)M careers largely depend on their awareness of their own science capital and the recognition of it by their community. This could be fixed by a more wide-spread implementation of open schooling programmes, possibly by schools engaging with initiatives like the ones represented by our storytellers, primarily operating outside of school or afterschool in the current reality.

3.5 Opportunities and challenges of STEAM storytelling in formal education

One of the challenges mentioned by a number of storytellers is overpacked curricula that is often accompanied by a compartmentalised approach to subjects rather than looking at the breadth of the curricula with multidisciplinary lenses on, when designing activities and timetables. In case school curricula are overcrowded with compulsory cognitive elements, the implementation of storytelling and STEAM approaches in general might be prevented by the lack of time. However, it is to be considered how much actual, meaningful learning is taking place in traditional, frontal

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classroom contexts, and how much of it is just short-term, study for the exam and forget type of learning.

At the same time, our storytellers explicitly said that STEAM and storytelling are means of preventing disengagement with school in general, thus it could be a vehicle in preventing early school leaving.

Mathematics teaching was especially highlighted as an area that could benefit a lot from storytelling approaches. Linking real life problems to mathematics has proven to prevent disengagement. It is not only important for the life of the individual learner, but various country examples clearly show that engaging mathematics teaching and higher economic results and level of innovation of a country go hand-in-hand. Two of our storytellers mentioned it as causal (rather than just correlation).

There are two crucial stakeholder groups that were mentioned by a number of storytellers as key for successful implementation of creative STEAM learning approaches: teachers and parents. In the case of teachers, teacher-to-teacher knowledge transfer is of utmost importance. The role of school leadership incentivising and supporting the use of innovative teaching methods is also a prerequisite. This, in many cases, needs to be accompanied or preceded by teachers first experiencing the impact of such methods so that they full-heartedly believe in them.

Parents also play a crucial role in embracing or rejecting creative STEAM methods. When a school is determined to implement such methods, they need to consider that parents can be gatekeepers preventing students from fully embracing these methods. Thus, the school should consider parents' previous experiences with science learning and engage them in planning the introduction and implementation of new teaching methods. As it is clear from the stories, once on board, parents are major accelerators of the education renewal process.

Based on the inspiration provided by the CREAM storytellers, the project and schools in general have a strong basis for translating successful creative STEAM methods to their own contexts and create new ones, in a best case scenario establishing partnerships with those already implementing them – be it a non-formal education provider, another school, a company or local communities/families.

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4 Outcome of context analysis

4.1 Introduction

SINERGIE, as responsible for the context analysis of CREAM project and the definition of the profile of actors and their current relationships, coordinated the task by providing the other Partners with the instructions on how to carry out a focus group, a toolkit with some materials to animate the workshop, and a timeframe to organise the activity by meeting the set deadlines. All Consortium Partners contributed to the implementation of the activity by organising at least one focus group per country in the months of May and June 2022, with the goal to collect inputs and ideas from different stakeholders on CREAM Creative Writing Laboratories (CWLs) model.

The context analysis aimed at identifying the different actors involved in STEAM learning, using innovative and creative teaching and training methodologies. The analysis was carried out through brainstorming sessions in a set of focus groups organised by each Partner, involving the staff and local stakeholders (e.g. companies, policy makers, high school students and teachers, family associations, etc.).

In this chapter, we will give evidence of some details of the focus groups in terms of organisation, number and role of participants; secondly, the main insights will be presented, following the same structure of the interview and summarising the inputs according to their theme; finally, we will draw conclusions and explain how these results will be useful for the design and implementation of CWLs. In doing this, we will make use of some canvases generally employed in design thinking activities in order to draw an ecosystem map for the Laboratories including all different stakeholders, and to analyse the profile of each CWL end user or beneficiary.

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4.2 Organisation

CREAM Partners organised 8 focus groups:

1. One was carried out by ESHA on 31/05/22 and saw the participation of 13 persons (12 onsite and 1 online), including representatives of non-formal STEM providers and students' parents. The group was international with people from Austria, Denmark, Finland, Italy, Poland, Romania and the UK.
2. Another one was organised by the three Italian Partners (SINERGIE, IEXS and VITECO) on 08/06/22. The group included 12 people (teachers, VET and education experts, professors, students' parents).
3. One meeting organised by DRPD NM with a professor of Mechanical Engineering expert in robot design.
4. The second workshop carried out by DRPD NM on 24/06/22 saw the participation of 12 persons and the group included teachers, educators, engineers and an art therapist.
5. GRM Novo Mesto organised a workshop on 28/06/22 with teachers from the school and from Ekonomska Šola Novo Mesto.
6. In Greece, EDUMOTIVA planned an online meeting with 13 persons, mostly from a teaching background. In fact, the group included a physicist, a principal at a Primary School,a principal at secondary school , teachers from primary schools, and Computer Science teachers from Secondary Schools and a Vocational High School.
7. The first workshop by the Polish Partners was with a group of 4 students from Warsaw University.
8. The second focus group by WUT and ZSO was conducted online and was characterised by the participation of 3 different groups of 4 persons each – students, teachers and parents.

In the following table, the most important information about the focus groups are summarised:

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FOCUS GROUP	ORGANISATION	COUNTRY	ONLINE / ONSITE	N° OF PARTICIPANTS
1	ESHA	International	Onsite	**13**
2	SINERGIE / VITECO / IEXS	Italy	Online	**12**
3	DRPDNM	Slovenia	Online	**1**
4	DRPDNM	Slovenia	Onsite	**12**
5	GRM Novo Mesto	Slovenia	Onsite	**12**
6	EDUMOTIVA	Greece	Online	**13**
7	WUT / ZSO	Poland	Onsite	**4**
8	WUT / ZSO	Poland	Online	**12**
				TOT = 79

Table 1: Total participation to CREAM focus groups

With the focus groups, the Consortium reached 79 stakeholders from different European countries: Slovenia, Poland, Italy, Greece, Austria, Denmark, Finland, Romania and the UK, as shown in the following map.

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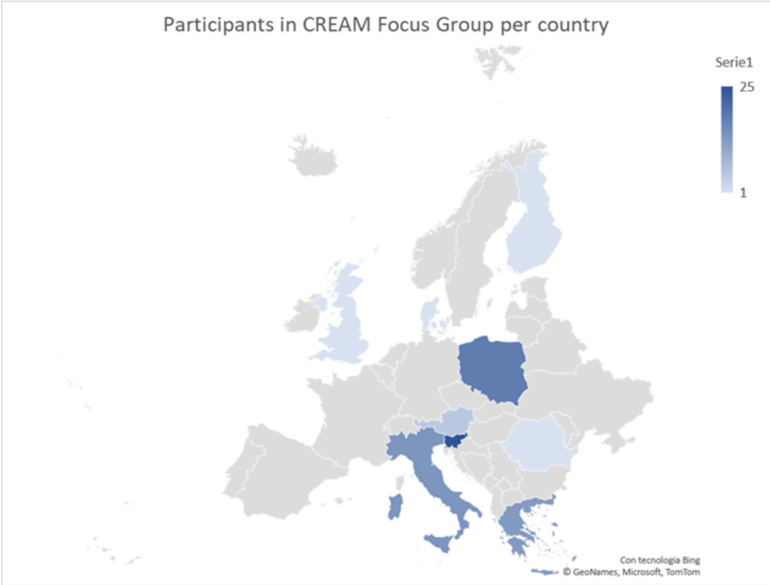
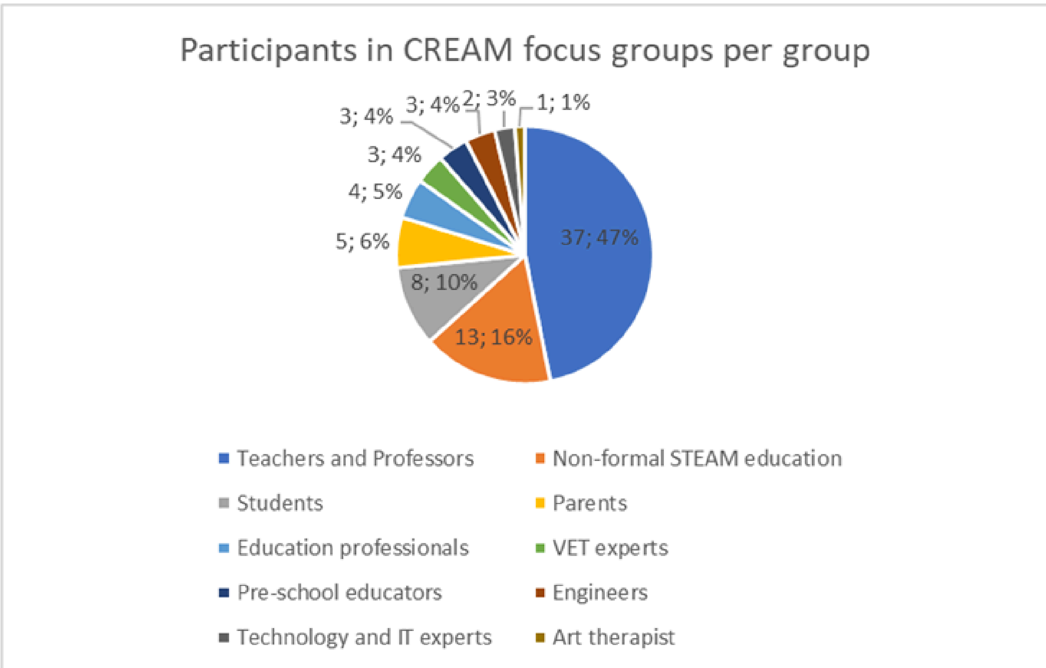


Picture 1: Participation to CREAM focus group per country

Among the participants, the most represented group was that of teachers and professors, followed by that of representatives of non-formal STEAM educational activities. At some distance, we find students and parents. The following graph shows the distribution of stakeholders according to the group they belong to.



Picture 2: Participation to CREAM focus group per group

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4.3 Report on context analysis

The following paragraphs summarise the main findings from the focus groups organised by CREAM partners and follow the same order of the questions that were proposed during the workshop. The interview had at least two goals: on the one hand, gathering information on initiatives similar to CREAM CWLs; on the other hand, collecting suggestions for CWL design.

4.3.1 Questions to gather information on other initiatives similar to CREAM CWLs

Are you aware of similar actions realised in our country / region?

An interesting action that is present both in Poland and in Italy is that of Children Universities, aimed at improving education standards and based on the concept that not all education takes place in schools. Children attend high-quality lectures delivered by university professors out of school hours. Sometimes, they collaborate with local schools to engage children in organising STEAM-related events.

Several storytelling activities take place online to involve children living in remote rural areas (e.g. in Finland). Though not obliged, some teachers organise these activities in the context of creative writing classes with their students, with the aim of bringing science closer to them in a simple way. An example comes from GRM Novo Mesto School in Slovenia and takes the form of "Laboratory Work" where students are invited to co-design the activity, participate in field trips where they do practical on-site work, and presented with a combined teaching approach where teachers of different subjects do joint classes.

Open Schooling activities are characterised by a type of learning that is open in terms of timing, location, teaching roles, instructional methods, access and any other factor related to the learning process. In certain countries, such as Denmark, it is compulsory, with Universities being the main providers of science engagement activities. An example of open schooling comes from Austria and is called Bildungsgräzl, which can be described as a partnership between schools or kindergartens and extra-curricular facilities in the domains of education, youth and social work, sport, culture and health.

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Another interactive experience is problem-based learning, where problem solving is used as a methodology to look at the external world outside the school doors, to identify real challenges (e.g. sustainability, poverty, poverty in education, inclusion, bad schooling) and to solve them by involving stakeholders from real-life situations. This also enables students to apply maths notions to real life and concrete problems, thus making the subject less abstract.

In certain countries like Poland the activities of this kind are few, and often based on teachers' initiative, who suggest students to perform hands-on work, organise lectures with University professors, etc. Some examples include a scientific workshop where participants were asked to build a nerve system out of plasticine, or invited to simulate the creation of a company. Unfortunately, activities of this kind are usually carried out in very little time and in a way that is not really professional.

In Greece, some schools organise robotic activities where students work in small groups with members having different roles – one of those being that of the secretary who keeps a diary, takes notes and records actions and ideas. It is important for students to come up with a presentation of their activities in order to learn how to articulate sentences that make sense. For these reasons, younger students are also stimulated to write reports explaining what they did during a scientific experiment by using a worksheet with specific prompts provided by the teacher.

Always in the robotics domain, it is important to mention the School of Robotics in Italy, which represents an excellent example of alternative didactic methodology. It teaches students how to use robots and machines to support inclusive education, help disabled and/or disadvantaged people, promote cultural heritage and solve societal problems.

Generally speaking, innovative teaching and learning initiatives tend to be organised more at the low-middle school level than in high schools. In any case, in order to ensure the success of such actions, collaboration with external entities is very important and, usually, partnerships are built between schools and universities and/or companies.

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Which actors have been involved in these initiatives? Which role did they play?

- Teachers, who should undergo a specific training or, at least, be provided with some form of special support, especially for those professors who have the courage to launch innovative initiatives within very traditional school systems. Their role is especially important because they can provide students with feedback and spark interest in them towards STEM disciplines.
- Students: in some countries they are seen as the end users of innovative learning initiatives (for example in Italy), while elsewhere there is much more focus on children's agency and responsibility.
- Parents, whose role is especially important to partner with the most innovative teachers and support them in launching activities in the schools.
- Mentors from research institutions, whose role is to supervise project works and support students in working efficiently and fruitfully.
- Schools.
- Universities.
- Non-formal education institutions and educators, usually with the role of initiators.
- Companies and/or firms located in the territory where a certain learning action takes place.
- School leaders / headmasters.
- Municipalities.
- Local Communities.
- National entities (e.g. Austrian Academy of Sciences).
- Museums and cultural institutions.
- Children's Universities.

How were the activities organised?

Usually activities are carried out in the school facilities during school time. In some countries they are considered extra-curricular activities and may also involve the participation of students' parents, while in other countries they are curricular activities or at least part of the school schedule. For example, high schools tend to organise one week of innovative activities in the form of a summer school, or one-day thematic workshops in cooperation with universities. Before carrying out a workshop of this

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kind, it is necessary to specifically train the teachers – as already happens in Italy and in Finland.

For groups of students aged 12-18, it may be advisable to organise small groups during the workshop in order to ensure that they work better. In any case, participation is on a voluntary basis and students should not feel obliged to take part.

Results of the workshop are often shown to parents and teachers in the form of a presentation or a brochure, as a way to make them aware of the purpose that the students want to achieve with the activity itself. Participants are also very much involved in deciding on the topics and usually they suggest some form of interactive activity (project, workshop or webinar). Interactivity and active learning techniques, in fact, are both very important for the successful implementation of the activity, which can take the form of association games, project simulations, guided conversations with a mentor, brainstorming followed by a wrap-up meeting, discussion on a given topic with one group in favour and one group against.

Before, during and after these workshops, it is very important to use the same language and the same communication methods that students normally use as a way to keep them involved.

In CWLs, teachers should definitely include an element of digital storytelling, which is encompassed in the concept of creative writing. It fosters the logic of problem-solving, improves the ability to analyse an element from multiple angles, and to give a final solution as an answer to a problem. Creative Writing can mean different things and the organisers of a CWL should be flexible in suggesting the type of written activity to carry out: it should not necessarily be a text, but it could also include choreography, reports, an autobiography, digital narrative, multimodal text, blog, participation in a forum or in an anti-logic competition, etc.

Which impact did the activities you mention had on students and their skills?

The most visible impact was that students from high school / gymnasium showed interest in continuing their studies in a scientific domain, but also saw an improvement in their general level of creativity and creative thinking. These activities also contributed to changing the students' mindset: most of them developed the habit

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of seizing everyday opportunities in the external environment, and to find concrete solutions to real-life problems. Besides, they learned to identify the links between different subjects, especially by tracing connections between their technological literacy and classic culture, science and humanities, and they noticed how they were all interconnected.

Another important impact was on the self-confidence of young people: in fact, students were able to organise successful activities by themselves, find a topic of their interest and put together a workshop. Interactive experiences helped students to develop their soft skills and their sense of leadership. This also impacted on their parents and teachers, who saw with their eyes what children were able to do and gave more value to their skills and abilities. Furthermore, students participating in CWL-like activities felt more motivated, especially because they were presented with customised activities in line with their skills, or also because they hoped to win some kind of reward or prize for performing well (e.g. a free ticket to a science museum). But the main source of motivation was an internal one, because they recognised that the skills they were learning thanks to innovative activities would be really useful in the future.

The impact tended to be low when there was no follow-up of these activities, when just one meeting was organised during the whole school year, or when the workshop tackled a topic that was not really interesting for the students. On the other hand, when the activity succeeds in sparking the students' interest, they feel more engaged in learning.

Furthermore, these activities positively impacted disadvantaged students, such as children of migrant background who discovered new study and career opportunities, and children living in remote rural areas who, thanks to online activities, were given the same learning and training opportunities as others.

CWLs, therefore, will probably help students in learning how to write scientific reports, which are characterised by a specific style. Usually they find it difficult to put on paper what they learned, or do not fully understand a written text when they read it (functional illiteracy); this kind of activity could really help them improve these fundamental skills. The difficulties many children find in studying scientific disciplines are due to the fact that they do not master the specific language, whose command is

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necessary to have a good understanding of all other subjects – including scientific ones.

4.3.2 Suggestions for Creative Writing Laboratories design

How would you improve the CWL concept?

As for the organisation of CWLs, it is necessary to clearly state their goal (i.e. inject more creativity and disciplinary integration between science and generic subjects / humanities) and answer the following questions: What is the relationship between the different actors taking part in the workshop? Who are the participants? Who leads the activity? Who benefits from the activity and how? What do students gain?

- CWLs should tackle real-life challenges for a problem-based approach to learning, and they should draw inspiration from an open schooling perspective.
- CWLs need to offer a multi-disciplinary / interdisciplinary approach to STEM and STEAM, where all subjects are interconnected and there is contamination with humanities and the narrative element of story-telling. It is important to keep science and humanities together and enhance integration between them; in fact, many students of science at university level do not know how to present the results of their researches in an understandable written form.
- CWLs will also build on students' scientific capital and celebrate the scientific knowledge they previously acquired through formal/non-formal education and real-life experiences.

As for the structure, CWLs are organised according to a co-design approach, with more motivated students allowed to suggest ideas and come up with topics. The introduction should include a discussion between students in order to test their knowledge and opinions, while the conclusion will include a collection of factual arguments. The impact of CWLs also needs to be evaluated, assessed and monitored.

Competence-based teaching and hands-on activities will be organised by the teachers. In order to make them ready and prepared for the activity, materials, presentations and manuals explaining the goals and the structure of the CWLs will be made

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available to them. Besides, it is suggested that teachers are always in contact with CREAM project experts for any logistic information.

Use of digital tools should be encouraged: text processing programmes, software for presentations, apps for cartoons / storytelling / web design. The activities need to be as interesting as possible as a way to further motivate students. A possible solution is to carry out tasks in **groups** and the smaller the group, the better. Each one will present a topic and then discuss it immediately after.

In order to perform successful CWLs, one should have enough time and give the activity a well-grounded **structure** because children need a follow-up to be really involved, they want to see the progression of their work, to feel like the creators of the whole process.

Assuming the point of view of the different stakeholders that can be involved in the realisation of the CWL, what expectations and needs do you think they have?

- **Students** – In order to properly learn, they need to actively participate in hands-on and creative activities such as CWLs, where they can discover competences that could help them in life (e.g. project management) or at least in getting better grades. At the same time, they require the freedom to choose which direction to give to their studies, seek new information and decide on the approach they want to adopt in their learning process. Participation in CWLs allows students to learn how to think clearly, draw correct conclusions, improve their eloquence and public speaking, conduct a discussion and express their point of view. It also represents a new experience or, at least, a way to spend time in a productive way together with their peers, with whom they will work in a team. Thanks to CWLs, students can increase their linguistic skills, since mastering them is a prerequisite for fully understanding any subject – including scientific disciplines.
- **Teachers** – The teachers willing to engage in CWLs will gain several advantages: first of all, they will improve their communication with students and bond with them out of curricular lessons; secondly, they will develop a sense of responsibility derived from the fact that they can take the initiative in organising and designing the activities (e.g. by suggesting topics that are interesting for the students); thirdly, they will discover a new form of teaching and transmitting

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notions and knowledge that is far more interactive and interdisciplinary; finally they will have concrete benefits in terms of visibility among other teachers and, hopefully, an increase in their salary. Collaboration between teachers of different disciplines and specialisations has to be fostered.

- **Non-formal education providers** – CWLs can play in favour of the normalisation and standardisation of an open schooling approach to become part of everyday school activities, thus enabling these professionals to become regular collaborators of the school.
- **Parents** – Since they are well aware of the problems of public schools, they are eager to participate in their children's school life, feel a sense of engagement, voice their opinions and provide suggestions. By participating in innovative learning experiences like CWLs, their children will improve their scholastic performance and, most likely, they will not need any additional tutoring. Parents also recognise that participation in CWLs will encourage children to study, identify their passions, improve their performances; in this way they will feel encouraged to think about their future. Parents usually support these projects because they believe that, if their children feel invested with an agency, they will also act in a more responsible way and have the opportunity to become the protagonists of their own life. When they are involved in these projects, in fact, students see the actual results of their work and experience an increase in self-esteem. This is especially true for younger kids, while students from high school also have the opportunity to determine their learning goals and build their own project around them.
- **Companies** – They play an important role in the professional life of future employees because the STEM skills that students receive as part of their education represent the basis of their training in the jobs of the future. In fact, companies are interested in getting to know potential new employees and in being informed on the type of skills and knowledge they develop at school.
- **Schools** – CWLs represent an interesting activity, which may draw attention to the school and improve its visibility. Testing new teaching methodologies will also make schools more modern, by offering innovative teaching and learning methods, and counteract the education crisis that many public schools are currently experiencing – especially in Italy. Finally, this kind of activity is very

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important to create a network of contacts and relations with other schools, or enhance collaboration between students from different schools.

4.4 CWL Beneficiary Profile Canvas of main stakeholders

Given that the three main groups of CWLs beneficiaries are students, teachers and parents, the following graphs will summarise in a visual form the advantages that they can get from participating in or fostering such activities, and how these benefits succeed in providing an answer to their problems. The graphs are based on the "Customer Profile Canvas" (Osterwalder et al., 2014), which describes a specific segment of customers or beneficiaries in a structured and detailed way, by emphasising in particular the following three elements:

- Jobs: what the customer tries to achieve in his/her work and life thanks to the service offered.
- Pains, i.e. the negative outcomes, obstacles, problems and risks related to the customer's job that he/she may solve by using the offered service.
- Gains, i.e. the advantages and concrete benefits that the customers will get when using or taking advantage of a certain service.

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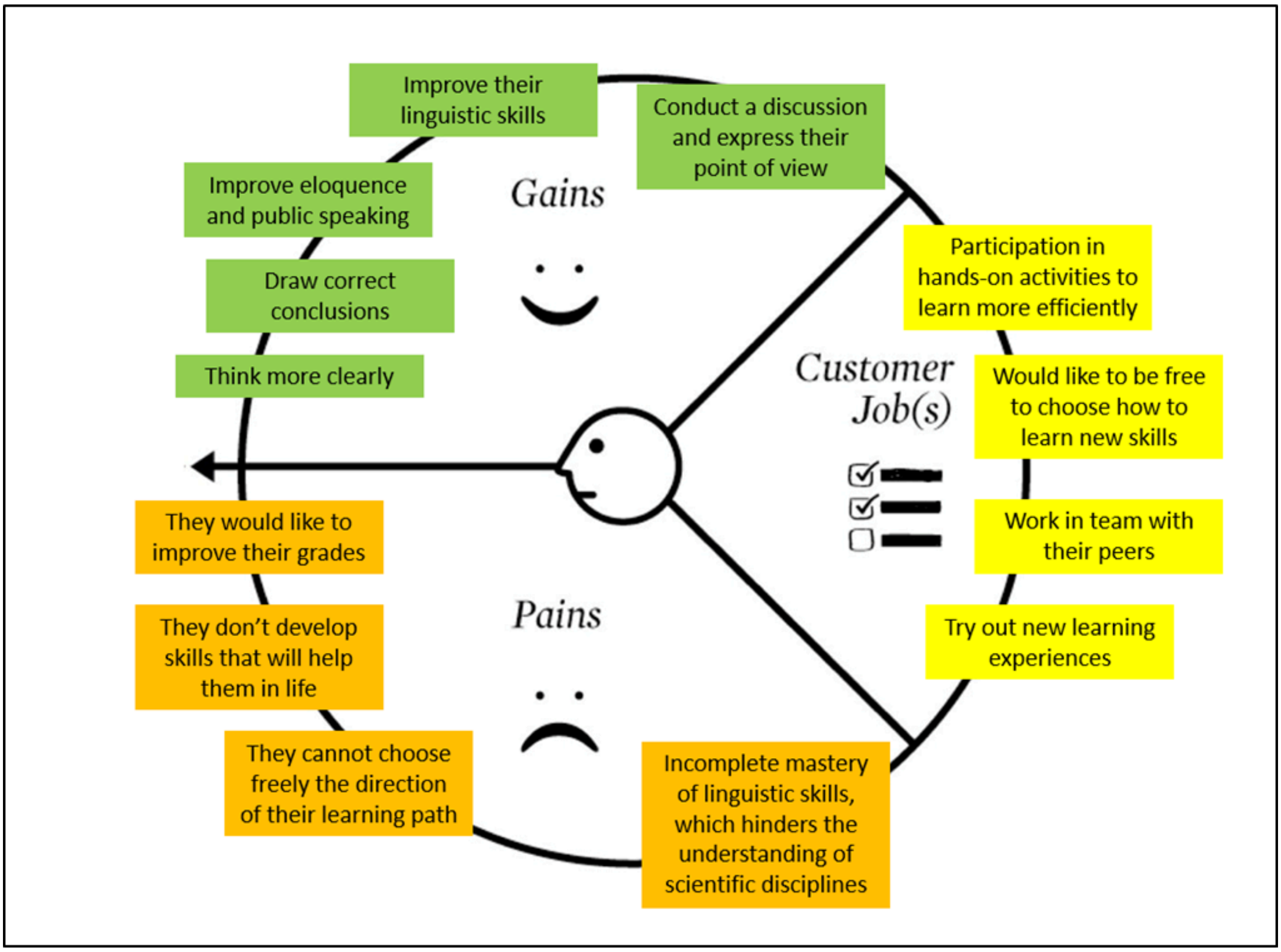
4.4.1 CWL Beneficiary Profile Canvas: Students



Picture 3: Customers Profile Canvas: Students

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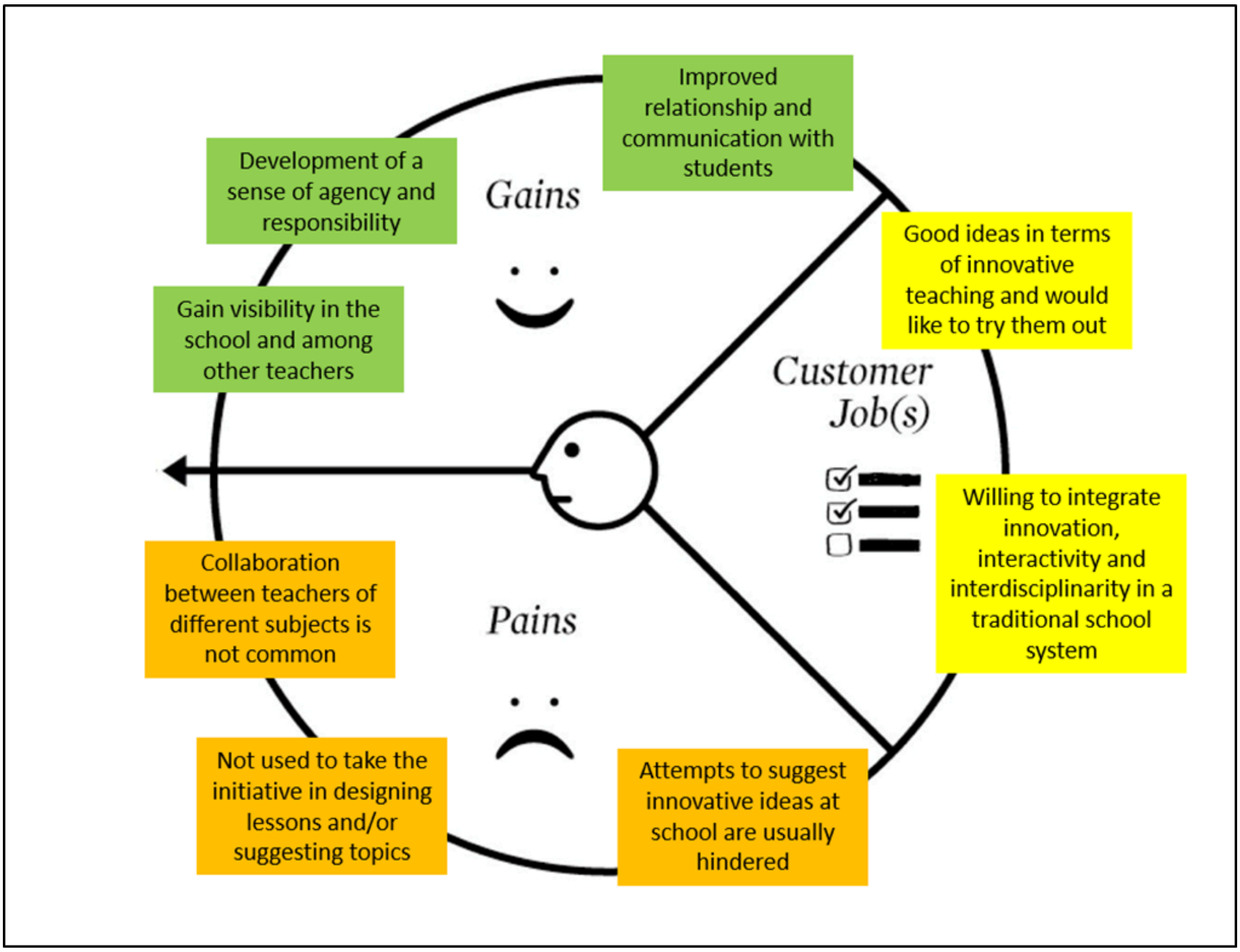
4.4.2 CWL Beneficiary Profile Canvas: Teachers



Picture 4: Customer Profile Canvas: Teachers

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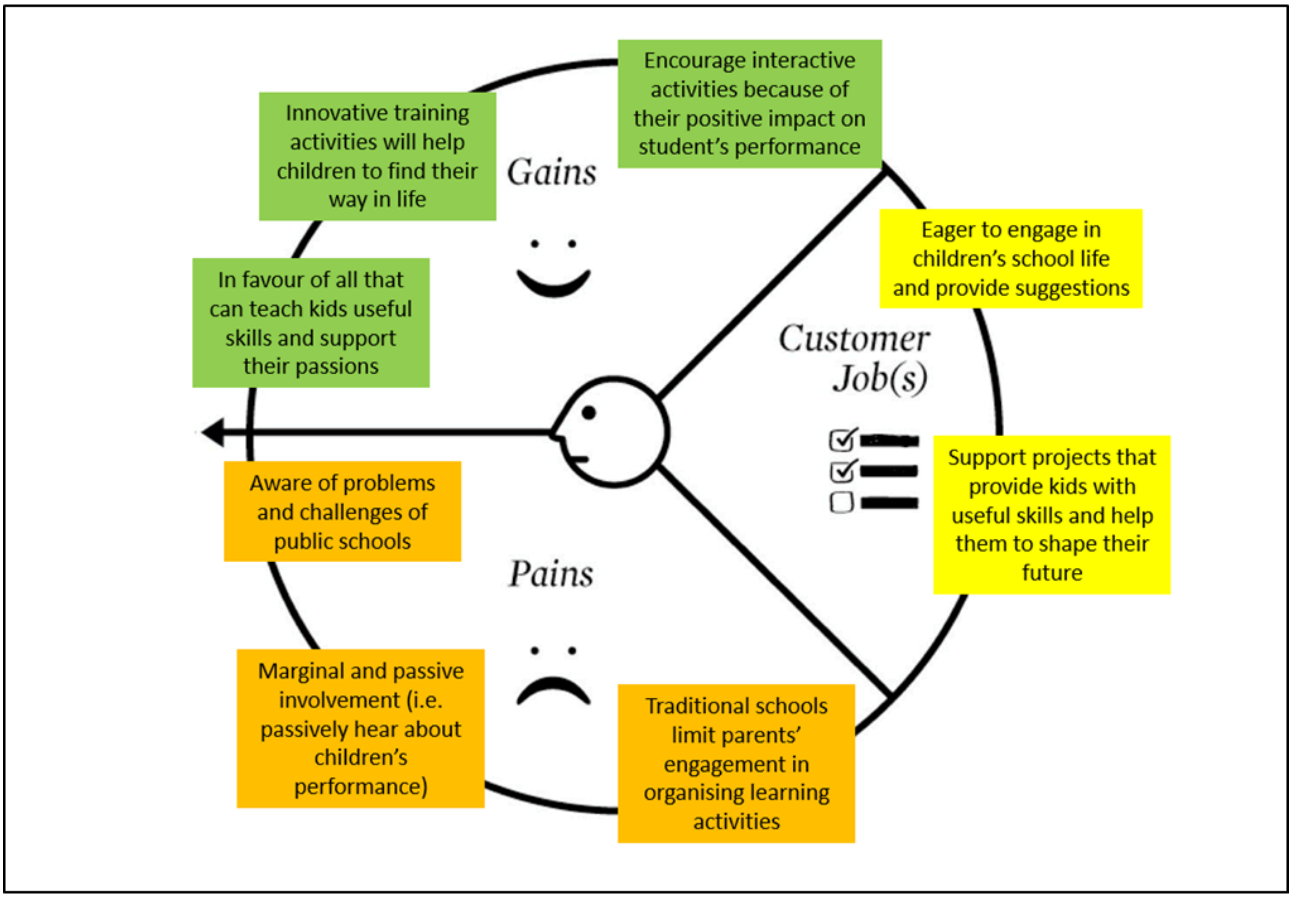
4.4.3 CWL Beneficiary Profile Canvas: Parents



Picture 5: Customer Profile Canvas: Parents

4.4.4 The Creative Writing Laboratory Ecosystem Map

Ecosystem Maps are synthetic visual representations of all the entities and the relationships between them, which characterise the ecosystem in which a certain product is offered and/or a service is supplied. Since their goal is to capture the key roles, the flows and the exchanges connecting them, ecosystem maps can really support in managing the complexity of service design.

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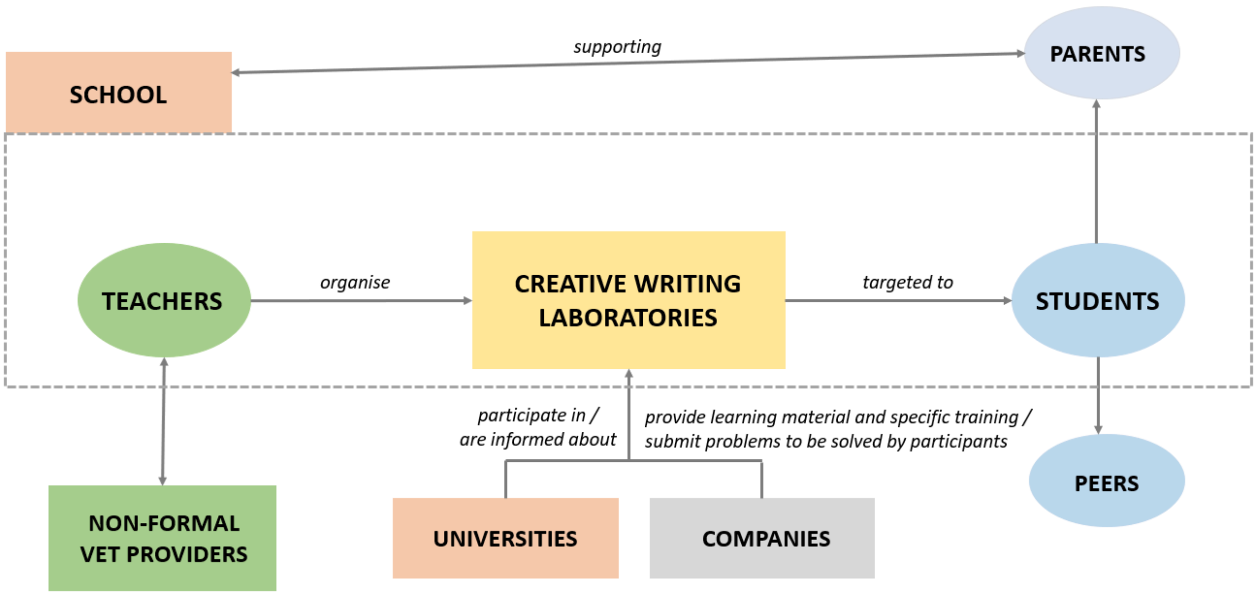
For the service offered by CREAM project, i.e. Creative Writing Laboratories, the following map was designed in order to include all the involved stakeholders and to clearly establish the relations between them.



Picture 6: CWL Ecosystem Map

4.5 Final Remarks

In the final paragraph, the main conclusions and recurrent topics emerging from the focus groups will be summarised so that they can be used for the organisation and implementation of CWLs.

First of all, it would be better to hold CWLs out of curricular school lessons and let students decide whether to participate in them or not, as this will make them feel less constrained and attract only those who are really interested. Besides, CWLs should be offered both as in-presence and online activities in order to reach a wider audience. Another interesting suggestion is to make use of digital and interactive tools (such as presentations, video editing tools, apps for storytelling, etc.) because in general they succeed in catching the students' attention and make them feel more engaged.

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Secondly, the role of the stakeholders will be hereby clarified: students are involved in the organisation and co-design of the activity as this will increase their sense of responsibility; the teachers who have the courage to suggest some form of innovation and interactivity in the learning experience should be adequately rewarded and provided with specific training material on how to carry out CWLs; external actors such as universities and companies will be involved too. The world of work could get a hint on the knowledge and skills that are taught at school, and discover the training needs of future employees.

Thirdly, laboratories should deal with real-life problems and challenges, be based on everyday reality and suggest a problem-based and interdisciplinary approach to learning, emphasising the links between scientific studies and humanities. They need to focus on writing because students often lack linguistic skills and are not able to express themselves in an organic written text. Since the goal is to counteract the growing functional illiteracy, CWLs need to be in line with the participants' interests and, thus, there should be some flexibility in terms of the type of writing exercises: this means that it is not necessary to write down a full text, but other forms of digital expression can be encouraged, such as drafting a blog entry, recording a video, etc.

If carried out efficiently, CWLs can really have a positive impact on students, who will be prompted to continue a scientific career, feel more confident and motivated to study, learn skills that will be useful in their future professional life and, most importantly, notice a change in their mindset because such activities will help them look at the external world in a more mindful way, understand real-life problems and challenges, and identify possible solutions. But for a CWL to be successful, two basic conditions need to be satisfied: ensuring that there is enough time to carry out the activity and provide a follow-up, and giving it a structured approach so that participants have the opportunity to receive feedback for the work accomplished.

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5 Definition of AI

5.1 Understanding AI

Artificial Intelligence (AI) refers to the creation of machines and systems that can perform tasks typically requiring human intelligence. These tasks include recognizing patterns, processing language, problem-solving, and decision-making. AI encompasses multiple subfields, including machine learning, natural language processing, robotics, and computer vision. At its current stage, AI has evolved from basic automation and rule-based systems to sophisticated models that can learn and adapt, generating outputs and insights from large datasets. Today's AI can autonomously perform a wide array of tasks, ranging from analyzing data trends to generating human-like text, making it a versatile tool in various industries, including education.

5.1.1 Importance of AI in Education

AI's relevance in education, especially in STEM (Science, Technology, Engineering, and Mathematics), cannot be overstated. As AI technologies advance, their integration into educational environments transforms how content is delivered and understood. In STEM education, where abstract concepts often require visualizations, step-by-step problem-solving, and personalized guidance, AI can play a critical role. For educators, AI offers tools to enhance lesson planning, track student progress, and adapt content to fit individual learning needs. By understanding AI's potential and ethical implications, educators can better utilize these tools to enhance creativity, engagement, and comprehension among students.

5.2 History of AI

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5.2.1 Early Foundations

The notion of artificial beings and intelligent systems is deeply rooted in human history and culture, often appearing in literature, mythology, and philosophical works. Stories like Mary Shelley's *Frankenstein* (1818) and Karel Čapek's play *R.U.R.* (Rossum's Universal Robots, 1920) explore themes of creating artificial life, questioning the moral and ethical implications of such endeavors. These early works highlight humanity's longstanding fascination with the concept of creating intelligent machines.

5.2.2 The Birth of Modern AI

AI as a scientific field took shape in the 1950s. The 1956 Dartmouth Conference is widely recognized as the birthplace of AI, where researchers like John McCarthy, Marvin Minsky, Nathaniel Rochester, and Claude Shannon came together to discuss the possibility of creating machines that could simulate human intelligence. Alan Turing's earlier work, especially his paper "Computing Machinery and Intelligence," laid the foundation by introducing the concept of machines that could "think" and the Turing Test, a criterion for evaluating a machine's ability to exhibit intelligent behavior indistinguishable from a human's.

5.2.3 Evolution of AI Technologies

From the 1960s onward, AI research progressed through several phases, from symbolic AI that relied heavily on rule-based systems to the machine learning boom of the 1980s and 1990s. The limitations of earlier AI systems, such as their rigidity and inability to scale, led to the development of machine learning, which allows systems to learn from data. The 21st century saw the rise of deep learning, powered by increased computational power and large datasets. Modern AI systems like GPT-4 can now generate human-like text, recognize images, and even create artistic works, demonstrating a leap in both capability and application.

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5.2.4 AI in Education: A Historical Perspective

AI's introduction into education began with early experiments in intelligent tutoring systems (ITS) in the 1980s and 1990s. These systems aimed to provide personalized instruction, adapting to the learner's pace and knowledge level. Although early ITS were limited in scope, they laid the foundation for AI's broader applications in education today. As AI matured, its role expanded to include content generation, assessment, adaptive learning, and enhancing student engagement through storytelling and creative writing. By embedding STEM concepts within narratives and interactive simulations, AI supports more effective teaching strategies tailored to diverse learning needs.

5.3. Advantages and Disadvantages of AI in Learning and Teaching

5.3.1 Advantages of AI in Education

5.3.1.1 Personalized Learning Experiences

One of the most prominent benefits of AI in education is the ability to deliver personalized learning experiences. AI algorithms can analyze individual student data—ranging from performance metrics to engagement levels—and adapt instructional content accordingly. In STEM subjects, where students often face different challenges based on their prior knowledge and learning styles, this personalization is crucial. For example, AI-driven platforms like adaptive learning

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systems can present a math problem in different ways based on the student's understanding, ensuring that the content is neither too easy nor overly challenging.

5.3.1.2 Instant Feedback and Support

Another key advantage is the provision of instant feedback. AI systems can analyze student responses in real time, identify mistakes, and provide corrective guidance. For instance, AI-powered writing tools can help students improve their scientific writing by suggesting edits, enhancing clarity, and refining structure. This immediate feedback loop helps students learn from their errors and encourages continuous improvement. In STEM education, where timely feedback is essential for mastering complex concepts, AI provides a significant advantage.

5.3.1.3 Enhanced Teacher Efficiency

AI systems can hading assignments and tracking student progress, which traditionally consume a significant amount of educators' time. By automating these processes, teachers can focus on more creative and engaging aspects of education, such as crafting personalized lesson plans, fostering class discussions, and guiding hands-on activities. For example, AI tools can automatically assess student work based on pre-defined rubrics, allowing teachers to focus on providing deeper, qualitative feedback where it matters most.

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5.3.1.4 Data-Driven Decision Making

AI's capability to analyze vast datasets allows educators to make data-driven decisions that enhance instructional quality. By analyzing patterns in student behavior, learning outcomes, and engagement, AI systems can identify gaps in understanding or areas where a particular teaching method might be falling short. For example, an AI system could analyze test scores and classroom interaction data to recommend adjustments to the curriculum, such as re-emphasizing certain concepts or introducing alternative teaching materials.

5.3.2 Disadvantages of AI in Education

5.3.2.1 Bias and Ethical Concerns

One significant concern surrounding AI is the potential for bias. AI systems are only as unbiased as the data they are trained on, and if the training data reflects existing societal biases, the AI's outputs will likely perpetuate these biases. This can manifest in educational contexts through unfair grading practices, biased recommendations, or exclusionary content. For instance, if an AI-based learning platform is trained on datasets predominantly featuring examples from a specific cultural background, students from other backgrounds might find the content less relevant or harder to engage with.

5.3.2.2 Privacy and Data Security

AI systems rely heavily on data, much of which is sensitive, such as student performance records, learning preferences, and behavioral insights. This raises significant privacy and security concerns. If improperly managed, this data could be misused, leading to breaches of student privacy. Educational institutions need to implement stringent data protection protocols to ensure that AI applications are secure and comply with ethical standards.

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5.3.2.3 Lack of Human Interaction

While AI can enhance learning, it cannot replace the human elements that are integral to effective education, such as empathy, mentorship, and emotional support. A potential pitfall of relying too much on AI is the depersonalization of learning. Education is not just about transmitting information; it's also about nurturing relationships, fostering collaboration, and building social skills. Over-reliance on AI could lead to a learning environment that is efficient but lacks the depth and warmth of human interaction.

5.3.2.4 Job Displacement Concerns

As AI becomes more capable, there are concerns about its impact on jobs within the education sector. While AI can handle administrative tasks and support personalized learning, there is a fear that it could lead to the reduction of teaching roles. However, the reality is more nuanced. AI is likely to change, rather than eliminate, the roles of educators. Teachers will increasingly need to focus on higher-order tasks such as mentoring, coaching, and fostering critical thinking, complementing the AI's role in managing data-driven and repetitive tasks.

5.4. Practical Applications of AI in Teaching STEM through Storytelling

5.4.1 Intelligent Tutoring Systems (ITS)

Intelligent Tutoring Systems (ITS) are AI-powered platforms designed to provide personalized instruction, often using storytelling elements to enhance engagement. For example, an ITS teaching physics might involve a narrative where the student is a detective solving a mystery using principles like force, motion, and energy conservation. As students navigate the storyline, the AI tailors questions and challenges based on their proficiency, adjusting the narrative and difficulty level dynamically to ensure a customized learning experience.

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5.4.2 AI-Generated Content and Narratives

AI can generate narratives and scenarios that embed STEM concepts within engaging stories. For example, an AI could create a fictional narrative about an engineer designing a sustainable city, incorporating real-world concepts related to civil engineering, environmental science, and urban planning. Students could interact with the story by making decisions that affect the outcome, allowing them to explore STEM principles in a contextual and engaging manner. This not only reinforces learning but also cultivates creativity and critical thinking.

5.4.3 Interactive Visualizations and Simulations

In STEM education, understanding complex systems and processes is often aided by visual representations. AI can generate interactive simulations where students can experiment with variables and see outcomes in real-time. For example, an AI-driven virtual lab might allow students to explore chemical reactions by adjusting concentrations, temperatures, and other factors, observing the effects instantaneously. These simulations can be narrated with AI-generated stories, placing students in roles like that of a lab scientist or engineer working on real-world problems.

5.4.4 Personalized Writing Assistance

AI-driven tools can assist students in improving their technical writing skills, particularly in areas like scientific reporting and documentation. For example, a student working on a lab report might receive AI-generated feedback on the clarity, structure, and accuracy of their explanations. The AI can highlight sections that lack

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coherence or suggest better ways to present data, enhancing the student's ability to communicate scientific concepts effectively.

5.4.5 Collaborative Storytelling Platforms

AI can support collaborative storytelling initiatives that involve integrating STEM principles into creative narratives. For instance, platforms that combine AI with collaborative writing tools can allow students to co-author stories with scientific themes. A group of students might create a science fiction tale exploring the implications of space exploration, with AI suggesting plot points based on scientific accuracy and logical coherence. Such activities encourage teamwork, research, and creativity, making STEM learning more holistic.

5.4.6 AI-Enhanced Assessment Tools

AI systems can streamline the assessment process by automatically grading assignments and providing detailed feedback. For example, AI could analyze essays or project reports not only for grammatical correctness but also for scientific accuracy and logical argumentation. This allows educators to focus on guiding students through more complex concepts, rather than getting bogged down in repetitive assessment tasks. AI can also provide adaptive assessments, where the difficulty of questions is adjusted in real-time based on student responses, ensuring that assessments are both challenging and fair.

5.4.7 Gamification of STEM Learning

Gamification involves turning learning activities into game-like experiences, where students earn points, unlock levels, and compete in challenges. AI can be integrated into these gamified systems to make the learning process more adaptive and responsive. For example, in a game focused on environmental science, AI could generate dynamic scenarios where students must balance economic growth with ecological sustainability. The AI could adjust the difficulty and complexity based on the

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student's performance, ensuring an engaging and educational experience that evolves with the learner.

5.4.8 Storytelling as a Pedagogical Tool

Storytelling is a powerful tool for making STEM subjects relatable and accessible. AI can help educators craft compelling narratives that link abstract concepts to real-world applications. For example, a narrative exploring the history of electricity could follow a young inventor learning about circuits and energy principles, with AI suggesting adjustments to make the story more educationally relevant. These stories can be interactive, allowing students to make decisions that affect the narrative, thereby reinforcing the learning objectives while maintaining engagement.

5.5. Ethical Considerations and Future Directions

As AI becomes more integrated into education, ethical considerations regarding its implementation become increasingly important. Issues such as bias, privacy, and the digital divide must be addressed to ensure that AI benefits all students equitably. Moreover, as AI continues to evolve, educators and developers must collaborate to develop systems that are transparent, fair, and aligned with educational values.

Looking forward, the role of AI in STEM education is likely to expand. Future AI systems could provide even more sophisticated narrative experiences, incorporate virtual reality elements, and offer more seamless integration with traditional educational practices. The key will be balancing technological innovation with pedagogical goals, ensuring that AI enhances rather than overshadows the human aspects of education.

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6 Conclusions and next steps

Conclusions:

Desk Research allowed Partners to identify a large variety of educational ideas, services and resources, which may inspire them and facilitate the development of CWL stories in the next project phases. Most of them come from non-formal education and are highly applicable in the Open Schooling process. The majority of sources and authors critically assess the current educational system, which is largely based on a fixed curriculum and mostly one-directional transmission of knowledge. In these circumstances, efficient development of 21st-century skills and competencies (creativity, communication, teamwork, critical thinking) is highly problematic, if carried out only within the current school environment. Furthermore, education is a system that is highly complex, interlinked at different levels (primary, secondary, undergraduate, and graduate), which makes any modification of the formal learning curriculum pretty difficult. The system is also deeply rooted in society and tradition and involves a few stakeholder groups (students, teachers, parents and, often indirectly, employers) who also formulate expectations regarding the goals of education and teaching strategies. It leads to a paradoxical situation: although the recent large-scale research shows that neither parents and students, nor employers wish curriculum to remain traditional, all the same it is very difficult to change the current system. Amongst many reasons, the biggest obstacles seem to be the inertia of the traditional schools and the resistance to the introduction of innovative teaching activities that many teachers are faced with when trying to implement such activities in traditional scholastic systems.

Therefore, the only effective way to develop critical 21st-century skills seems to be incremental, ground root activities, based on the understanding and commitment of all the above-mentioned groups. An opportunity and all the same a challenge for the education transformation process is the wide availability of many digital tools, educational content, and partially or full-fledged ideas.

The bottleneck in this process may be the teachers, who not only would have to update their digital skills and theoretical knowledge about education, but would also have to modify the way they have delivered their lessons often for a long time. To

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address this issue teachers should be equipped with some preparatory and training material (e.g. how to conduct an effective workshop, or CWL in context of CREAM projects). The positive information commonly expressed by many students is that young people at large yearn for different types of learning activity than traditional lessons: workshops, competitions, groups projects are properly arranged and are then long remembered.

A big challenge to the transformation of education is how to find enough time and organizationally arrange creative activities at school given the current tight school program focused on fixing curriculum and passing exam priorities.

A common objection raised largely by students is that the subjects and topics they learn will not be useful in their future life and especially in their future work. Though in general not necessarily true, this belief is behind many students' decision to leave higher education, in particular STEM. To counteract this negative tendency, educational content should present topics and problems which have a direct impact on students' life and work. In addition, starting from the secondary education level (or even earlier) they should be familiarised at school with what the people currently do in different professions and which competencies are required. To this end, first hand experience is critically needed, as teachers usually do not know other occupations. Industry and corporations are rather not likely to address this issue at the secondary education level, as they are primarily interested in hiring university students. However, many parents, if encouraged by school, could present their job characteristics to the students. In general, active parents' interest in their children's education and cooperation with teachers and schools at the secondary education levels seems to be necessary to change current education systems. Parents' engagement may lead to the organisation of free extra curricular activities on a voluntary basis.

Workshops, debates and other non traditional teaching initiatives, CWLs being an example, can have a positive impact on students, who will be prompted to continue a scientific career, feel more confident and motivated to study, learn skills that will be useful in their future professional life and, most importantly, notice a change in their mindset because such activities will help them look at the external world in a more mindful way, understand real-life problems and challenges, and identify possible solutions.

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The urgent educational need, clearly noticed by many people, is critical information assessment. Currently, when the majority of news are fake, or biassed, or carefully selected to support an advanced formulated thesis, the people (especially young) are highly vulnerable to manipulation and unwanted marketing. Not only it leads to wrong decisions or distorted views on life, but also may negatively impact the teenager's mental health.

Next steps

After the PR1 exploratory, research phase, whose results are described in this report the consortium will proceed with the following actions:

- The development of the CREAM Creative Writing Laboratory model with a co-design approach in which partners will play with personas, their journeys and relationships, and define an approach that is tailored to different users' needs. The objective behind this activity is to create CWL session scenarios, which would possibly correspond well to real-life situations and relations between involved persons (students, teachers, parents, educators, industry representatives). We will define roles, relationships, methods and rules of CWL.
- The next step will be the implementation of pilots of the CREAM CWL model in schools in Italy, Poland, Slovenia, Greece and The Netherlands. Based on experience and evidence gathered during these pilots, we will finalise the model definition, as well as gather evidence and stories in order to further promote the model.
- Finally we will make the CWL model available for the public: schools and educational environment (as main target users) and policy makers, and promote it within the broad educational community. To this end, a few documents will be produced, made publically available and shared: (i) Guidelines for replication of CREAM CWL model, (ii) a practical manual (with toolkit) for schools to guide them in the replication of CWLs model, and (iii) a policy brief addressed to policy makers (expected towards the project end in 2024). All this material will be shared by major open educational resources, the project webpage and social media profiles as well as the partners' dissemination channels (institutional WebPage, contact with schools and teachers).

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