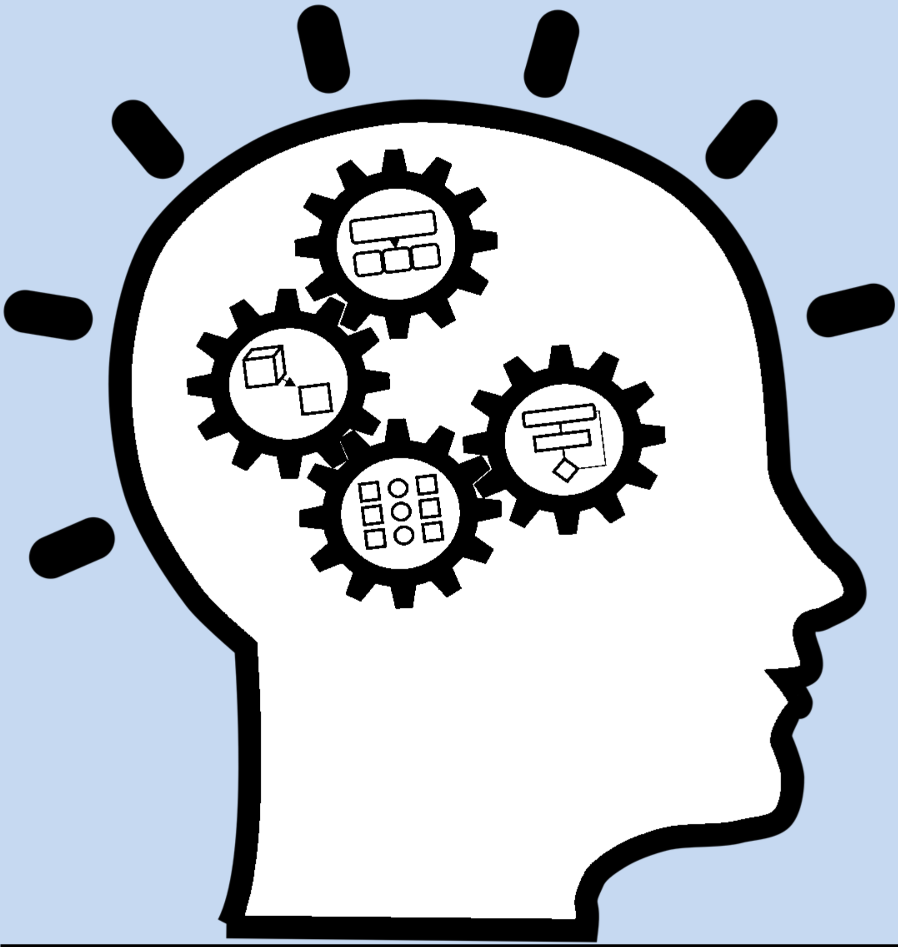
UNIVERSITY OF THE AEGEAN

LTEE lab
University of the Aegean
ltee.aegean.gr



Computational Thinking Integration Guide for Secondary Education Teachers

Version F.01

August 2022

ComputT
Computational Thinking at School

Erasmus+ KA201 Project: 2019-1-EL01-KA201-062883

Co-funded by the Erasmus+ Programme of the European Union

ΙΔΡΥΜΑ ΚΡΑΤΙΚΩΝ ΥΠΟΤΡΟΦΙΩΝ
ΙΚΥ

Computational Thinking Integration Guide for Secondary Education Teachers

Version F.01

Published by University of the Aegean – Laboratory of Learning Technology and Educational Engineering as deliverable of the “Computational Thinking at School” - “CompuT”, Erasmus+ KA201 project - Project Code: 2019-1-EL01-KA201-062883.

Authors:
Fesakis George, Prantsoudi Stavroula, Mavroudi Elisavet,
Volika Stamatia, Kefalas Ioannis

Learning Scripts edited by:
George Fesakis, Stavroula Prantsoudi, Elisavet Mavroudi, Konstantinos Zervas, Ioannis Kefalas, Georgia Papamargariti, Alexandra Papamargariti, Evangelia Stamatarou, Manuel Toro Casaucao, Kristine Feness, Monica Langeland, Sabine Lauw, Borghild Marie Opdahl, & Trude Sætveit

Learning Scripts Evaluations and Reflections by:
Anastasios Savas, Vasileios Kasapidis, Monica Langeland, Stavroula Prantsoudi,

August 2022

To cite this work:
Fesakis, G., Prantsoudi, S., Mavroudi, E., Volika, S., Kefalas, I. (2022). *Computational Thinking Integration Guide for Teachers* (5th ed.). Rhodes, Greece: University of the Aegean - LTEE Lab.

CompuT

Computational Thinking at School

Partners:

Directorate of Secondary Education in Dodecanese

University of the Aegean, Laboratory of Learning Technology and Educational Engineering (LTEE), Rhodes, Greece

2º Upper Secondary School of Rhodes, "Kazoulleio", Rhodes, Greece

Secondary School of Gennadi, Rhodes, Greece

Secondary School of Zipari, Kos, Greece

CEP La Laguna, Tenerife, Spain

IES EL SOBRADILLO, Tenerife, Spain

Fyllingsdalen videregående skole, Bergen, Norway

Agrupamento de Escolas de São João da Talha, Lisbon, Portugal

Table of Contents

1. Introduction

The purpose of the present Teachers' Guide is to provide some key information concerning the concept of Computational Thinking (CT) and its integration in the education practice. The Guide has been developed within the framework of the "Computational Thinking at School" - "CompuT", Erasmus+ KA201 project [Project Code: 2019-1-EL01-KA201-062883] and will serve as a map to guide all teachers and stakeholders involved in the project to: a) get acquainted with the concept of Computational Thinking and its dimensions, b) understand and reflect on the role it can and should play both in modern education and science, and finally, c) get familiar with the methodology and develop techniques for integrating Computational Thinking in everyday teaching practice.

The guide also suggests several resources and existing repositories of educational scenarios that have been developed in the course of relative initiatives for the integration of CT in education. In addition, the guide provides an appendix that will be listing the scenarios that will have been developed by the participating partners in the context of the CompuT project.

The rest of the document is structured as follows; Section 2 provides an overview of the various definitions of CT as well as of the important milestones in the evolution of the concept. The various dimensions of the concept are described and briefly explained in the section. Section 3 describes the rationale on how CT interacts with Computational Science and how CT constitutes a basic method of producing science. Section 4 deals with the very important issue of the integration of CT into education; the clarification of the meaning of the term, the difficulties involved, the role of the teachers, the current situation in European countries as well as our approach within the framework of the project (in-service training with tests in field). Development of Computational Thinking Education has become an area of many initiatives in recent years, several of which are presented in Section 6.

2. The concept of Computational Thinking

Although Computational Thinking has gained popularity in recent years, the concept is not new and its history in Computer Science can be traced back to separate time points in the past. Known from the 1950s and 1960s as "Algorithmic Thinking", it can be argued that CT is a way of thinking through which problems are formulated as input-to-output conversions and algorithms are sought to implement these conversions. (Denning 2009).

Two great pioneers in computer education, Alan Perlis and Seymour Papert, have highlighted the value of computer programming knowledge since the discussions of the 1950-1990 period (Grover & Pea, 2013), also motivated by the 1980s computing sciences movements (Tedre & Denning, 2016). It is worth recalling here that personal computers appeared in the 1970s and spread in the 1980s. Back in 1962, Alan Perlis was the first to put forth the idea that all college students should understand computation theory and learn computer programming as a medium to study a wide variety of other topics, more effectively (Guzdial, 2008). A few years later, in 1967, Papert (1991) created LOGO programming language specially designed as an alternative approach to mathematics teaching and algorithmic thinking. In the years that followed, Papert, made popular the idea of programming as a means of developing algorithmic thinking, promoting his robotic turtle and LOGO programming language in the context of K–12 education (Papert, 1996).

In 2006, the publication of Jeanette Wing's homonymous article in Communications of the ACM (Wing, 2006) brought the concept of Computational Thinking back to the forefront. In that article it is stated that “Computational thinking involves solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science” (Wing, 2006). Wing claimed that “CT represents a universally applicable attitude and skill set that everyone, not just computer scientists, would be eager to learn and use”, thus generating a still ongoing international debate on the nature of CT and its role in education (Barr & Stephenson, 2011; Grover & Pea, 2013; Kalelioglu et al., 2016).

In related workshops organized by both the US National Research Council (NRC) and associations such as CSTA and ISTE (NRC, 2010; CSTA & ISTE, 2011) participants failed to agree on key definitions and expressed differing views on the purposes and nature of CT (NRC, 2011). To move the discussion forward, in 2011 Wing proposed a new definition of CT according to which “Computational thinking is the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent” (Wing, 2011). Wing’s arguments about the importance of CT are developed along two axes: i) On the one hand, CT provides people with a set of skills, techniques, methods, and attitudes to solve a wide range of problems. ii) On the other hand, CT confronts us with the challenge of machine intelligence asking for what people can do better than machines and what machines are better than humans at.

As the debate on the scope of Computational Thinking broadened, other definitions also emerged. Aiming at creating an “operational definition”, that is, a list of the key concepts and skills related to CT, along with examples of how these could be incorporated into different subjects, CSTE and ISTE, presented CT as a problem-solving process that includes characteristics, such as formulating problems in a way that enables people to use a computer and other tools to help solve them, organizing and analyzing data logically, representing data through abstractions, such as models and simulations, automating solutions through algorithmic thinking, etc. (ISTE & CSTA, 2011). Royal Society (2012) has proposed another definition, according to which Computational Thinking is not only a human construct but is also present in nature, which performs calculations in the sense of transforming information representations such as in the process of DNA transcription. According to this definition, “Computational thinking is the process of recognizing aspects of computation in the world that surrounds us and applying tools and techniques from Computer Science to understand and reason about both natural and artificial systems and processes” (Royal Society, 2012). Only as recently as 2016, CSTA issued the CSTA K-12 Computer Science Standards, which -among others- states that Computational Thinking "is a problem-solving methodology that extends the "kingdom" of computer science to all disciplines, offering the tools for analyzing and developing solutions to problems that can be solved through computation. With a focus on abstraction, automation and analysis, CT constitutes a key component of the broader IT field” (CSTA, 2016).

Despite the efforts of scientists and institutions, the scientific community has not yet come to a commonly accepted definition (Rose et al., 2017; Weintrop et al., 2016; Fessakis et al., 2018) and many issues, concerning both the concept and the related dimensions and practices (Lye & Koh, 2014; Fesakis, et al. 2018), as well as the human resources involved in its development and teaching, remain open (Barr & Stephenson, 2011). CT competence development is nowadays widely recognized as a central issue in education by the scientific community and the policy makers (Freeman et al., 2017; Parliamentary Standing Committee on Education, 2016) the proper approach of which requires systematic and multi-faceted research.

2.1. The CT dimensions

The structural dimensions that constitute Computational Thinking, as well as the skills that are associated with it, have not yet been fully elucidated and are being actively discussed, while large body of publications are still being produced on the field. In her homonymous article, which sparked a renewal of interest in the concept, Wing suggested that all aspects of Computational Thinking include abstraction, problem decomposition, pattern recognition, algorithmic thinking, and logical thinking (Wing, 2006). Isbell and Stein followed, arguing that CS curricula should be revised to include basic skills in modeling, scaling, simulation, abstraction, automation and data interpretation, a set of skills also known as the **computationalist mindset** (Isbell, et al., 2009). CSTA and ISTE suggested that Computational Thinking consists of 9 basic dimensions and corresponding skill areas, such as data handling (collection, analysis, representation), problem decomposition, abstraction, algorithms and procedures, automation, parallelism, and simulation (CSTA & ISTE, 2011).

A reasonable question that arises, therefore, is whether CT is an umbrella concept describing the loose assembly of pedagogically significant dimensions of CS, a practice of CS, or a distinctive entity concerning a specific kind of thinking in the context of computation. The debate on the dimensions of the concept continues and several other sets of dimensions have been proposed from time to time, exacerbating the ambiguity still surrounding the conceptual framework (NRC, 2010; Barr & Stephenson, 2011; Grover & Pea, 2013; Selby, 2015).

In 5 popular papers published in the field, it is suggested that Computational Thinking consists of the dimensions presented in Table 1.

Table 1. Proposed Sets of Dimensions of Computational Thinking

Barr & Stephenson, 2011	**Lee, et al., 2011**	**Grover & Pea, 2013**	**Selby & Woollard, 2013**	**Angeli, et al., 2016**
Abstraction	Abstraction	Abstraction and patterns generalization	Abstraction	Abstraction
Algorithms & Procedures		Algorithmic notions of flow control	Algorithmic Thinking	Algorithms (includes sequencing and flow control)
Automation	Automatization			
	Analysis			
		Conditional logic		
Problem Decomposition		Structured Problem Decomposition (Modularizing)	Decomposition	Decomposition
		Debugging and systematic error detection		Debugging
		Efficiency and performance constraints	Evaluation	
			Generalizations	Generalization
		Iterative, recursive, and parallel thinking		

Parallelization				
Simulation				
		Symbol systems & representation		
		Systematic processing of information		

Informal definitions for CT dimensions, based on what is stated in the specific publications, can be considered as follows (Table 2).

Table 2. Basic CT Dimensions Definitions

CT Dimension	**Definition**
Abstraction	The process of simplifying an object by ignoring the unnecessary details to make it easier to understand. Trying to hide details without altering the representation.
Algorithmic Thinking	Method of achieving a solution by clearly defining the steps.
Automation	Performing repetitive commands quickly and efficiently through a computer. Computer programs = "automation abstractions".
Decomposition	Breaking problems down into smaller parts that may be more easily solved. Understand, resolve, develop and evaluate the parts individually.
Debugging	Systematic application of analysis and evaluation using testing, tracing, and rational thinking to predict and verify results.
Generalization	Identify patterns, similarities and links and exploit these characteristics. Quickly solve problems based on previous solutions to similar problems.

Concerning the classroom curriculum level, and the design of learning activities, CT is perceived as a complex, multidimensional concept. Fessakis et. al. (2018) attempted to provide the union of the proposed sets of CT dimensions. Hence, the set of dimensions, which the various definitions seem to highlight, include: creative problem solving, algorithmic approach to problem-solving, problem solution transfer, logical reasoning, abstraction, generalization, representation and organization of data, systemic thinking, evaluation, social impact of computation. In the same publication, the dimensions of Computational Thinking included in various initiatives of CT in education already implemented worldwide (Teaching London Computing, Computing at School, CSTA & ISTE) were combined to form the set of dimensions which is shown in Table 3.

A short description of each dimension along with some resources and examples of scenarios are presented in Appendix I.

Table 3. Proposed set of CT dimensions

Algorithmic Thinking (AL)
Abstraction (AB)
Generalization (GE)
Logical reasoning (LR)
Pattern matching (PM)
Problem decomposition (PD)
Problem translation (PT)
Evaluation (EV)
Representation (RE)
Data collection (DC)
Data representation (DR)
Data analysis (DA)
Modeling (MO)
Simulation – (SIM)
Automation (AUT)
Sequencing (SE)
Testing (TE)
Understanding People – (UP) // Includes Artificial Intelligence (AI)

Concluding the discussion on the meaning of CT, one can deduce that, despite the numerous definitions proposed, CT remains an ambiguous term for most teachers. In the context of the CompuT project, CT is not considered a distinctive entity concerning a specific kind of thinking, like e.g., spatial thinking, logical thinking etc. CT is not either considered an umbrella concept describing the loose assembly of pedagogically significant dimensions of CS. In the context of CompuT, CT concerns the use of Computer Science concepts, methods, and techniques as part of the methodology of other disciplines. Computational Thinking nowadays is considered rather a mindset than a distinct way of thinking in terms of cognitive science. Furthermore, epistemologically, CT is an interdisciplinarity mean. More specifically, CT is a Computer Science practice (Denning, 2009; Denning & Martell 2015), concerning the application of computation as a problem solving and epistemological mean in several disciplines. This approach also reflects the interaction of CT with Computing Science.

3. The scientific significance of CT

Back in 1982, the Nobel Prize in Physics was awarded to Ken Wilson for his work on the development of computational models that simulated the phase transitions in materials (https://www.nobelprize.org). Wilson worked with scientists in other fields and, by promoting computational simulation -previously unavailable mode of science-identified Computing as a key pillar of science, along with theory and experiment (Kadanoff, 2013). Earlier, in 1969, as the director of the Software Engineering Division of the MIT Instrumentation Laboratory, Margaret Hamilton contributed to the history of mankind, by leading the software team that landed astronauts on the moon. In the context of the development of NASA's Apollo spaceship navigation and guidance system, Hamilton and her team implemented a series of physical and digital simulations and developed appropriate algorithms for controlling cyber-ship systems (Cameron, 2018).

The course of Computing Science has continued to grow and its contribution to the sciences and engineering has become more significant. Most recently, in 2017, Rainer Weiss, Barry Barish and Kip Thorne were awarded a Nobel Prize in Physics "for decisive contributions to the LIGO detector and the observation of gravitational waves". The LIGO probe experimentally confirmed the scientific model of a natural phenomenon, gravitational waves (Abbott et al., 2016), formulated 100 years earlier by Einstein and led to the need for revision of the hitherto known models of the universe, since it detected more black hole collisions than those predicted by Einstein's gravitational wave model (Lee, 2018). Computational methods were also employed by Katie Bouman and her colleagues, astronomers, physicists, mathematicians, and engineers, who collected 5 Petabytes (5,242,880 Gigabytes) of data from a network of 8 telescopes installed on 4 different continents as part of the Event Horizon Telescope project (EHT) of MIT. These data were submitted for processing by algorithms created specifically for this purpose and resulted in the publication of the first photograph of a black hole in April 2019 (MIT News, 2019).

In the already existing collaboration of science with engineering to model natural or artificial phenomena, Computing Science has added the ability to control the machines made by engineers to mimic the models created by scientists as representations of natural phenomena (Lee, 2018). As early as the mid-1980s, universities began to establish new departments under the title of “Computing Science”, independent of the existing "Computer Science" departments, reinforcing the distinction between the two disciplines. It is indicative that, nowadays, accepted scientific research can be carried out in fully controlled in vitro environments, through clinical studies in living organisms (in vivo), but also exclusively on a computer or through computer simulations (in silico). The term in silico was first used in public back in 1989, to characterize “experiments solely carried out by a computer”, thus introducing a new way of producing science in the research world.

Computational Thinking, then, is not just a tool available to scientists, but a way of doing science and has gradually been recognized by other sciences, not as a concept derived from Computer Science, but as a concept derived from science itself, and is essential to the advancement of science (Denning, 2009). Computers are tools and not the subject of study and Computing, as "the process of recognizing the forms of computing around us and applying computing tools and techniques for understanding and reasoning about natural and artificial systems and processes" (Royal Society, 2012), constitutes a basic method of producing science.

This new, inevitable, way of producing science was not available until recently and its advent has allowed scientists to experiment, both in the virtual and in the real world, with new solutions and problem-solving strategies. By combining computers with

Computer Science concepts and practices, scientists of all disciplines have the appropriate epistemological tools to solve interdisciplinary problems in the context of other knowledge fields. This combination may also constitute the conceptual framework for the wider use of Computer Science in general education, given its view as the fourth major scientific field, together with the Natural Sciences, Social Sciences and Life Sciences (Rosenbloom, 2004), but also because of its central position within the interdisciplinary approach to education and training in the fields of STEAM (Science, Technology, Engineering, Arts & Mathematics) (Fesakis et al., 2018; Henderson, Cortina, Hazzan, & Wing, 2007).

It is beyond doubt that in any future society, the development of Computational Thinking will be a strategic asset for scientific and technological progress. The Center for Computational Thinking of Carnegie Mellon University in the US, has already set out its mission "... to advance computing research and advocate for the widespread use of computational thinking to improve people's lives" and, recognizing the revolutionary impact of Computer Science on scientific research and discovery, it characteristically states that "it is nearly impossible to do scholarly research in any scientific or engineering discipline without an ability to think computationally." (Center for Computational Thinking, Carnegie Mellon, 2019). Indicative of the importance of High-Performance Computing in scientific and technological progress is the awarding of scientists who are promoting the application of computational methods to sciences, by organizations such as Partnership for Advanced Computing in Europe (http://www.prace-ri.eu). Computational Thinking is unquestionably an important capability for the modern citizen, on which future scientific and technological progress could be based (CSTA & ISTE, 2011). The effort to integrate it into mainstream education is seen as a pressing issue for the education community and educational policy makers worldwide.

4. Integrating Computational Thinking in School Curriculum

The scientific implications of Computational Thinking and its interdisciplinary aspect have been supported by a large body of literature and researchers who have linked Computational Thinking skills to the teaching of various subjects. Mathematics and Science (Barcelos & Silveira, 2012; Weintrop et al., 2016), Biology and Physics (Sengupta et al., 2013), Language and History (Lee, Martin & Apone, 2014) and Informatics (Rodriguez et al., 2013, 2017), are some of the areas in which Computational Thinking concepts and practices find application, demonstrating and enhancing its interdisciplinary.

Despite the recognition of the importance of Computational Thinking, however, there is a lack of empirical research on its integration across the full range of K-12 education (Atmatzidou & Demetriadis, 2016). Questions related to this integration touch on issues such as:

- appropriate subjects

- educational approaches
- age levels
- software tools and hardware infrastructure
- appropriate assessment methods

Such questions still constitute a major concern for the research and educational community (Fessakis et al., 2018). In addition, the preparation and support of teachers for CT integration constitutes a critical challenge. Currently teachers need to confront with the ambiguity of the CT integration in education. The ambiguity is also intensified by the confusion among the teachers regarding the above factors, but also by the concept of CT, as such (Fesakis, Prantsoudi & Mavroudi, 2018; Fesakis & Prantsoudi, 2019; Yadav et al., 2011; 2014).

In several European and American countries, education systems have already set a strategic goal for the development of CT (EC-COM (2018) -24 & 22; Parliamentary Standing Committee on Education, 2016) and the concept already holds a place in existing curricula and educational practices in use, both in-school and out-of-school contexts (Mannila et al., 2014). A systematic review of the literature, however, highlights the fragmentation of CT research, both at the level of concepts, as well as at the level of teaching methodology and practice. Methods that have been explored and proposed for teaching the concept of Computational Thinking and its individual dimensions include the use of educational robotics activities (Atmatzidou & Demetriadis, 2016), the combination of educational robotics with digital games, (Leonard et al. 2016), CS unplugged activities (Rodriguez et al., 2017), or a combination of digital and traditional games (Wu & Richards, 2011; Lee et al., 2014). The interdisciplinary nature of the concept is proposed to be illustrated through modeling and simulation in the context of STEM education (Sengupta et al., 2013), while digital storytelling software (Storytelling Alice SA, Alice 2.2) and 3D game programming are also suggested (Werner et al., 2012).

Additional proposals include unplugged and kinesthetic activities, interdisciplinary projects, use of programming to implement dimensions of Computational Thinking, digital storytelling, educational robotics, interactive card and poster creation, experimentation, and simulation, as well as educational games (Mannila et al., 2014). Weintrop and his colleagues (2016) emphasize the interdisciplinary application of Computational Thinking, proposing a framework for integrating it into Mathematics and Science courses through appropriately designed activities. The contribution of unplugged activities in eliminating the misconception that CT is solely related to computer use, is also considered important (Rodriguez et al., 2017).

In terms of integrating Computational Thinking into compulsory education curricula in Europe, one can currently (2019) distinguish three trends:

1. **Curriculum Renewal Process:** United Kingdom, France, Finland, Poland, Italy, Turkey, Denmark, Portugal, Malta, Croatia, Scotland.

2. **Design for CT inclusion:** Czech Republic, Ireland, Norway, Wales, Greece, the Netherlands, Sweden.
3. **Investing in long-term tradition in computer science:** Austria, Cyprus, Israel, Lithuania, Hungary, Slovakia.

Introduction is mainly focused on Secondary Education, while efforts are also being done in Primary Education.

Yadav et al. (2011; 2014) highlight the significance of the role of teachers and their preparation in such an endeavor. This is where CompuT project focuses. Appropriate preparation of teachers through theoretical training along with design experiments in real classrooms conditions.

The comparative analysis of the current situation on CT integration in the national educational systems of the partner countries will be published as Appendix II of this guide in the second version of the document.

The systemic integration of CT in the educational system, at a national level, requires the establishment of corresponding policies, the development of CT curriculum (and/or the integration of CT in the curriculum of the existent subjects), the supply of appropriate educational resources (textbooks, learning scenarios, educational software, digital learning environments, educational materials (e.g. robotics kits, physical computing kits), as well as the professional development and constant support of teachers.

CompuT project contributes to the integration of CT in European education by comparatively analyzing the current situation regarding CT in the educational systems of the partner countries, along with the creation of educational resources and the training of teachers. To support the integration of CT in national educational systems, several other international initiatives have already been developed. Some of the most significant ones are presented in the next section, since they can lead teachers' CT pedagogical and content knowledge, while at the same time provide educational material, learning scenarios and training resources.

5. International Initiatives for CT Integration in Education

Several initiatives outside the context of formal education had initially sought to address the gap between the social needs for Computational Thinking skills and provided education. These initiatives - some of which spread internationally - were mainly developed in informal settings, are therefore not necessarily in line with the constraints of the national curricula and tend to enhance participatory technology culture. The following Tables outline some of the initiatives that have been implemented, both at European level (Table 4) and at a global level (Table 5).

Table 4. European Initiatives for the Integration of Computational Thinking

Initiative	Description
CodeWeek.	http://codeweek.eu/: EU code week is run by volunteers, it was launched in 2013 and in 2018, 2.7 million people in more than 70 countries around the world took part in it.
all you need is { C<3DE }	http://www.allyouneediscode.eu/el: This European initiative brings together a number of various stakeholders to promote coding and computational thinking at all levels of education, as well as informal settings. The project was created in June 2014 under the auspices of the European Commission.
CAS Barefoot Supported by BT	http://barefootcas.org.uk/: Since 2014, the Barefoot project has been supporting primary school teachers across England prepare for the changing computing curriculum. The project content comprises educational scenarios, teacher resources and workshops. At the end of 2018, Barefoot had reached over 2 million children and over 70,000 teachers are part of the Barefoot community.
Computing at School	https://www.computingatschool.org.uk/: The mission of this initiative is to provide leadership and strategic guidance to all those involved in Computing education in schools.

Table 5. Global Initiatives for the Integration of Computational Thinking

Initiative	**Description**
CODE	https://code.org/: Code.org was launched in 2013 and is a nonprofit organization dedicated to expanding access to Computer Science in schools and increasing participation of women and underrepresented minorities. Tens of millions of students (Hour of Code) and 1 million teachers (Code Studio) have participated to date.
CoderDojo	https://coderdojo.com/: CoderDojo is a global movement of free, volunteer-led, community-based computer programming clubs for young people, 7-17 years old. 58,000 young people are being creative with technology in 1876 active "dojos" with the help of 12,000 volunteers in 108 countries.
Bebras	www.bebras.org/: Bebras is an international initiative aiming to promote Informatics (Computer Science, or Computing) and computational thinking among school students of all ages. More than 2,780,000 participants from 54 countries participated in the 2018 challenge.
CS UNPLUGGED	http://csunplugged.org/: CS Unplugged is a collection of free teaching material that teaches Computer Science through engaging games and puzzles which do not require the use of a computer.
code club	https://www.codeclub.org.uk/: A global community of volunteers, educators, and partners to run free coding clubs where 9 to 13-year-olds build and share their ideas. There are currently over 13,000 clubs in over 160 countries, supporting over 180,000 young people learning to code each week.
Made w/ Code Google	https://www.madewithcode.com/: Google-funded initiative to attract girls to programming and reduce the gender gap in technology. Provides programming learning resources and material.

Recognizing, however, that the pedagogical value of any innovation cannot be proven in practice unless there are measurable results, the area of evaluating Computational Thinking becomes particularly relevant. As part of the search for appropriate assessment methods, the idea of creating a competition to evaluate students' knowledge on the fundamentals of Computing and Computational Thinking (Dagienė, 2005; 2006) prospered.

5.1. Bebras Challenge

Bebras International Challenge on Informatics and Computational Thinking, hereinafter referred to as Bebras, was born in 2004, in Lithuania, by Prof. Valentina Dagienė from the University of Vilnius, aiming to promote Informatics (Computer Science or Computing) and Computational Thinking among school students at all ages. Today, it constitutes the extracurricular Informatics activity with the world's largest audience. The challenge has been held annually since 2004 and is an international initiative of the homonymous international community (The Bebras Community, 2017). The name Bebras comes from the Lithuanian word for beaver, a clever, hard-working, and determined animal, whose features inspire both the creators and participants of the challenge.

The challenge is aimed at students of all levels of education, from preschool to high school, and its spread has been rapid. The first event was held in 2007, with the participation of 50,000 pupils from 6 countries, and since then a growing number of countries are organizing Bebras challenges. In 2017, Bebras took place in more than 45 different countries with approximately two million students participating (Bellettini et al., 2018), while for the 2018-2019 school year, the challenge was organized in 48 countries with a total of 2,634,974 students (https://www.bebras.org/).

The International Bebras Community is an association of organizations, from several countries, active in information technology and education. Community structure includes, at national and international level, the National Bebras Organizer (NBO), the International Bebras Committee (IBC) and the Bebras Board (Bebras Board-BB). The International Bebras Committee (IBC) is comprised of (i) full members (over 45 countries today) and (ii) Observers, including Greece and 20 other countries. The Bebras Board (BB) is elected through fully democratic processes and is the executive body of the community (Bebras Community Statutes, 2015). Over the years and with the growth of the community, world-wide experience and know-how have accumulated, leading Bebras to be a multi-productive challenge today. In addition to organizing challenges of different levels/categories, community members organize a variety of other activities such as open-ended discussions on Informatics and CT, task solving seminars, teacher training workshops and task creation workshops.

5.1.1. The Tasks

The purpose of Bebras Challenge is to raise awareness of pupils on Computer Science and Computational Thinking, through a set of inspirational tasks that are tailored and distributed across age groups. Bebras tasks are developed collaboratively, in a special workshop held annually for this purpose (International Bebras Tasks Workshop), with the participation of CS scientists and Educators from all over the world. Each country-member of the Bebras community is represented by the National Organizer of Bebras (NBO), a non-profit organization responsible for organizing the Bebras competition at national level. Each country provides a set of task proposals, and the whole repository of task proposals is then discussed at the workshop. The national contest organisers create their national task set by selecting tasks from this repository. The tasks are independent of prerequisite knowledge and involve concepts that are central to Informatics. Bebras tasks' developers seek to motivate students to deal with Informatics and to think deeper about technology. Taking into consideration the lack of a joint Informatics curriculum, they would also like to cover as many topics on Informatics and computer literacy as possible.

A good Bebras task should be:

- representing informatics concepts
- easily understandable
- solved within 3 minutes
- short, e.g., presentable at a single screen page
- solvable on a computer without the use of other software or paper and pencil
- independent of specific systems
- interesting and/or funny

Bebras tasks are appropriately divided into age groups, depending on their level of difficulty. For the categorization of the tasks, a two dimensions scheme proposed by Dagienė et al. (2017), has prevailed. The dimensions evaluated according to this scheme are a) Computer Science Domain and (b) Computational Thinking Skills, developed through each task. Computer Science Domains can come from one of the following categories (Dagienė, Sentance, & Stupurienė, 2017):

- Algorithms and Programming
- Data, data structures and representations
- Computer processes and hardware
- Communication and networking
- Interaction - systems and society

On the other hand, the Computational Thinking Skills that are used for the categorization are the Computational Thinking dimensions proposed by Computing at School (Dagienė, Sentance, & Stupurienė, 2017; Csizmadia et al., 2015; Selby & Woolard, 2013):

- Abstraction (AB)
- Algorithmic Thinking (AL)
- Decomposition - (DE)
- Evaluation - (EV)
- Generalization (GE)

The two above dimensions of categorization are embedded in an accompanying field, “It’s Computational Thinking” that is added to the analysis of the solution of each task in a special booklet that is distributed after the completion of the contest. Each task is assigned one Computer Science Domain and up to 3 Computational Thinking Skills.

Bebras challenge is generally intended to be a fun, controlled learning experience with a relatively short duration for the participating students. The challenge is already proving to be a successful model of non-formal informatics education and at the same time an attractive and effective tool for promoting problem solving and CT. However, the need to encourage the participation of both the students and teachers should not be neglected.

What follows are three examples of Bebras Tasks, based on the official task template of the Bebras Community. The certain tasks have already been used in challenges around the world and were presented in the solutions booklets in Australia and the UK.

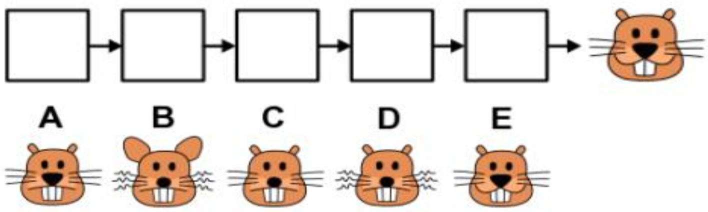
5.1.2. Bebras Tasks examples

Example 1

Animation

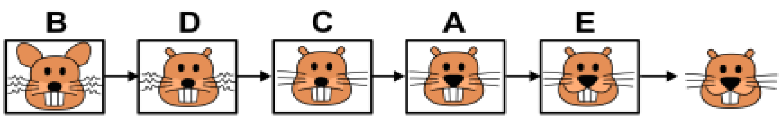
Kits:
Castors: B
Juniors: A
Intermediates: A
Seniors:
Elite:

Taro is planning an animation of a face that is made from a sequence of pictures. To make the animation run smoothly, only one feature of the face should change from one picture to the next. Unfortunately, the pictures got mixed up. Now Taro must find the correct order again. Luckily, he knows which picture is last.



Question: Put the pictures in the correct order by dragging them onto the squares.

Answer:



Explanation: The ears change from large to small. The whiskers change from curly to straight. The nose changes from small to large. The mouth changes from plain to smile. The number of teeth changes from 3 to 2. It is best to work backwards to solve this!

It’s Computational Thinking: ***Skills: Abstraction (AB), Decomposition (DE), Evaluation (EV), Generalisation (GE)***

It’s Informatics: In order to find the differences between the pictures, you have to find the essential attributes of the faces first. The list of attributes and their possible values is:

- ears: small, large
- mouth: plain, smile
- nose: small, large

- number of teeth: 2, 3
- whiskers: curly, straight

Face A can now be described as: *(ears: small, mouth: plain, nose: large, number of teeth: 3, whiskers: straight).* In computing, it is very usual to model things from the real world as "objects" that have attributes and values.

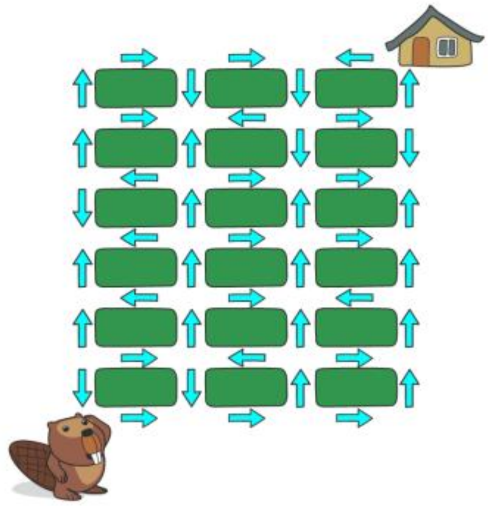
Retrieved From: UK Bebras Computational Thinking Challenge Answers Booklet (2015), available at: http://www.bebras.uk/uploads/2/1/8/6/21861082/ukbebras2015-answers_1.pdf

Example 2

The way home

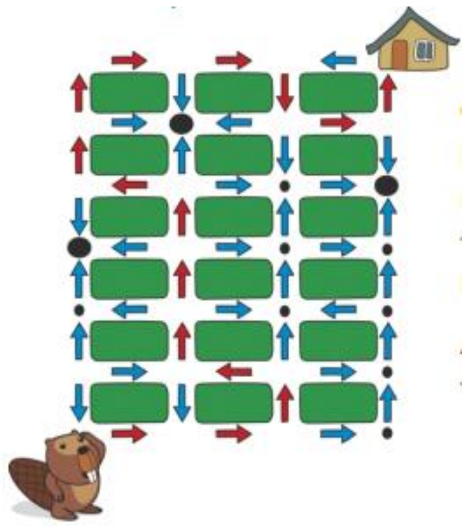
Year 3+4: **C**
Year 5+6: **B**
Year 7+8:
Year 9+10:
Year 11+12

Mark the path from the beaver to his home. You can click on one arrow at a time to make the correct sequence. (To delete your choice, click on the arrow a second time).



Question: Show the path home without creating any loops.

Answer and explanation: One way of solving this is to first identify *black holes* (see big black dots on the left) where the beaver can enter but not escape. We can also identify places that can only lead to a black hole (little black dots). The answer then becomes obvious. An alternative strategy is to follow the arrows backwards from the house.



It's Computational Thinking: ***Skills: Decomposition (DE), Pattern Recognition (PR), Abstraction (AB), Algorithms (AL)***

It's Informatics: Finding a route is one of the classical problems in algorithm theory. *Backward searching* and identifying *black holes* are two algorithmic techniques used to solve such problems.

Retrieved From: Bebras Australia Computational Thinking Challenge 2018 Solutions Guide (2018), available at: https://www.bebras.edu.au/wp-content/uploads/2019/02/Bebras-2018-Solution-Guide.pdf

Example 3

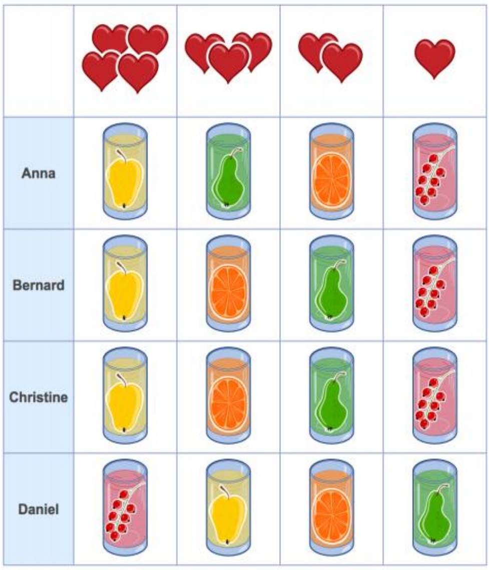
Soda shop

Kits: Intermediates:
Castors: Seniors: B
Juniors: Elite: B

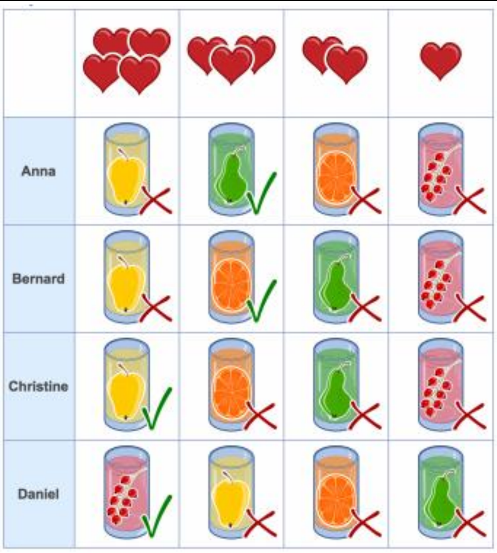
Four friends are on a road trip and decide to stop to get a drink at a nearby soda shop. Each of the friends has a preference for which drink they want as shown in the table below.

The soda shop offers four drinks, however, they are running out of stock and only have one of each. The drink each person prefers most is listed below with a number of hearts in the column heading yo show how much they like the drink.

Task:
Assign a drink to each person by clicking on the drink in his or her row. Make sure you get the maximum amount of hearts!



Answer and explanation: The maximum amount of hearts is 14.



It's Computational Thinking: ***Skills: Abstraction (AB), Algorithmic Thinking (AL), Evaluation(EV)***

It's Informatics: Optimisation is a very important part of Computer Science. In this situation, we are trying to maximise the happiness of the group. Optimisation problems are ubiquitous in Computer Science.
This problem is a type of matching problem. Here, friends are trying to get matched to the best possible drink to make the group happy. These problems are extremely important in the real world.

Several constraints in many cases of the real-world problems make it harder to find a set of matches that will benefit everyone the most.
Retrieved From: UK Bebras Computational Thinking Challenge Answers Booklet (2017), available at: http://www.bebras.uk/uploads/2/1/8/6/21861082/uk-bebras-2017-answers.pdf

6. Scenario resources

This section presents an illustrative selection of learning scenarios to better attribute the concept of incorporating Computational Thinking in a classroom. The selected scenarios do not require special equipment, nor prior knowledge, to be implemented, and they are parts of the resources collections of some initiatives mentioned in the previous section. These indicative scenarios will serve as a basis on which to base the development of new scenarios within CompuT.

Table 6. CT Scenario resources

TITLE	DESCRIPTION	CURRICULUM LINKS	GRADE	LINK	CT DIMENSIONS
Teaching London Computing – Computing at School (CAS) & CS4FN					
Pixel Puzzle Pictures and CT	Follow an algorithm to solve Color-by-number and logical thinking puzzles to understand image representation.	Computing, Maths, Art, History	PK-9	https://teachinglondoncomputing.org/pixel-puzzles/	AL, AB, PD, RE, LR, GE
Pixel Puzzle Pictures and CT	Solve word search puzzles and learn about computational thinking and search algorithms.	Language	6+	https://teachinglondoncomputing.org/word-searches/	AL, PM
The tour guide activity	Devise a tour that gets a tourist from their hotel to all the city sights and back to their hotel.	Computing	8+	https://teachinglondoncomputing.org/the-tour-guide-activity/	AB, RE, AL, SE, DE, EV
Barefoot Computing - Computing at School (CAS)					
World map logic	In this activity students look at sequences of commands to predict what they do. They use logical reasoning to explain their predictions before programming and testing their commands to see if their predictions are correct.	Geography	4-6	https://www.barefootcomputing.org/resources/world-map-logic-activity	AL, LR, RE, EV
Solar System Simulation	In this activity pupils create a simulation of the Earth orbiting the Sun using Scratch.	Science	4-6	https://www.barefootcomputing.org/resources/solar-system-simulation	AB, AL, RE, MO, SIM, EV
Tut, clap or jive	pupils create hand clapping, hand tutting or hand jive sequences of movements. Pupils break the sequence of actions down into parts and in	Physical education	4-6	https://www.barefootcomputing.org/resources/decomposition-unplugged-activity-ks2	AL, PM, PD, DE, GE

	so doing are decomposing. Pupils link this idea to breaking problems down when creating computer programs such as animations or games.				
Sudoku unplugged activity	Students work in pairs to complete sudoku puzzles, using logical reasoning.	Maths	5+	https://www.barefootcomputing.org/resources/logical-reasoning-unplugged-activity	AB, LR, PD
Bug in the Water Cycle	Students are challenged to detect and correct the error in a number of water cycle programs.	Computing, Science, Geography	5-6	https://www.barefootcomputing.org/resources/bug-in-the-water-cycle	AB, GE, LR, DE, EV
International Society for Technology in Education (ISTE)					
Research Skills	Students will demonstrate the ability to expand or restrict a set of internet search results by changing the search terms or adding Boolean modifiers to the search terms.	Interdisciplinary	6-8	https://id.iste.org/docs/ct-documents/ct-teacher-resources_2ed-pdf.pdf?sfvrsn=2f	LR, DA, DR, AB, DC, MO, SIM, AUT, AL, GE, EV
Alternatives to the Civil War	The students will construct the basic outline of an adventure game to show how the war might have been avoided or accelerated had different decisions or actions occurred earlier.	Interdisciplinary	9-12	https://id.iste.org/docs/ct-documents/ct-teacher-resources_2ed-pdf.pdf?sfvrsn=2f	AB, SE, AL,
Traffic Jam	Students construct a conceptual model (computer-based or paper based) of the relationships between the variables affecting a traffic jam problem.	Interdisciplinary	8+	https://id.iste.org/docs/ct-documents/ct-teacher-resources_2ed-pdf.pdf?sfvrsn=2f	AB, LR, PD, DR, DA, MO, SIM, RE, TE

The above scenarios are indicative and can be transformed and adapted to the needs of each teacher and classroom. The initiatives' collections include a large number of learning scenarios to help teachers integrate CT in their classrooms and the interested reader can refer to their websites. In the context of this guide, these scenarios serve as examples that will help members of the CompuT community create their own scenarios.

7. Learning Design of CT integration scenarios

7.1. Teaching as a design science

Adopting, in the context of CompuT, the modern view, so aptly put by Laurillard (2012), teaching is considered as the art and science aiming to create powerful experiences to learners with the formally defined goal of developing their personal knowledge and capabilities. Teaching is less a kind of a *theoretical science*, aiming to describe and explain some aspect of the natural or social world, but rather a *design science* aiming to improve the world. According to this view, teaching resembles engineering, architecture, and computer science more than history and physics. Design sciences are not only aiming to understand and explain how things are, but in addition, they are concerned on how things should be (Simon, 1996). As Laurillard (2012) states *"A design science uses and contributes to theoretical science, but it builds design principles rather than theories, and the heuristics of practice rather than explanations, although like both the sciences and the arts, it uses what has gone before as a platform or inspiration for what it creates. Teaching is more like a design science because it uses what is known about teaching to attain the goal of student learning and uses the implementation of its designs to keep improving them." (p. 1).*

Design of teaching and learning is a complex interdisciplinary problem requiring the control of several parameters and the coordination of many participating actors to shape proper human interactions, to support knowledge construction. For the thorough approach of the teaching design challenge, a more detailed model of its content is necessary. To support this purpose, we propose Goodyears' (2015) model of the teaching design.

7.2. What teaching design involves

Goodyear (2015) considers teaching as a form of design science *"that uses a distinctive mode of thought and set of tools and methods"* and further elaborates in the teaching design problem proposing a model which uses the learning task as the key building block of the pedagogical designs. In the Goodyear's approach there are three key learning design components: good *learning tasks*, supportive physical and digital *environments,* and modes of *social organization*. As depicted on Figure 1, this *teaching as design* conception brings the concept of "learning activity" into focus. The implementation of a learning task assignment outcomes a learning activity. In the context of CompuT, the terms *activity* and *task* are often used interchangeably, as the prescription of learning experiences, but in fact they slightly differ. A task is the specification of a work unit, with specific deliverables, that is assigned to students. To implement a task, students develop real activity which outcomes their learning experience. So, tasks are pretexts for learning experiences which are developed during the corresponding learning activities. These pre-specified learning activities have to be designed as a roadmap which guides students through the learning process but does not predetermine what they will do in an overdetailed manner (Dillenbourg, 2002). Although they are given a *task* to complete, students are free to explore and re-shape their learning environment by using *the tools and resources* provided and choose how they will interact with *other people in groups or individually*.

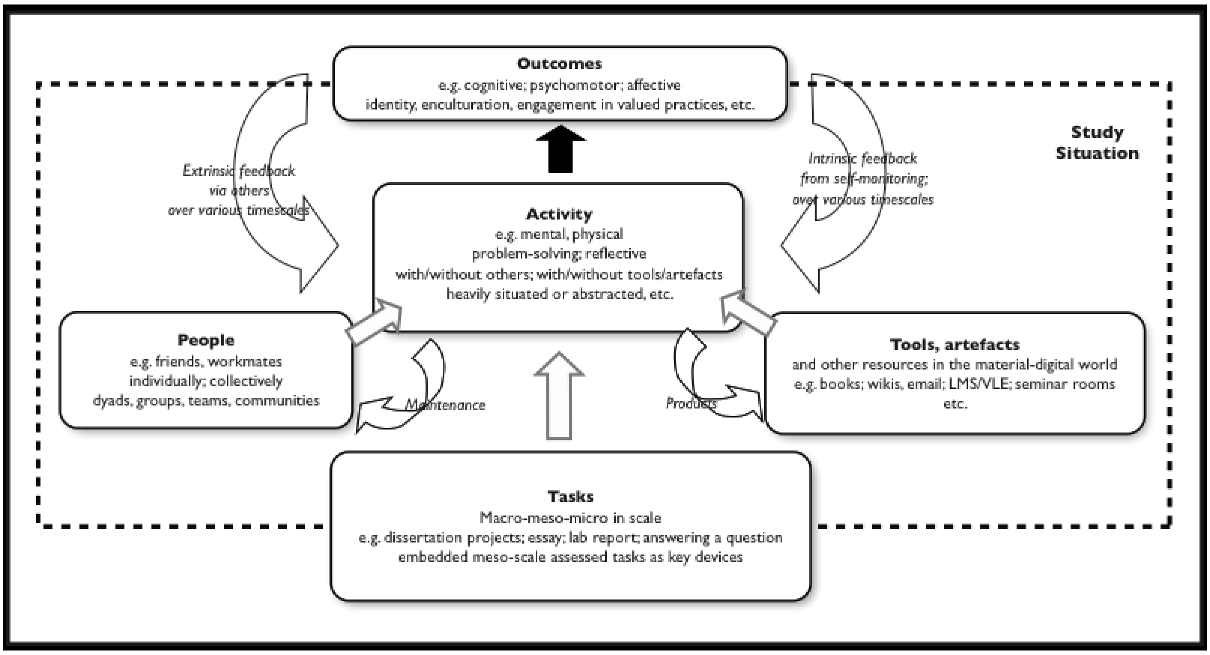


Figure 1. Teaching as design conception by Goodyear (2015).

This way, they actively participate in the learning process, leading to predetermined *learning outcomes* that have been caused by their own effort to make meaning in the context of the learning activity. In addition, students receive *feedback*, both extrinsic from others and intrinsic from their own self-monitoring, which makes it easier for them to repeat the techniques they followed and the actions they took when solving this activity, as well as to apply them to similar activities.

Consequently, a teaching designer should prescribe learning activities inventing and/or selecting sequences of learning tasks, which the learners implement interacting with others and using tools and artefacts in order to obtain pre-determined outcomes. This is the main challenge for the designer. In addition, the designs should be as much authentic, attractive, and engaging as possible, so as to be consistent with the modern pedagogical models and learning theory. Learning design is similar to some kind of entertainment design, except from the fact that the primary aim of a teacher is to obtain learning goals, not just fun.

In any case, teaching design produces a kind of prescription of action which is usually called teaching or learning plan, lesson plan, learning script or pedagogical scenario. Lesson plans are usually much simpler and are exclusively intended to teachers. On the contrary, scripts and scenarios are intended to both teachers and students and are often accompanied by learning material and/or implementation data and feedback which are important for the improvement of the design implementation. Hereafter, we are focusing on scripts.

7.3. Pedagogical Scenario or Learning Script as the product of teaching design

The outcome of teaching design usually consists of a set of learning resources, the description of a learning environment and a set of steps-instructions which shape the learners' interactions to solve a problem or complete a sequence of tasks. This set of instructions, along with the description of everything needed for their implementation, is called a learning script or pedagogical scenario (Dillenburg, 2002). Often the learning scripts have also a kind of plot and roles that the learners will perform. This approach of teaching as storytelling (Egan, 1989) makes the learning tasks authentic and engaging, both, mentally and emotionally, for the learners. The efficient shaping of learners' interactions (learner-learner, learner-teacher, learner-resources/environment) to obtain the learning outcomes determines the effectiveness of the scenario. Learning scenarios should be detailed up to a level that learners will have no doubt on what they are asked to do, but also no overdetailed (overscripting) so that learners can always choose alternative ways to do thinks and trigger their thought instead of just executing simple commands. Some general forms of effective collaborative learning scenarios such as Jigsaw, ArgueGraph and the Grid, are described by Dillenburg (2002). To take advantage of the perspective of teaching as a design science and be able to share the teachers' expert knowledge, it is essential to use a mean to externalize the learning/teaching designs of the teachers. These external representations of the learning/teaching design could be shared and annotated with meaningful comments, results, notes, assessment, and other information concerning their implementation.

7.3.1. Learning design representation methods

Apparently, the next phase of the teaching design application, is the representation of the teacher's designs. The formalism of a learning design (e.g., the blueprints in terms of building design) is still in contention, partly because of the multiple origins of interest in design approaches (e.g., Education Science, Computer Science, etc.) (Dalziel et al, 2016). Since there is not a commonly acceptable standard formalism for the representation of teaching designs, we need to adapt a specific representation for the scopes of CompuT project, that is a *learning script template*. Before moving on with the presentation of the learning scenario template which will be used in the context of CompuT, we briefly present some common methods used in other cases.

According to Agostinho (2006), *"Learning design is a representation of teaching and learning practice documented in some notational form so that it can serve as a model or template adaptable by a teacher to suit his/her context"*. For this reason, there are many different learning design representations, which are presented in a wide variety of forms, for example plain text, case studies, or even flow-charts.

Designs as case studies: The simplest method to represent a learning design and/or a pedagogical pattern is to use textual description to document the design as a case study. This informal way, apart from having the advantage of expression freedom, also supports the detailed description of the design pattern and the understanding of its implementation in real classrooms. On the other hand, the lack of structure or diagrammatic means of simple textual descriptions may lead to difficulties in communication, comparison, and generalization of the solution in new contexts.

Design patterns as solution templates: Design patterns could be represented by using the “Teaching Method Template” (Laurillard, 2012, p. 212), which describes a teaching design in terms of: 1) general data, e.g. Summary, Rationale, Learning outcomes, Duration, Group size, Learner characteristics, and Setting; 2) detailed teaching information, e.g. Sequence of activities, Roles, Assessment method, Resources, References; and 3) comment sections, such as Teacher reflection, Student feedback, and Peer review. Such a form is commonly used mainly because of its similarity to the lesson plans that teachers are familiar with.

Diagrammatic representation of learning designs: Design patterns could be represented using diagrammatic techniques. There are several graphical grammars proposed for learning designs e.g., flow charts, Petri-nets, UML, LAMS etc. Some of the diagrammatic techniques are quite formal to be interpretable by computers software. In this section we briefly describe one of the first diagrammatic representations of learning designs proposed in the pioneering Learning Design project funded by the Australian Universities Teaching Committee (AUTC) (Oliver et al, 2002, 1999). The Learning Design Project considers a “graphical formalism” for the learning design, which assigns different symbols on each of the three learning design elements: *triangles* for **resources**, *rectangles* for **tasks**, and *circles* for **support**.

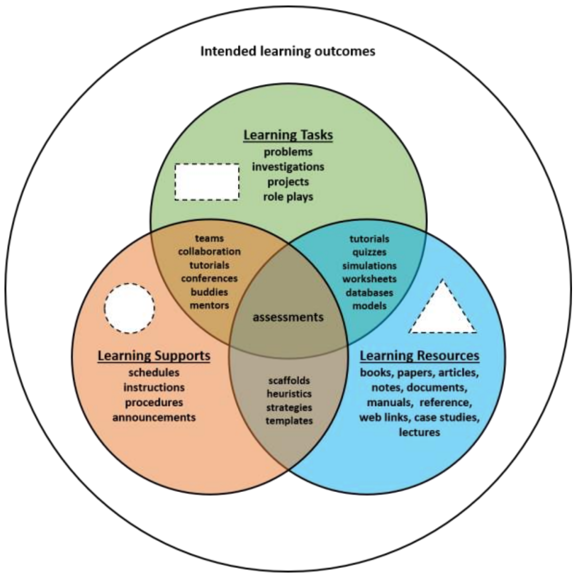


Figure 2. Components of a Learning Design

These elements, presented in the form of a flow chart, depict the chronological order and the interactions that occur between them. Students need to use and interact with the provided resources, to implement the tasks/learning activities that are assigned to them, getting support throughout these processes. Figure 3 below presents an example of a simple learning design sequence with concurrent activities.

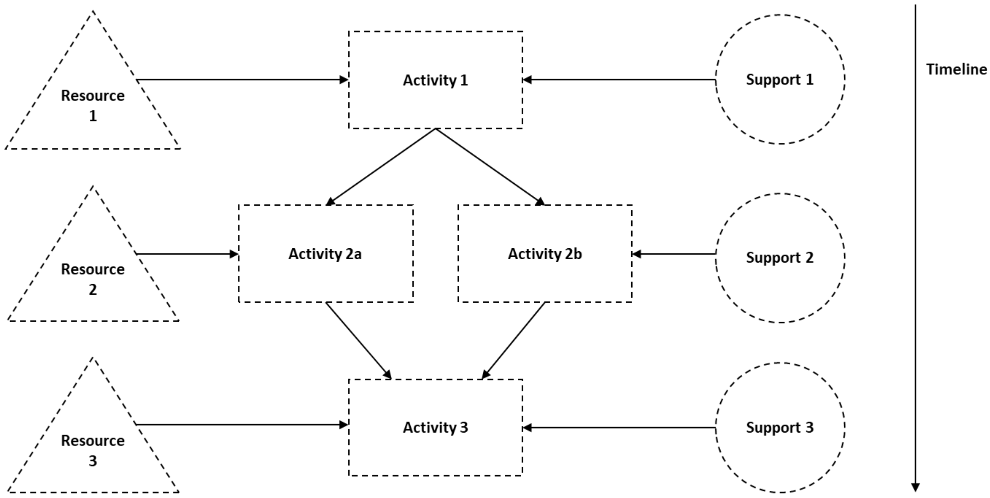


Figure 3. Example of a Learning Design sequence

The elements of the learning design process *"highlight the importance of planning specific roles for learners, the teacher and the technology in the learning environment"* (Oliver et al, 2002, 1999). In the rapidly changing learning environments of today, these roles need to be reconsidered.

7.3.2. Representation of learning scenarios in the context of CompuT

In the context of Comput we shall use the learning scenario template described in Appendix III. The proposed template is a synthesis of various good practices, such as Europeana1, Aesop's project2, CS Unplugged, CSTA/ISTE CT Resources for K-12 Educators project, adapted for the needs of CT and CompuT. For the clarification of the template some specific examples of use are presented in Section 8.

7.4. Design patterns as a means of sharing learning design experience

As teachers invent and implement in practice several learning scenarios, they gain *teaching experience*. This means that teachers discover which methods or techniques work more effectively through their interaction with students. It is crucial that all this experts' knowledge is communicated, that is, articulated and so that other teachers can build on it and continue the innovating, testing, improving, sharing cycle. Therefore, it is important to build a community of researchers and practitioners to help maintain a knowledge base concerning the teaching/learning designs, so that we can

1 http://www.europeana.eu
2 http://aesop.iep.edu.gr

improve education quality by studying the designs and their learning outcomes. Laurillard (2012) argued on that idea as follows: *"Ideally, teachers should be able to enact design science as part of their normal professional practice and have the means to act like design researchers themselves, i.e., documenting and sharing their designs."*, (p. 7).

In other words, what if after several implementations of similar learning scenarios, we could identify a generalized form of them, which could be applied in several similar situations that share some common features and conditions? This generalized form of scenario constitutes a compact knowledge representation for the solution of a group/family of learning problems and it is called learning design pattern e.g., the jigsaw script for the formulation of collaboration in several contexts is an example of a learning design pattern (Kobbe et al, 2007).

In general, *"A design pattern is a semi-structured description of an expert's method for solving a recurrent problem, which includes a description of the problem itself and the context in which the method is applicable…. Design patterns have the explicit aim of externalizing knowledge to allow accumulation and generalization of solutions and to allow all members of a community or design group to participate in discussions relating to the design."* (Mor & Winters, 2007). The key elements of a design pattern are the "problem", the "context", the semi-structured description of the "solution", and the fact that this is "externalized knowledge" (Goodyear, 2005). Design pattern is a key construct for design sciences and refers to techniques of representing generalized reusable solutions to significant problems. these compact knowledge representations could be e.g., general blueprints for specific types of bridges or the general design of an electronic amplifier etc. Design patterns are usually drafted, shared, reviewed, and refined through an extended process of collaborative conversation. Thus, design patterns have the potential to make a major contribution to the sharing of techniques and expert knowledge among developers of learning activities and teachers. In the context of CompuT we will be working on the pedagogical scenario level of abstraction and, if possible, we aspire to propose some pedagogical patterns generalizing the tested scenarios.

7.5. Design methodology - A model for the process of learning design

The methodology presented within the framework of this project -as a starting point- constitutes an adaptation of an operational model for designing educational scenarios which incorporate ICT, proposed by Komis et al (2013). *"This framework is based on a conceptualization where methodological and pedagogical issues are suitably integrated to facilitate the teaching and learning process, … Moreover, a structured and systematic educational intervention should give emphasis on and carefully select the appropriate teaching approaches. Such issues refer to defining an objective and the goals which meet early childhood children's needs, to using additional teaching strategies, to comprising didactic transposition on programming concepts and to* *developing appropriate teaching material. These teaching practices are based on pedagogical principles such as project-based learning, child-centered learning, collaborative learning, and well-organized learning environments."* (Missirli & Komis, 2014). The framework was invented for learning design in the preschool level but in fact it is independent of the students' age level.

An educational scenario refers to both teachers and students and describes a complete instructional intervention, that is, the specific objectives/goals, the potential learning difficulties, and the implementation process, which is usually structured as a series of appropriate activities, along with the proposed teaching strategies, assessment procedures, and so on.

The specific model draws from the TPACK framework proposed by Mishra and Koehler (2006). TPACK (Technological Pedagogical Content Knowledge) provides a theoretical model for effective teaching using ICT and as illustrated in Figure 4, it comprises three basic components presented as three intersecting circles and representing content knowledge, pedagogical knowledge, and technological knowledge.

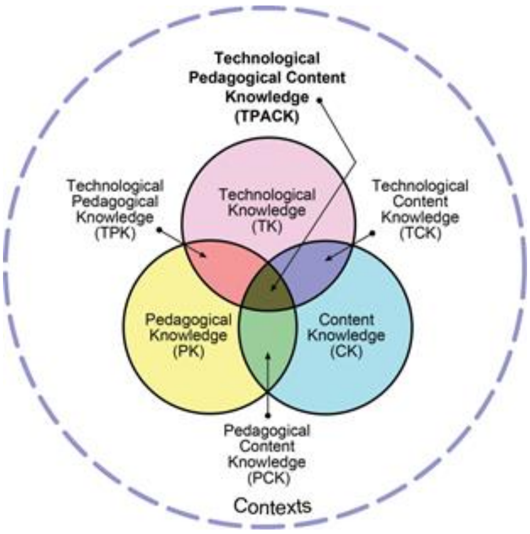


Figure 4. The TPACK Image (rights free – taken from http://tpack.org/).

The TPACK model addresses the fact that teaching with technology demands both, deep knowledge of subject matter contents and enhanced learning pedagogies.

The seven (7) phases of the methodology presented in this guide (Fig. 5), albeit distinct, are highly interdependent. Although some of them could be developed in parallel, they should be viewed as discrete steps of a logical progression.

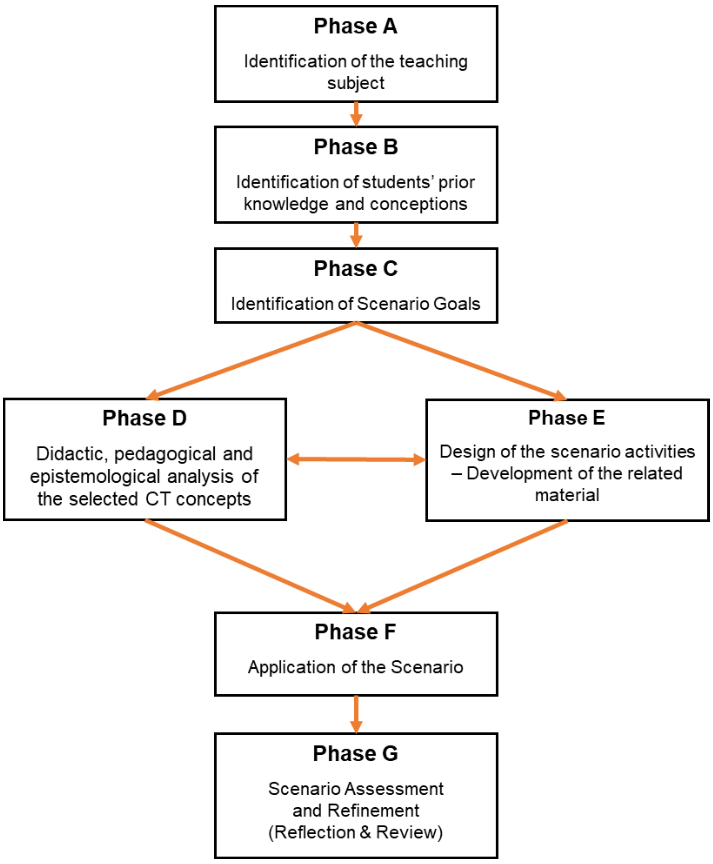


Figure 5. The learning scenario design process

The 7 phases of the proposed methodology are briefly presented below.

Phase A - Identification of the teaching subject: An educational scenario is usually designed aiming to address one or more main concepts in a curriculum subject area. It may also be interdisciplinary, targeting concepts from different subject areas while in some cases it may even address concepts beyond the curriculum. It should be noted at this point that, since one of the primary objectives of the scenarios to be developed within the CompuT project is the cultivation of CT, this parameter should be considered when selecting concepts. In addition to the subject area(s) involved, in this phase it is also necessary to specify information, such as:

- The title of the Educational Scenario
- The level of the target students' population
- The prerequisite cognitive skills
- The CT dimensions involved

Phase B - Identification of students' prior knowledge and conceptions: Issues that the designer/teacher has identified through his/her experience or difficulties/problems that have been documented in the literature and are related to the children´s perceptions, representations, prior knowledge and potential errors, should be extensively discussed in this section.

Phase C - Identification of Scenario goals: The teaching objectives –often referred to as "learning outcomes"- of the educational scenario are clearly formulated and listed in this step. Furthermore, the learning outcomes are presented, grouped with respect to various criteria such as:

- Subject matter
- CT dimensions involved
- Use of ICT (digital literacy)
- Learning process (learn how to learn)

The learning outcomes describe what students will be able to do after having completed the educational scenario, actual behaviors that are both observable and measurable. The objective statements should, therefore, contain "active" verbs such as analyze, compare, describe, distinguish, locate, list, plan, etc. Verbs, such as know, realize, think, etc., that express feelings, thoughts or similar, should be avoided in the description of the knowledge outcomes.

Phase D - Didactic, pedagogical and epistemological analysis of the selected CT concepts: As Dagdidelis & Papadopoulos (2010) argue, "The importance of the concepts taught in school is tightly connected with the present opinion about the status of these concepts in the knowledge system that is "transmitted" by the school. The relative value of these concepts is determined by a rather complicated framework of didactic principles which in any case change very often. For example, some concepts or methods might be extremely important during a historical period of time and literally disappear in another… In other cases, the significance of the taught concepts depends on their conceptual connection with other ones and on their future usage…". Very often, the development of new methods or concepts and their evolution is a consequence of developments in the relevant discipline or social practices associated with them. All these evolution phases cannot be presented in class, of course. However, the aware teacher can organize his/her lesson in a way that highlights these concepts. Moreover, the teacher should take into consideration the possibility of similar concepts existing in other lessons or even everyday life. The existence of such interconnections can be very productive (from a teaching point of view). In the case of the educational scenarios on CT dimensions, it is important that the scenario designer provide the relation with the CS domains.

The didactic and pedagogical analysis refers to the body of knowledge related to issues such as the representation, description and transformation of scientific concepts and processes, misconceptions, pre-existing knowledge or cognitive difficulties of students, as well as in pedagogical strategies and techniques that are effective in practice, etc.

Phase E - Design of the scenario activities – Development of the related material: This, undoubtedly, constitutes the most crucial phase of the scenario development, since all the procedures that both students and teachers have to follow in order to meet the scenario goals, are defined here (Komis et al, 2013).

There are at least four types of tasks-activities that an educational scenario should incorporate:

- Tasks-Activities for the cognitive and psychological preparation of the class, as well as for the detection of any prior knowledge.
- Tasks-Activities for the subject teaching
- Consolidation-Validation tasks-activities (activities for the comprehension and the integration of new knowledge)
- Assessment tasks-activities.

Scenario tasks-activities - to a large extent - determine the form and content of the accompanying worksheets that will be shared to the students for classroom implementation. Each activity implements one or more didactic strategies or teaching techniques.

In addition to the design and the development of a series of activities, the scenario designer should also provide clear information with regards to:

- The management of the process
- Classroom organization
- Both the theoretical and the teaching approaches of the scenario, that is, the underlying learning theories and the teaching strategies, involved.

Phase F - Application of the Scenario: Usually, the first application of the scenario in a real class setting should be considered a pilot one, performed with the objective of evaluating its effectiveness and making proper adjustments for its later implementation. The development of the scenario, thus, follows a spiral procedure. The first, pilot intervention is expected to highlight the weak points of the scenario, both in terms of process and content.

Phase G - Scenario Assessment and Refinement: The findings of the previous phase will provide information to help refine the educational scenario. The relevant documentation including comments, teachers' suggestions for potential extensions, etc. should also be included here.

Undoubtedly the learning design process is much more complex than any almost linearly described procedure of consecutive steps. The designers will have to repeatedly come back to previous steps of the design process; they can skip steps or implement them in a different sequence. Nevertheless, the 7-phase model presented above could be very useful at the beginning of the teaching design procedure, because it provides a way of beginning and reaching an end with a first draft of the scenario. It is also useful as a reminder of several important decisions which should be taken during the teaching design process.

7.6. Teaching techniques and practices of Computational Thinking

Teaching design differs according to the subject it concerns, as there are specific teaching methods and Didactics related to each field. Thus, the creation of learning scenarios for Computational Thinking should count on the existing techniques and practices. Such techniques are presented in the following chapter.

Even though CT is acknowledged for the central role it can possess in education (Freeman et al., 2017), still many issues concerning the teaching and learning of it remain open (Barr & Stephenson, 2011). Existing research has connected the learning/teaching of CT with modern and progressive learning/teaching methods and means, such as the use of educational robotics (Atmatzidou & Demetriadis, 2016), digital educational games (Mannila et al., 2014), modelling and simulation in STEM education (Sengupta et al., 2013), use of unplugged activities or interdisciplinary application of CT in the context of Mathematics and Science subjects (Weintrop et al., 2016). The selection of the teaching methods that will be used is probably one of the most important design decisions teachers have to make when planning the instruction process. There are several kinds of knowledge and ways to know e.g., analytical, experiential, and experimental, each of them valuable on its own way. Each kind of knowledge can be built more effectively using the appropriate teaching method, e.g., essay composition for analytical, role playing for experiential, and modelling/simulation for experimental knowledge. Teachers choose the appropriate teaching methods to employ according to the learning outcomes they aim to achieve for the learners, in the context of a specific curriculum. This section presents some of the existing teaching methods to be considered during the design of the learning scenarios.

Table 7. Teaching techniques and practices of Computational Thinking

Teaching technique or CT practice	**Description**
Tinkering	Tinkering is about hands-on experiences, trying something out to discover what it does and how it works. Children are natural tinkerers and creative learning experiences can result from their direct experience with materials, new tools, and skills, which are nowadays available following the recent technological and creative revolution (Martinez & Stager, 2019). Students often build up experiences of cause and effect ("if I do this, that will happen"), while trying ideas and experimenting. The freedom to explore things encourages their creativity and confidence (Bers, et al., 2014). When introducing any new digital device or software environment, tinkering is a great way to start. Teachers can foster imagination and creativity of their students by encouraging them to try out novel ideas, even those that do not seem applicable. Find out more examples and ideas about tinkering at: https://www.barefootcomputing.org/concepts-and-approaches/tinkering?IconItemUrl=tinkering

Learning by design	Learning by Design (LBD) is an approach to learning science deeply based on project-based inquiry. LBD lays its roots in case-based reasoning and problem-based learning and is used to help students get familiar with science concepts and skills fundamental to their future life and career. Students are intended to be able to tinker, learn and make decisions using the two major components of the LBD model: a) a design/redesign cycle, where they attempt to reach a solution based on their prior knowledge, working alone or in groups, comparing/contrasting ideas, addressing a design challenge and running an activity to examine that issue, and b) an investigation cycle, where students explore and experiment, reflect, apply, evaluate and generate a solution to the problem (Kolodner, et al., 2003). Students get involved in the concepts and learn them while completing the design challenge in front of them. For example, to learn about motion and forces they are asked to build miniature vehicles, or to learn about gravity, measuring and metric units they are asked to build a device for lifting heavy objects, or design a parachute made of coffee filters. Find out more about Learning by Design in Middle school at: https://www.cc.gatech.edu/projects/lbd/home.html
Collaborative problem solving	Collaboration is the process of two or more people or organizations working together to complete a task or achieve a goal (Marinez-Moyano, 2006). When people collaborate, better results can be achieved, and this also applies in the classroom. Students may collaborate on the solution of a problem or task and learn from each other's strengths and weaknesses, while working together and each one is contributing his/her specialism. Examples of collaborative work could be the creation of a shared document in Google Docs, the creation of a blog, or an entry in Wikipedia. Students could also collaborate on the schools' sports teams, or a school play or event. More ideas on collaborating at: https://www.barefootcomputing.org/concepts-and-approaches/collaborating
Collaborative inquiry	In collaborative inquiry students work in groups, supported by the teacher, and engage themselves in self-regulated activities. The aim is to create a new culture in classrooms, where motivation and interest in science fosters. Students use steps and methods similar with those that scientists use, trying to gain knowledge on scientific processes (Bell, et al., 2010). To solve a problem, students follow a 4 stages process: plan, act, observe and reflect. http://elearning.tki.org.nz/Professional-learning/Teacher-inquiry/Collaborative-inquiry
Learning by modelling/ simulation	Simulation technologies have applications in many industries nowadays, from healthcare to entertainment, and education could not be unaffected. A simulation is an approximate imitation of the operation, over time, of a process or system (Banks, et al., 2001). Modelling is the use of models (physical, mathematical, or logical representations of a system which contains key parameters of the physical model), as a basis for simulations in order to develop data that will help in making decisions (NSF, 2006). People create models in their minds (mental models), implicitly or explicitly, trying to make better sense of the world around them (Hanisch, et al., 1991). Thus, the use of modelling and simulation, both considered important tools of scientific reasoning, can help students understand science deeper and make better sense of the world that surrounds them (Penner, 2001). To introduce Computer Science into science classrooms within the context of modeling and simulation, code.org and Project GUTS (Growing Up Thinking Scientifically) partnered to

	deliver a middle school science program about life, physical and earth sciences, which you can find at: https://code.org/curriculum/science.
Learning by invention	The need to increase the number of innovators through the education system is critical. Piaget was one of the pioneers who supported the view that invention is the best way to understand (Piaget, 1973). Learning by Invention represents a situation where students identify the problem, experiment, collaborate, think critically, and engage themselves in hands-on experiences, to solve real world problems by creating inventions. Students become more creative and confident, while during the process some of them discover what it is, that they want to do for life. More information on Invention Education at: https://inventioneducation.org/
Learning by coding/ debugging	When facing a difficult problem or task, debugging, or troubleshooting, can be used to determine a suitable solution which may have not been reached on a first attempt. There are four steps in a debugging process: 1) the student must first identify that something is not working (for example, a robot programmed to do so, is not turning), 2) he/she must decide whether to keep the original goal or switch to an alternative (make a decision on whether he/she still wants the robot to turn, or simple moving is enough), 3) generate a hypothesis as to the cause of the problem (hypothesize that an instruction is missing) and 4) attempt to solve the problem (try to find the correct instruction and add it at the right place, so that the robot turns) (Bers, et al., 2014). According to previous research, children can acquire and transfer debugging skills on activities outside of the programming context (Salomon & Perkins, 1987). More information and resources about debugging can be found at: https://www.barefootcomputing.org/concepts-and-approaches/debugging
Pair programming	When it comes to programming, pair programming is a particularly effective way to write code. Two programmers share a workstation, with one of them, the 'driver', having control of the keyboard/mouse and actively implementing the program by dealing with the details of writing the code. The second programmer, called 'navigator' or 'observer', is looking at the bigger picture of the program, thinking strategically about the direction of the work, while instructing and guiding the 'driver'. The two persons frequently switch roles (Wiliams, 2001). In a class environment, two students can collaborate in such a way during any activity involving programming, thus enhancing creativity and collaboration. The two students regularly swap, so they both build up experience in each role. All the resources presented in previous sections that involve programming activities could be used in this case.

The selection of the proper learning method lies mainly upon the educator, who is expected to implement the method with his/her students. This selection depends on the certain circumstances and available material and largely affects the educational process and learning outcome. The methods described above are only a part of the existing ones and each teacher is free to select and adjust them properly to achieve his/her goals.

7.7. Some proposed action sequence patterns for the learning scenarios

The sequence of activities could follow traditional instructional models or more modern, progressive, and student-centered ones.

7.7.1. Traditional instructional models

Such as the nine events of instruction (Gagne, 1985; Gagne et al., 1992)3: *Gain Attention, Inform Learners of the Objectives, Stimulate Recall of Prior Knowledge/Learning, Present the Stimulus (content or learning activity), Provide Guidance to the Learners, Elicit Performance from the Learners, Provide Feedback to the Learners, Assess the Performance of the Learners, Enhance the Retention & Transfer of the New Skills, Knowledge, and/or Attitudes.* Or the use of similar simpler sequential models e.g., Students cognitive/emotional preparation activities - Teaching activities - Reinforcement Activities - Assessment Activities, or 1. Introduction/ warm-up, 2. Instruction/ presentation, 3. Practice (with feedback)/Application, 4. Review or Summary, 5. Evaluation/Testing etc.

7.7.2. Student-centered learning activity models

Alternatively, it is possible to develop the sequence of activities according to student-centered models which are obviously consistent with the constructivist pedagogy and so support the production of corresponding pedagogy learning scenarios. Some well-known such models, for example, are:

- **Inquiry learning models:** For example, the 5Es model for inquiry instruction: 5E=Engage, Explore, Explain, Elaborate, Evaluate or variations such as Engage, Explore, Reflect, Extend, Discussion etc.
- **Experiential models:** Using the Kolb's Experiential Learning Cycle: 1. Concrete Experience, 2. Reflective Observation of the New Experience, 3. Abstract Conceptualization, 4. Active Experimentation.
- **Experiment learning models:** Question, Background Research, Hypothesis, Test/Experiment, Analyze Data, Draw Conclusions, Communicate Results.
- **Collaborative Learning:** Using various CSCL-Scripts.
- **Learning by design and/or making:** Analysis, Design, Development, Implementation, Evaluation.
- **The studio or the Future classroom model**[4]: Organizing the learning activities in two or more of the six learning areas-zones of a Future classroom, namely: Interact, Exchange, Investigate, Create, Present, Develop.

---

3 Gagné, R. M., Briggs, L. J., & Wager, W. W. (1992). Principles of instructional design (4th ed.). Forth Worth, TX: Harcourt Brace Jovanovich College Publishers
Gagne, R. (1985). The Conditions of Learning (4th ed.). New York: Holt, Rinehart & Winston
4 http://fcl.eun.org

7.7.3. Assessment

In the beginning of the scenario, initial assessment could be helpful for diagnostical and awareness purposes. During the main sequence of the scenario some formative assessment activities should be included. At the end of the scenario, assessment activities along with structured feedback provision advance the opportunities for learning. To figure out the assessment method, the designer needs to answer questions like: *How will learning be identified? How will student learning and performance be detected?* According to the constructivist paradigm students should be assessed by applying the knowledge they have constructed in authentic situations.

7.8. Thematic units of Computational Thinking Scenarios in CompuT

In the context of the CompuT Project we have selected some thematic units to drive the development of the scenarios. It is quite often for teachers to start experimenting with CT through the implementation of ready learning scripts selected from online repositories. The design of a new CT learning script is a challenging and complex task. The proposed thematic units could facilitate the introduction of teachers in the design of CT learning scenarios. Interested teachers can take advantage of the suggested topics by combining them with key concepts and problems from his/her field of expertise. The designer should find common elements among the proposed thematic unit and the subject matter he/she wants to teach, to develop a CT learning script. Often, the underlying scientific relation among the related fields drives this effort e.g., Computational linguistics progress of automatic natural language understanding could be a starting point for language related learning scenarios.

A brief description of the thematic units proposed in the context of CompuT, as frameworks to start thinking from, for the design of CT learning scripts, follows.

- **Educational Robotics and physical computing – STEAM scenarios**

Use of educational Robotics kits in the context of interdisciplinary education to develop key competences such as mathematical literacy, scientific-technical and social competences. Educational Robotics tools enhance students' creative thinking and engage them with the STEAM field of education, to help them discover their talents and flairs and even possible future studies and careers. Students can program robots in science classes e.g., build a robot to work on problems related to motion, position, direction (mathematical education), or use graphical environments and program, virtual or real, robots to solve problems, or construct models of everyday objects (e.g., vehicles, machinery). It is recommended that students work in groups of 2-4 persons, to build social competence. Well known, widespread Educational Robotics kits include Lego Mindstorms or Wedo, Thymio, Cozmo, Parallax etc. Educational Robotics may concern the use and/or programming of ready-made devices, or the assembly of predefined building blocks, or the freer use of materials and design of a robotic synthesis. Some material parts of the Robots could be constructed using 3D printing.

The difficulty of the Educational Robotics learning scripts could be scaled in an analogous manner.

In a more flexible application of Educational Robotics, teachers could base the development of CT learning scripts on the use of Physical Computing and automation technology. The use of physical computing kits such as Arduino, Raspberry pi, micro:bit, makey-makey or other microcontrollers, empower STEAM education and help students develop skills that will allow them to become the scientists and artists of the future. Several educational resources are available for students from middle school to university. The physical computing device or the custom-made robotic synthesis could be build connecting the microcontroller to sensors and code. The sensors could be ready-made or build by the students. The design, construction, calibration, and code control of a sensor could drive the development of a rich learning scenario that combines science, CT, as well as the makers' movement values, thus providing the framework for meaningful learning that engages students into discovering knowledge by making things on their own5. You may encourage your students to create, or use sensors (even mobile phones have sensors) to measure things like changing weather, light, sound etc. An extension of the sensor building scenario would involve building a weather station (using sensors to collect weather data and analyzing them), programming automatic water systems (programming water flow controllers), etc. Students could also be required to build manipulatives such as programmable waving machines and music boxes, adder models (mechanical calculators), Goldberg machines, automatic piano players, autonomous cars etc., or even create digital art, music etc. and several other amazing artefacts as pretexts to approach various concepts and techniques.

- **Computational science projects – Coding for learning Math and Science**

Scientists use scientific calculation programming environments in their work. This is usual practice in modern scientific reality. Students could get familiar in the study for learning through coding with the same programming environments in the context of well-designed learning scenarios. Modelling and simulating phenomena, automating calculations, visualizing processes and/or data could be key scientific activities in such scripts. Such projects are more easily integrated in Math and Science curriculums. Such, well known and wide-spread scientific programming environments include: Octave, Julia, Python, Jupyter, MATLAB, R, Mathematica, Wolfram, Processing, NetLogo, InsightMaker, StarLogo TNG, Snap! etc. The learning scripts could refer to:

1) Math concepts e.g., microworlds or code explorations of math concepts e.g., probability, pi or phi calculation - visualization, discrete mathematics

---

5 For some more ideas for sensors see:
http://www.senseit.org/, https://tryengineering.org/teacher/making-sense-sensors/
https://assistcenter.org/education-overview/wearable-device/teacher-resources/
https://education.theiet.org/secondary/teaching-resources/sensors/
https://nextlab.golabz.eu

computations, math’s and sound (Fourier analysis), fractal and recursion explorations, chaotic systems concept etc.

2) Modelling and Simulation of physical phenomena and systems. Science experiments can now be modeled in computers. Students can experiment and better understand physical phenomena through building models in code and exploring digital simulations, running their code, cultivating their CT skills. Abstract versions of the systems, represented in code, can be used to study their performance, if a real system is too difficult or too expensive to construct. They can even program their own COVID-19 Simulator with Scratch. Students could in this manner reinforce the scientific (experimental) method in silico and get familiar with the modern approach of scientific research.
3) Bifocal modelling[6] is the modern approach of digital modeling/simulation in Science Education that combines coding and physical computing. Bifocal modeling offers the opportunity to combine physical and virtual experimentation by experiencing a scientific phenomenon through two lenses in parallel – a real experiment and a computer model. In the context of inquiry-driven learning, you can upgrade your students CT skills by guiding them to design and develop experiments, use sensors to collect data and then build a model to match the data they collected

- **Data science projects – CT for Social Science and Statistics**

Data analysis software is increasingly used on every science field and children should be prepared to handle big data in their future careers. Big data handling tends to be a crucial matter and future scientists[7] should be able to manage big amounts of data, process them and extract useful and applicable conclusions, while improving their CT ability. Students could engage with data processing at an early age. In addition to the obvious Statistical projects, Social Science offer several opportunities to develop learning scripts concerning data collection and analysis. Biology and Science or engineering projects based on data analysis are also possible. In data analysis projects, both, general purpose software e.g., Excel or Calc, R, etc., as well as specially designed educational data analysis software[8] such as CODAP, Fathom, TinkerPlots etc., could be used. The study of significant algorithms[9] used by popular services such as Google search, recommendation systems etc., could trigger discussions on the implications of data analysis to everyday life and the society in general.

---

6 See e.g. https://fablearn.org/bifocal-modeling/

7 See the article titled “The end of theory:The Data Deluge Makes the Scientific Method”, https://www.wired.com/2008/06/pb-theory/

8 For more information visit:
https://codap.concord.org/,
https://learn.concord.org/dynamic-data-science,
https://www.pathway.ai/home

9 https://algorithmstoliveby.com, Nine algorithms that changed the future - http://www.di-srv.unisa.it/~uv/PA2019-20/Nine.pdf

- **History of science and technology – epistemology projects**

Science History and epistemology projects may prove a source of effective and engaging learning scripts ideas. Presented in the proper context, is it possible to approach any subject in an interdisciplinary way to combine history, science, engineering, math, etc. Students can research and discuss older scientific devices and instruments, e.g., Pascaline, Antikythera mechanism, sextant, thermometer, automata etc. The reconstruction or the building of digital and hardware models of these ancient scientific instruments is a means for learning about Science, Scientific methodology, History, Culture etc. In addition, discussion about their role and the way they operated, their modern substitutes, are also proposed tasks to develop learning scripts that combine CT with interdisciplinary and transdisciplinary learning.

- **Digital games, software, or mobile apps development Projects**

Mobile devices have conquered everyday life and students are familiar with their use since their early age. In addition, children are always fond of playing games and, as they grow, they use an increasing number of applications on their mobile phones or tablets. What about combining these two phenomena and using mobile devices in schools to help achieve educational goals? Students can be asked to program a game in a programming platform (e.g. Scratch, Snap!, Python, etc.) or create an application for their mobile phone (AppInventor, arisgames.org, taleblazer.org, etc.). The theme of the students' creation can relate to any subject of the curriculum for example students could code adventure games, scavenger hunts, treasure hunts, math, or logical puzzles, or even tourist guides. Sometimes all you need is to come up with a good idea for a software application e.g., to facilitate the local community of cat lovers; This could also serve as a starting point for coding for CT learning.

- **Digital humanities projects**

Using computing for studying and researching humanities issues could be also a fruitful source for the development of CT learning scripts. Digital humanities concern the use of computing tools for the creation and analysis of digital archives, textual mining, analysis and visualization, sentiment analysis, online publishing, digital and interactive fiction/storytelling, digital art and creativity, Natural Language Processing, and translation, etc. Digital humanities have significant applications since e.g.: scientists are trying to build algorithms to write poetry, "feeding" them with data and patterns, Google Translate offers written and oral translation in over 100 languages, Sentiment analysis tools use computational linguistics and text mining to identify the sentiment behind a text, ML models are trained to recognize feelings through face images and texts etc. The teachers could create learning scripts as adaptations of authentic digital humanities projects10 in the appropriate scale. Digital Humanities

10 For some examples visit: https://twinery.org, https://teachinglondoncomputing.org/poetry/, https://cognimate.me:2635/home

tools makes the CT integration in the theoretical subject matters possible and give prove examples that CT is not relevant only to Math and Science Education.

- **Artificial Intelligence Projects – CT in computational cognition**

Artificial Intelligence especially with the modern Machine Learning applications has also significant social and scientific impact. Children often interact with Artificial Intelligence every day unconsciously and their education on the subject should start as early as possible. They can program a computer to play games (e.g., tic-tac-toe, or rock-paper-scissors), recognize something in a photo or recognize voice, or sentiment. They can explore machine learning and its limitless potential using data from different scientific phenomena. They can program robots and experiment with techniques that mimic human senses and capabilities such as speech recognition and computer vision, Natural Language Processing. Students could try to answer questions such as could our mobile phones hear and understand what we are saying? Is this commercial related to the oral discussion I had previously with my colleagues. Students could play games against AI players (e.g., chess, go) to try to make sense of their capabilities and/or make their own versions of game player software. Students could also use symbolic computation applications such as photomath11 app or MS OneNote handwriting recognition and automatic math solving. The discussion on ethical issues and bias deriving from the possible bad training of an algorithm is also a good starting point for learning script scenarios (e.g., the deepfake use in social media). Modern software environments make possible the development of sophisticated AI projects for K1212.

- **Studio approach projects – or projects for the future classroom**

Some schools following the studio approach to interdisciplinary learning have formulated special classrooms organized with various learning zones. More particularly the Future Classroom Lab project13 promotes specific classroom configuration in schools all over Europe with six learning zones: Interact, Exchange, Investigate, Create, Present, and Develop (Figure 6).

Each of which has especially designed space and resources to facilitate different learning strategy (inquiry, experiment, presentation, discussion, design etc.).

---

11 https://photomath.app

12 For AI in K12 resources see for example:
https://github.com/touretzkyds/ai4k12/wiki
http://cognimates.me/projects/
https://machinelearningforkids.co.uk/
https://code.org/oceans
https://ai.google/education/
https://aieducation.mit.edu

13 https://fcl.eun.org, http://www.eun.org/el/professional-development/future-classroom-lab

According to FCL these spaces all together form a unique way to visualize a new, holistic view on teaching.

Figure 6. The Future Classroom sample design (source: http://www.eun.org/el/professional-development/future-classroom-lab)

The requirement to use the learning zones "forces" the designer to use the abovementioned modern learning methods and produce digital technologies enhanced learning. So, in schools where a future classroom or a space configured as a studio with various learning zones may be available, it is likely that the teachers may develop CT learning scripts to utilize these facilities. Some ideas for CT learning scripts in future classroom facility include:

- ✓ Digital storytelling for our school or city
- ✓ Development of mobile game for orientation to our school or city using Augmented Reality authoring (e.g., TaleBlazer, Aris, Blippar, ActionBound)
- ✓ Building of a 3D model of an area and enhancing it with the use of Augmented Reality for tourists or visitors
- ✓ Augmented Reality enhanced Interactive Posters for local flora/fauna or historical people
- ✓ Building devices or robotic syntheses using parts produced by 3D printing

- **Unplugged experiential projects**

Unplugged activities can help students (and teachers) disconnect CT from the use of computers, using games, puzzles, tricks, etc. Various CT dimensions can be approached through properly selected activities, from different subject fields, varying from Mathematics and Literacy to Arts and Music. The main resource of examples for unplugged CT learning scripts is the website of the homonymous project: https://csunplugged.org/en/topics/curriculum-integrations/. Another possible starting point for the development of unplugged CT learning scenarios is the development of manipulatives that integrate CT concepts, e.g., build a programmable music box14.

14 See an example: https://www.instructables.com/id/Build-a-Programmable-Mechanical-Music-Box/

8. Some examples of scenarios

Some examples proposed by the LTEE group will be described briefly in this section. Detailed descriptions according to the template will be provided in Appendix IV. Exemplar Learning Scenarios.

No	Title	Description
1	**The History of Computation Automation**	The scenario focuses on Pascal's mechanical calculator, the famous Pascaline. Students learn about the history of computation automation and the first machines used to make simple calculations. They discuss their utilities and the way they function. They are then asked to construct a simplified version of a Pascaline and then use their model to perform a few calculations. This is a scenario that unites History, Arts and Computer Science in a creative, educational way.
2	**Search engines - Finding Needles in the World's Biggest Haystack**	The scenario deals with some of the core algorithms of the Web search. Through the various activities, students are led to a step-by-step discovery of some of the aspects that the indexing and ranking techniques of the search engines, employ. Additionally, a first approach to the description of the structure of a web page through HTML, is attempted.
3	**Machine Learning - The feelings detector machine**	The purpose of this scenario is to introduce students to the basic concepts of Machine Learning. Students are asked to program the computer so that it recognizes feelings, based on the text that a user enters. To do so, they train a machine learning model and use it to build an algorithm in Scratch, so that the algorithm recognizes the user's feelings based on the text he/she types.
4	**Cryptography**	This learning scenario is an introduction to security issues and cryptography methods. Morse code, Braille code, and Caesar cipher method are used to introduce students to the ways they can encrypt or decrypt a message. The scenario intends to teach in a simple, unplugged way, methods, and practices of encrypting and decrypting messages, so that students gain understanding and knowledge of the concept of cryptography and learn how they can protect their communications from third parties.
5	**CompuT Contest – "Be Computationally Intelligent"**	Students are going to use mobile learning and the Internet of things to organize a school contest. The purpose of the contest is to find the most qualified student in computational thinking concepts in their school. A pool of Computational Thinking questions will be used, students will create the questions and assign QR codes to them, run the contest,

		collect, evaluate, and process the data and find the winner. Working in a collaborative way, they are asked to structure a school event based on Computational Thinking.
6	**Studying the Skyros Archipelago Lizards**	This scenario involves students in an authentic data analysis project with the aim of generating scientific knowledge, since it is based on a large set of data which comes from real research. The scenario also falls within the field of CT because it employs several CS practices in solving problems in the field of biology. Students will summarize data sets, interpret them based on simple knowledge in the field of Biology, construct chart graphs, practice spatial reasoning, compare subsets of data based on the values of mean and variance, filter outliers, test hypotheses, and finally, they will suggest the collection of further data to answer questions. The scenario constitutes an adaption of (Tally, 2019)
7	**Studying Cam Carpets to learn mathematics and computational thinking**	The students experiment with Cam Carpet idea first using everyday material and light sources and progressively more formal tools to mathematise and make sense of the optic phenomena involved. First, students try a simple projection using light source and, pen and pencil to experiment with the optic illusion behind Cam Carpets. Then, they use Geogebra for the geometric analysis of simple cases of cam carpet phenomena (e.g. they will compute the cam carpet for simple letters) progressively they are introduced to the analytical model behind the cam carpets using equation systems for key point coordinates and finally, they model the optics using matrices. Finally, they can apply the new knowledge in an optional outdoor activity in which they represent the name of their school three-dimensionally as a Cam Carpet in the school yard. Thus, through the sequence of the various learning tasks, they better comprehend the maths related to the use of computing technology and improve their Computational Thinking skills. During this project, students will use their knowledge in Maths, Science and Arts.
8	**Let´s talk to the machines**	In this scenario, students will learn how to decompose simple algorithms sequentially and how to express and communicate them through flowcharts.
9	**“Useless” robots**	In short terms this project is about building a “useless robot” to inspire teachers and students to further their knowledge of electronic design and programming. A useless robot solves a problem you didn’t know that you had. For example, “do you need someone that can wave to you?” Make a waving robot.

		One possible solution to this can be done with the ARM-based microcomputer called Microbit. The Microbit is easily programmable with their own block-based programming language (Makecode) so little to none programming experience is required. In addition to programming the microbit, the students must design a robot using cardboard and whatever decorations they want. In this way, the task is twofold and appeals to several students. The students work together in groups to solve the task, both in relation to design and programming.

9. Conclusion/Discussion

This edition of the guide contains all the information that will be communicated during the "Computational Thinking at School" - "CompuT" Erasmus+ KA201 project [Project Code: 2019-1-EL01-KA201-062883] participants' inaugural meeting at the University of the Aegean, in Rhodes. As stated in the introductory section of the guide, the aim at the start of the project is for the participating teachers to get to know and gain some familiarity with the concept and the dimensions of Computational Thinking, as well as to understand and reflect on the role it can and should play in modern education and science. Additional topics discussed in the guide include (a) integrating computational thinking into formal education; the challenges and difficulties that such an endeavor entails, (b) getting the picture of various relevant initiatives that have been and are being developed internationally, with special focus on the Bebras Computing Challenge (c) the study of educational scenarios that have been developed within the framework of the aforementioned initiatives, designed to cultivate Computational Thinking and finally (d) bringing the participants in contact with the scenario design methodology for integrating Computational Thinking, which will provide them with the tools, models and techniques to develop their own scenarios in order to integrate CT. This guide has been arranged to make it easy for the participants to quickly get to the information they need.

Through the knowledge, skills, and experience that the participating teachers are expected to develop during the project implementation, new scenarios and ideas will emerge that will gradually enrich the guide. Furthermore, another very interesting perspective can be found in the feedback observations that are expected to be drawn from the implementation of the proposed scenarios in real-world classroom conditions. It can, at a first level, help improve the scenarios while at a second level lead to new practices, techniques, and methodologies.

References

Abbott, B. P. (et al. LIGO Scientific Collaboration and Virgo Collaboration) (2016). Observation of Gravitational Waves from a Binary Black Hole Merger. *Physical Review Letters, 116*(6). American Physical Society. https://doi.org/10.1103/PhysRevLett.116.061102

Agostinho, S. (2006). The use of a visual learning design representation to document and communicate teaching ideas. In L. Markauskaite, P. Goodyear & P. Reimann (Eds.), *Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education* (pp. 3-7). Sydney, Australia: Sydney University Press.

Angeli, C., Voogt, J., Fluck, A., Webb, M., Cox, M., Malyn-Smith, J., & Zagami, J. (2016). A K-6 Computational Thinking Curriculum Framework - Implications for Teacher Knowledge. *Educational Technology & Society, 19*(3), 47–57.

Atmatzidou, S., & Demetriadis, S. (2016). Advancing students' computational thinking skills through educational robotics: A study on age and gender relevant differences. *Robotics and Autonomous Systems*, *75*, *Part B*, 661–670. https://doi.org/10.1016/j.robot.2015.10.008

Banks, J., Carson, J., Nelson, B., & Nicol, D. (2001). Discrete-Event System Simulation. Prentice Hall. p.3.

Barcelos, T. S., & Silveira, I. F. (2012). Teaching Computational Thinking in initial series: An analysis of the confluence among mathematics and Computer Sciences in elementary education and its implications for higher education. In *2012 XXXVIII Conferencia Latinoamericana En Informatica (CLEI)*, pp. 1–8. https://doi.org/10.1109/CLEI.2012.6427135

Barr, V., & Stephenson, C. (2011). Bringing computational thinking to K-12: What is involved and what is the role of the computer science education community? *ACM Inroads*, *2*(1), 48-54. https://doi.org/10.1145/1929887.1929905

Bebras Board (2015). Bebras Community Statutes, RC 3, May 21, 2015.

Bell, T., Urhahne, D., Schanze, S., & Ploetzner, R. (2010). Collaborative Inquiry Learning: Models, Tools and Challenges. International Journal of Science Education, 32(3), 349-377.

Bellettini, C., Carimati, F., Lonati, V., Macoratti, R., Malchiodi, D., Monga, M., & Morpurgo, A. (2018). *A Platform for the Italian Bebras*. In *CSEDU* (1), 350-357.

Bers, M. U., Flannery, L., Kazakoff, E. R., Sullivan, A. (2014). Computational thinking and tinkering: Exploration of an early childhood robotics curriculum. *Computers & Education* (72), 145-157. Elsevier

Cameron L., (2018). *What to Know About the Scientist Who Invented the Term "Software Engineering"*. IEEE Computer Society. Available at https://www.computer.org/publications/tech-news/events/what-to-know-about-the-scientist-who-invented-the-term-software-engineering

Carnegie Mellon University Center for Computational Thinking http://www.cs.cmu.edu/~CompThink/index.html.

Computer Science Teachers Association (CSTA), & International Society for Technology in Education (ISTE) (2011*). Computational Thinking: Leadership Toolkit (1st ed.)*. Retrieved in January 2020, from http://www.iste.org/docs/ct-documents/ct-leadershipt-toolkit.pdf?sfvrsn=4

Csizmadia, A., Curzon P., Dorling, M., Humphreys, S., Ng, T., Selby, C., & Woollard, J. (2015). *Computational thinking: a guide for teachers*. Retrieved January 15, 2020, from https://community.computingatschool.org.uk

CSTA. (2016). *A Model Curriculum for K-12 Computer Science: Final Report of the ACM K-12 Task Force Curriculum Committee*. Retrieved in January 2020, from http://csta.acm.org/Curriculum/sub/CurrFiles/K-12ModelCurr2ndEd.pdf

Dagdidelis, V., & I. Papadopoulos (2010). Didactic Scenarios and ICT: A Good Practice Guide. In M. D. Lytras, et al. (Eds.), Technology Enhanced Learning. Quality of Teaching and Educational Reform. First International Conference, TECH EDUCATION 2010. Athens, Greece, May 19-21, 117-123. Berlin Heidelberg: Springer.

Dagienė, V. (2005). Competition in information technology: an informal learning. *Digital Tools for Lifelong Learning*, Warsaw, Poland, 28-31 August, pp. 228-234.

Dagienė, V. (2006). Information technology contests – introduction to computer science in an attractive way. *Informatics in Education, 5*(1), 37-46.

Dagienė, V., Sentance, S. & Stupurienė G. (2017). Developing a two-dimensional categorization system for educational tasks in informatics*. Informatica, 28* (1), 23-44.

Dalziel, J., Conole, G., Wills, S., Walker, S., Bennett, S., Dobozy, E., Cameron, L., Badilescu-Buga, E. and Bower, M., (2016). The Larnaca Declaration on Learning Design. *Journal of Interactive Media in Education*, 2016 (1), p.7. DOI: http://doi.org/10.5334/jime.407

Denning, P. (2009). The Profession of IT Beyond Computational Thinking. *Communications of the ACM, 52* (6), 28-30.

Denning, P. J., & Martell, C. H. (2015). *Great principles of computing*. Cambridge, Massachusetts: The MIT Press.

Dillenbourg, P. (2002). Over-scripting CSCL: The risks of blending collaborative learning with instructional design. In P. A. Kirschner. *Three worlds of CSCL. Can we support CSCL?*, Heerlen, Open Universiteit Nederland, pp.61-91, 2002.

EC-COM (2018) 22: On the Digital Education Action Plan.

EC-COM (2018) 24: Proposal for a Council Recommendation on Key Competences for Lifelong Learning.

Egan, K. (1989). Teaching as storytelling: An alternative approach to teaching and curriculum in the elementary school. *University of Chicago Press*.

Fesakis, G. (2018). *Introduction to the applications of digital technologies in education: From Information and Communication Technologies (ICTs) to Digital Ability and Computational Thinking.* Gutenberg. (In Greek)

Fessakis, G. & Prantsoudi, S. (2019). Computer Science Teachers' Perceptions, Beliefs and Attitudes on Computational Thinking in Greece. *Informatics in Education* (in press).

Fessakis, G., Komis, V., Mavroudi, E., & Prantsoudi, S. (2018). Exploring the scope and the conceptualization of Computational Thinking at the K-12 classroom level curriculum, In M. S. Khine (Ed.) (2018). *Computational Thinking in the STEM Disciplines: Foundations and Research Highlights*. Switzerland: Springer.

Freeman, A., Adams Becker, S., Cummins, M., Davis, A., & Hall Giesinger, C. (2017). *NMC/CoSN Horizon Report: 2017 K–12 Edition*. Austin, Texas: The New Media Consortium.

Goodyear, P. (2005). Educational design and networked learning: Patterns, pattern languages and design practice. *Australasian Journal of Educational Technology*, 21(1), 82–101.

Goodyear, P. (2015). Teaching as design. HERDSA *Review of Higher Education*, 2, 27-50.

Grover, S., & Pea, R. (2013). Computational Thinking in K–12 A Review of the State of the Field. *Educational Researcher, 42*(1), 38–43.

Gudzial, M. (2008). Paving the way for computational thinking. *Communications of the ACM, 51*(8), 25-27.

Hanisch, K. A., Kramer, A. F., Hulin, C. L. (1991). Cognitive representations, control, and understanding of complex systems: a field study focusing on components of users' mental models and expert/novice differences. *Ergonomics, 34*(8), 1129–1145.

Henderson, P. B., Cortina, T. J., Hazzan, O., & Wing, J. M. (2007). Computational thinking. In *Proceedings of the 38th ACM SIGCSE Technical Symposium on Computer Science Education (SIGCSE '07),* pp. 195–196. New York: ACM Press.

International Society for Technology in Education (ISTE) & Computer Science Teachers Association (CSTA) (2011). *Computational Thinking: Teacher Resources. Second Edition.* Retrieved in January 2020, from http://www.iste.org/docs/ct-documents/ct-teacher-resources_2ed-pdf.pdf?sfvrsn=2

Isbell, C., Stein, L., et al. (2009). (Re)Defining Computing Curricula by (Re)Defining Computing. *ACM SIGCSE Bulletin 41*(4), 195-207. https://doi.org/10.1145/1709424.1709462

Kadanoff, L. P. (2013). Kenneth Geddes Wilson (1936–2013) Nobel-prizewinning physicist who revolutionized theoretical science. *Nature International Journal of Science, 500* (30).

Kalelioglu, F., Gulbahar, Y. & Kukul, V. (2016). A Framework for Computational Thinking Based on a Systematic Research Review. *Baltic Journal of Modern Computing, 4*(3), 583–596.

Kobbe, L., Weinberger, A., Dillenbourg, P., Harrer, A., Hämäläinen, R., Häkkinen, P.,& Fischer, F. (2007). Specifying Computer-Supported Collaboration Scripts. *International Journal of Computer-Supported Collaborative Learning*, 2, 211–224.

Kolodner, J. L., Crismond, D., Gray, J., Holbrook, J., Puntambekar, S. (1998). Learning by Design from Theory to Practice. EduTech Institute and College of Computing, Georgia Institute of Technology, Atlanta. Retrieved from: https://www.cc.gatech.edu/projects/lbd/htmlpubs/lbdtheorytoprac.html

Komis, V., Tzavara, A., Karsenti, T., Collin, S., & Simard, S. (2013). Educational scenarios with ICT: An operational design and implementation framework. In R. McBride & M. Searson (Eds.), *Proceedings of society for information technology & teacher education international conference 2013* (pp. 3244–3251). Chesapeake, VA: AACE

Laurillard, D. (2012). *Teaching as a design science: Building pedagogical patterns for leaning and technology*. New York: Routledge.

Lee, E. A. (2018). Modeling in engineering and science. *Communications of the ACM, 62*(1), 35–36.

Lee, I., Martin, F., & Apone, K. (2014). Integrating Computational Thinking Across the K–8 Curriculum. *ACM Inroads*, *5*(4), 64–71. https://doi.org/10.1145/2684721.2684736

Lee, I., Martin, F., Denner, J., Coulter, B., Allan, W., Erickson, J., & Werner, L. (2011). Computational thinking for youth in practice. *ACM Inroads, 2*(1), 32–37.

Leonard, J., Buss, A., Gamboa, R., Mitchell, M., Fashola, O. S., Hubert, T., & Almughyirah, S. (2016). Using Robotics and Game Design to Enhance Children's Self-Efficacy, STEM Attitudes, and Computational Thinking Skills. *Journal of Science Education and Technology*, *25*(6), 860–876. https://doi.org/10.1007/s10956-016-9628-2

Lye, S. Y., & Koh, J. H. L. (2014). Review on teaching and learning of computational thinking through programming: what is next for K-12? *Computers in Human Behavior, 41*, 51-61.

Mannila, L., Dagienė, V., Demo, B., Grgurina, N., Mirolo, C., Rolandsson, L., & Settle, A. (2014). Computational Thinking in K-9 Education. In *Proceedings of the Working Group Reports of the 2014 on Innovation & Technology in Computer Science Education Conference* (pp. 1–29). New York, NY, USA: ACM. https://doi.org/10.1145/2713609.2713610

Marinez-Moyano, I. J (2006). *Exploring the Dynamics of Collaboration in Interorganizational Settings*, Ch. 4, p. 83, in Schuman (Ed.). *Creating a Culture of* Collaboration. Jossey-bass.

Martinez, S. L. & Stager, G. S. (2019). Invent to Learn: Making, Tinkering, and Engineering in the Classroom, 2nd edition. Constructing Modern Knowledge Press.

Misirli, A., & Komis, V. (2014). Robotics and programming concepts in early childhood education: A conceptual framework for designing educational scenarios. In Research on e-Learning and ICT in Education (pp. 99-118). Springer, New York, NY.

MIT News (2019). *Astronomers capture first image of a black hole*. http://news.mit.edu/2019/eht-astronomers-direct-image-black-hole-0410

Mor, Y., & Winters, N. (2007). Design approaches in technology-enhanced learning. *Interactive Learning Environments*, 15(1), 61–75.

Mor, Y., Mellar, H., Warburton, S., & Winters, N. (Eds.). (2014). *Practical design patterns for teaching and learning with technology*. Springer.

National Research Council (2010). *Committee for the Workshops on Computational Thinking: Report of a workshop on the scope and nature of computational thinking*. Washington, DC: National Academies Press.

National Science Foundation (NSF), (2006). Report on Simulation-Based Engineering Science . Blue Ribbon Panel. 2006-05-01. Retrieved from: https://www.nsf.gov/pubs/reports/sbes_final_report.pdf

Papert, S. (1991). *Mental storms: Children, Computers and Powerful Ideas*. Translation: Stamatiou E. Athens: Odysseas.

Papert, S. (1996). An exploration in the space of mathematics educations. International Journal of Computers for Mathematical Learning, *1*(1): 95-123. Retrieved January 10, 2019, from http://www.papert.org/articles/AnExplorationintheSpaceofMathematicsEducations.html

Parliamentary Standing Committee on Education (2016). *National and social dialogue. Findings, proposals and implementation timetable* (in Greek). Available at https://www.minedu.gov.gr/publications/docs2016/morfotikwn_porisma.pdf

Penner, D. E., (2001). Cognition, Computers and Synthetic Science: building knowledge and meaning through modeling. Review of Research in Education, 25, pp. 1-36.

Piaget, J. (1973). To understand is to invent. New York:Grossman

Prantsoudi, S., Fesakis, G., & Mavroudi E. (2018). Computer Science Teachers' Perceptions, Beliefs and Attitudes. (In Greek). In St. Dimitriades, V. Dagdilelis. T. Tsiatsos, I. Magnisalis, D. Tzimas (eds.) Proceedings of the 9th panhellenic Conference "Didactics of Informatics" (pp. 86-93), Thessaloniki, 19-21 October 2018.

Retalis, S.; Georgiakakis, P., & Dimitriadis, Y. (2006). Eliciting design patterns for e-learning systems. *Computer Science Education*, 16(2), 105-118.

Rodriguez, B., Kennicutt, S., Rader, C., & Camp, T. (2017[U1]). Assessing Computational Thinking in CS Unplugged Activities. In *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education* (pp. 501–506). New York, NY, USA: CM. https://doi.org/10.1145/3017680.3017779

Oliver, R., Harper, B., Hedberg, J., Wills, S. & Agostinho, S. (2002). *Formalising the descriptions of learning designs 2002,* 496-504. https://ro.uow.edu.au/edupapers/193

Oliver R. (1999) Exploring strategies for online teaching and learning, *Distance Education*, 20:2, 240-254, DOI: 10.1080/0158791990200205

Rose, S., Habgood, J., & Jay, T. (2017). An exploration of the role of visual programming tools in the development of young children's computational thinking. *El. Journal of e-learning*, *15*(4), 297-309.

Rosenbloom, P. (2004). A new framework for computer science and engineering. *Computer, 37*(11), 31-36. https://doi.org/10.1109/MC.2004.186

Royal Society (2012). *Shut down or restart: The way forward for computing in UK schools*. Retrieved January 10, 2020, from http://royalsociety.org/uploadedFiles/Royal_Society_Content/education/policy/computing-in-schools/2012-01-12-Computing-in-Schools.pdf

Salomon, G., & Perkins, D. N. (1987). Transfer of cognitive skills from programming: when and how? Journal of Educational Computing Research, 3, 149–169.

Selby, C. C. (2015). Relationships: Computational thinking, pedagogy of programming, and bloom's taxonomy. In *Proceedings of the workshop in primary and secondary computing education* (pp. 80-87). New York: ACM.

Selby, C. C., & Woollard, J. (2013). *Computational Thinking: The Developing Definition*. University of Southampton (E-prints).

Sengupta, P., Kinnebrew, J. S., Basu, S., Biswas, G., & Clark, D. (2013). Integrating computational thinking with K-12 science education using agent-based computation: A theoretical framework. *Education and Information Technologies*, *18*(2), 351–380. https://doi.org/10.1007/s10639-012-9240-x

Simon, H. A. (1996). *The sciences of the artificial, 3rd ed. Cambridge*, Mass: The MIT Press.

Tedre, M., & Denning, P. J. (2016). The Long Quest for Computational Thinking. In *Proceedings of the 16th Koli Calling International Conference on Computing Education*

Research (pp. 120–129). New York, NY, USA: ACM. https://doi.org/10.1145/2999541.2999542

The Bebras Community (2017). *The Bebras international challenge on informatics and computational thinking*. https://bebras.org

Weintrop, D., Beheshti, E., Horn, M., Orton, K., Jona, K., Trouille, L. & Wilensky, U. (2016). Defining Computational Thinking for Mathematics and Science Classrooms. *Journal of Science Education and Technology, 25*(1), 127–147.

Werner, L., Denner, J., Campe, S., & Kawamoto, D. C. (2012). The Fairy Performance Assessment: Measuring Computational Thinking in Middle School. In *Proceedings of the 43rd ACM Technical Symposium on Computer Science Education* (pp. 215–220). New York, NY, USA: ACM. https://doi.org/10.1145/2157136.2157200

Williams, L. (2001). Integrating pair programming into a software development process. 14th Conference on Software Engineering Education and Training. Charlotte. pp. 27–36. doi:10.1109/CSEE.2001.913816. ISBN 0-7695-1059-0.

Wing, J. (2006). Computational thinking. *Communications of the ACM, 49(3),* 33-36.

Wing, J. (2011). Research notebook: Computational thinking –What and why? *The Link Magazine of Carnegie Mellon University's School of Computer Science*. Retrieved, January 18 2019, from http://www.cs.cmu.edu/link/research-notebook-computational-thinking-what-and-why.

Wu, M. L., & Richards, K. (2011). Facilitating Computational Thinking Through Game Design. In *Proceedings of the 6th International Conference on E-learning and Games, Edutainment Technologies* (pp. 220–227). Berlin, Heidelberg: Springer-Verlag.

Yadav, A., Mayfield, C., Zhou, N., Hambrusch, S., & Korb, J. T. (2014). Computational Thinking in Elementary and Secondary Teacher Education. *ACM Transactions on Computing Education*, *14*(1), 1–16. https://doi.org/10.1145/2576872

Yadav, A., Zhou, N., Mayfield, C., Hambrusch, S., & Korb, J. T. (2011). Introducing Computational Thinking in Education Courses. In *Proceedings of the 42nd ACM Technical Symposium on Computer Science Education* (pp. 465–470). NewYork, NY, USA: ACM. https://doi.org/10.1145/1953163.1953297

Appendices

Appendix I. CT Dimensions, definitions, and examples.

CT DIMENSION	DEFINITION & EXAMPLES
ALGORITHMIC THINKING	Algorithmic thinking is a way of getting to a solution through the clear definition of the steps needed. For example, we all learn algorithms for doing multiplication at school. If we (or a computer) follow the rules we were taught precisely we can get the answer to any multiplication problem. https://teachinglondoncomputing.org/resources/developing-computational-thinking/algorithmic-thinking/ https://www.barefootcomputing.org/concepts-and-approaches/algorithms
ABSTRACTION	Abstraction is a way to make problems or systems easier to think about. It simply involves hiding detail – removing unnecessary complexity. The skill is in choosing the right detail to hide so that the problem becomes easier without losing anything that is important. A school timetable is an abstraction of what happens in a typical week. It shows key information about classes, teachers, rooms and times but ignores further layers of detail such as learning objectives and activities. https://teachinglondoncomputing.org/resources/developing-computational-thinking/abstraction/ https://www.barefootcomputing.org/concepts-and-approaches/abstraction
GENERALISATION	Generalisation is a way of quickly solving new problems based on previous problems we have solved. We can take an algorithm that solves some specific problem and adapt it so that it solves a whole class of similar problems. Then whenever we have to solve a new problem of that kind we just apply this general solution. For example, a pupil writes a computer program to draw a series of shapes, such as a square and a triangle. If he/she then wants to draw an octagon or a 10-sided shape, he/she can adjust the algorithm and use it to draw any regular polygon. https://teachinglondoncomputing.org/resources/developing-computational-thinking/generalisation/
LOGICAL REASONING	Logical reasoning helps us explain why something happens. At its heart, logical reasoning is about being able to explain why something is the way it is. There are many ways that children draw on logical reasoning across the curriculum. In science, pupils should be able to explain how they've arrived at certain conclusions from the results of experiments. In history, pupils should understand how our knowledge is constructed from a variety of sources, and they should be able to discuss the logical connections between cause and effect. They'll also use logical reasoning to analyse philosophical arguments. https://www.barefootcomputing.org/concepts-and-approaches/logic https://csunplugged.org/en/computational-thinking/

PATTERN MATCHING	Pattern recognition in problem solving is key to determining appropriate solutions to problems and knowing how to solve certain types of problems. Recognizing a pattern, or similar characteristics helps break down the problem and also build a construct as a path for the solution. Ever find yourself saying, 'where have I seen this before', could be a significant step in computational thinking. Patterns exist between different problems and within a single problem. https://sites.google.com/isabc.ca/computationalthinking/pattern-recognition https://www.barefootcomputing.org/concepts-and-approaches/patterns https://teachinglondoncomputing.org/pattern-matching-puzzles/ https://csunplugged.org/en/computational-thinking/
PROBLEM DECOMPOSITION	Decomposition is a way of thinking about problems, algorithms, artefacts, processes and systems in terms of their parts. The separate parts can then be understood, solved, developed and evaluated separately. This makes complex problems easier to solve and large systems easier to design. As a simple example, making breakfast can be decomposed into a number of smaller tasks. Or if we are developing a game, different people can design and create the different levels independently provided key aspects are agreed in advance. https://teachinglondoncomputing.org/resources/developing-computational-thinking/decomposition/ https://www.barefootcomputing.org/concepts-and-approaches/decomposition
PROBLEM TRANSLATION	You can use Computational Thinking to think about how to translate real-world processes for a computer to understand. An example might be making a sandwich or traveling a path. Furthermore. one of the most important standards of Computational Thinking is the need for a translation process from a higher-level language to machine executable code. https://teachinglondoncomputing.org/resources/
EVALUATION	Evaluation is about making judgements, where possible in an objective and systematic way. Every day, we make judgements about what to do and what we think, based on a range of factors. Evaluation is about judging the quality, effectiveness and efficiency of products, solutions, processes and systems. We ascertain whether they're fit for purpose. One approach could be to consider specific criteria, e.g. a design goal or specification, or user needs. Evaluation is something that occurs daily across schools. Pupils evaluate their work; teachers evaluate lessons, learning and progress. Self- and peer-assessment can help to develop children's evaluation skills, as they make judgements using success criteria and consider potential improvements. https://www.barefootcomputing.org/concepts-and-approaches/evaluation https://teachinglondoncomputing.org/resources/developing-computational-thinking/evaluation/ https://csunplugged.org/en/computational-thinking/

REPRESENTATION	The representation of a problem has a significant impact to the problem-solving difficulty (Rich & Knight, 1991); Solaz-Portolés & Lopez, 2007), e.g. see the mutilated chessboard problem (Rich & Knight, 1991; MCP, 2019). The familiarization to several problem representation methodologies constitutes a strategic goal for problem solving competency development. Computer Science enhances the applicability of well-known problem representation systems such as geometry, algebra, calculus. In addition, CS offers new representation systems such as finite state automata, semantic networks, predicate logic, neural networks, interactive stories, code etc. CT Representation Dimension concerns the use of computational implementations of representation systems in problem solving of several disciplines. Examples of learning scenarios related to representation follows: THE KNIGHT'S TOUR ACTIVITY https://teachinglondoncomputing.org/resources/inspiring-unplugged-classroom-activities/the-knights-tour-activity/ THE BRAIN-IN-A-BAG ACTIVITY https://teachinglondoncomputing.org/resources/inspiring-unplugged-classroom-activities/the-brain-in-a-bag-activity/ ERROR DETECTION https://classic.csunplugged.org/error-detection/ FINITE STATE AUTOMATA https://classic.csunplugged.org/finite-state-automata/#Treasure_Hunt THE MUDDY CITY https://classic.csunplugged.org/minimal-spanning-trees/ References MCP (2019). Mutilated chessboard problem. In Wikipedia, The Free Encyclopedia. Retrieved 17:32, January 11, 2020, from https://en.wikipedia.org/w/index.php?title=Mutilated_chessboard_problem Rich, E., & Knight, K. (1991) Artificial intelligence. McGraw-Hill. Solaz-Portolés, J. J., & Lopez, V. S. (2007, December). Representations in problem solving in science: Directions for practice. In Asia-Pacific Forum on Science Learning and Teaching (Vol. 8, No. 2, pp. 1-17). The Education University of Hong Kong, Department of Science and Environmental Studies.
DATA COLLECTION	All sorts of data practices involve computational thinking. Collecting data, analyzing data, and representing data in different ways all help you think about a problem. Data collection is the process of gathering appropriate information. For example, students develop a survey and collect both qualitative and quantitative data to answer the question: "Haw global warming changed the quality of life?". https://id.iste.org/docs/ct-documents/ct-leadershipt-toolkit.pdf?sfvrsn=4
DATA REPRESENTATION	All sorts of data practices involve computational thinking. Collecting data, analyzing data, and representing data in different ways all help you think about a problem. Data Representation is the process of depicting and organizing data in appropriate graphs, charts, words, or images. For example, groups of students represent the same data in different ways based on a position relating to the question: "Has global warming changed the quality of life?" Different representations may result in varying conclusions. https://id.iste.org/docs/ct-documents/ct-leadershipt-toolkit.pdf?sfvrsn=4

DATA ANALYSIS	All sorts of data practices involve computational thinking. Collecting data, analyzing data, and representing data in different ways all help you think about a problem. Data Analysis is the process of making sense of data, finding patterns, and drawing conclusions. For example, the use of appropriate statistical methods that will best test the hypothesis: “Global warning has not changed the quality of life”. https://id.iste.org/docs/ct-documents/ct-leadershipt-toolkit.pdf?sfvrsn=4
MODELING	A model is an abstract representation of a real system. Models often use mathematical and computational ideas to express relationships between entities of interest. A model is an example of abstraction. https://ctpdonline.org/computational-thinking/
SIMULATION	Simulation is the process of having computers or machines do repetitive or tedious tasks. For example, create an animation to demonstrate the understanding of a process, or use a model of a simple ecosystem to conduct experiments that answer what happens to the ecosystem if some percentage of the producers die. https://id.iste.org/docs/ct-documents/ct-leadershipt-toolkit.pdf?sfvrsn=4
AUTOMATION	Automation is the process of having computers or machines do repetitive or tedious tasks. Real-world examples of automation include barcodes, teller machines and library bar codes. An example of automation could be to program a sensor to collect pollution data and then use a computer program to sort the readings from maximum to minimum CO_2 levels. https://id.iste.org/docs/ct-documents/ct-leadershipt-toolkit.pdf?sfvrsn=4
SEQUENCING	Programmers ‘sequence’ instructions: putting them in the right order. Sequences are often placed in to ‘loops’, doing the same sequences of instructions over and over. Sequences and loops occur in nature too. Lifecycles, for example, are sequences of events happening in a loop. https://teachinglondoncomputing.org/sequencing-and-looping-puzzles/
TESTING	Thorough testing, double checking, and attention to detail, are concepts of great importance while solving problems. https://teachinglondoncomputing.org/resources/computational-thinking-magical-book-magic/
UNDERSTANDING PEOPLE	Computing is not just about technology; it is about understanding people too. When we solve computing problems, we are solving them for people. Computational thinking is the general group of problem-solving skills that students learn because of studying computing. However, it just as important to make programs usable by people – or they will not be used. https://teachinglondoncomputing.org/free-workshops/4-computational-thinking-its-about-people-too/

Appendix II. CT integration in the national educational systems of the partners

Computational Thinking in Greece

In Greece, education is mandatory for K-6 grades (primary education, ages 5-12) and 6-9 grades (Gymnasium - mandatory secondary education, ages 13-15). The Greek National Curriculum was developed in 2011 and is valid since then. The Curriculum is common for all public schools of the country and it consists a mix of Information and Communication Technologies (ICT) and Computer Science (CS). The Curriculum provides for 1 hour/week of ICT lessons for each grade of **primary school** (grades 1-6) and is structured around 4 basic strands.

1. **ICT as a learning - cognitive tool** running through all the Curriculum subjects: I know, create and express myself with ICT (I know the computer and how to use it, I create and express myself using digital painting, multimedia and presentations, I create using text editing).
2. **ICT as a problem-solving methodology**, for the cultivation of methodological skills and high-level skills (research, critical and analytical thinking, synthetic ability, communication skills and collaboration skills): I inquire-explore, discover, and solve problems using ICT (I create concept map models of problems, I solve problems using spreadsheets, I create computer programs, I implement research/work projects).
3. **ICT as a technological tool** for the adequacy of handling modern environments: I get to know the Internet, I communicate and collaborate.
4. **ICT as a social phenomenon**, for the acquisition of wider digital educations and understanding of the new social and cultural environment: I develop digital literacy and citizenship.

The Curriculum is Computational Thinking (CT) compatible. Under the strand “I implement research/work projects”, teachers are free to implement educational projects with their students concerning any CS concepts and/or practice (e.g. robotics, STEM technology etc.).

In lower **secondary school** (mandatory, grades 7-9, ages 13-15), there also is a Computer Science class for 1 hour/week. The Curriculum in this case is constructed around 4 basic strands.

1. **Computer Science in the modern world**: basic concepts
2. **Use and create**: create with text editors
3. **Search, communicate and collaborate**: get to know the Internet and communicate, create and express using multimedia and presentations, search and collaborate through the Internet
4. **Explore, discover and solve problems**: program computer devices and robotic systems, solve problems using spreadsheets

The Curriculum highlights that Code writing and computer programming are directly related to Computational Thinking and aim to cultivate and develop Computational Thinking skills, such as problem solving and system design. Therefore, the cultivation and development of computer skills and attitudes through the teaching of programming arises as a natural result. The teacher is free to use any logo-like programming environment or tile-based visual programming environment to achieve learning goals related to Computational Thinking, such as problem understanding, analysis, abstraction, algorithms, error detection etc.

National Curriculum for primary and secondary education are currently reviewed and are expected to change during 2023. Computational Thinking is plays a central role in the new Greek CS education Curriculum.

Computational Thinking in Norway

School and education in Norway:

Education is compulsory and free for children and adolescents aged 6-16. All youth between the ages of 16 and 19 are legally entitled to three years of upper secondary education. In 2020 , it was carried out a comprehensive renewal of the curricula in the Norwegian school, called LK20. In LK20, clear guidelines are given that computational thinking and programming are important skills that students must have in their future and it is emphasized that it is important that students acquire basic skills in this so that they can develop good skills in problem solving and develop the ability to think critically about the use of technology and programming (Andersen 2020).

The Norwegian Directorate of Education uses the following definition of Computational thinking as the basis for the renewed curricula :

> "To think algorithmically is to assess which steps are needed to solve a problem, and to be able to use one's technological competence to get a computer to solve (parts of) the problem. This also includes an understanding of what kind of problems/tasks can be solved with technology and what should be left to people" (Directorate of Education, 2019)

Furthermore, the Directorate of Education writes:

> "Computational thinking involves breaking down complex problems into smaller, more manageable sub-problems that can be solved. It includes organizing and analyzing information in a logical way and creating methods (algorithms) to arrive at the desired solution. It is also about creating abstractions and models of the real world by removing unnecessary details and focusing on what is relevant to the problem and solution in question. A solution to a specific problem can often be generalized so that it can be used to solve similar problems, and solutions to several subproblems can be combined to solve more complex problems.
> The computational thinker must be systematic and analytical in his work, but it is at least as important to be creative, experimental and open to alternative solutions. It requires a curious and exploratory approach to formulating and solving problems. Making mistakes along the way is an important part of the process, and the algorithmic thinker must have strategies to detect that something is wrong and correct the mistakes. This requires a "cognitive fitness" to not give up, and it is important to train this by working on continuous improvement during the process. Good solutions do not arise in a vacuum, and collaboration and sharing are therefore central working methods for the algorithmic thinker" (Directorate of Education, 2019)

The Norwegian curriculum LK20 consists of an overarching part, the distribution of subjects and hours and curricula in the various subjects. The curriculum defines five basic skills: reading, writing, arithmetic, oral skills and digital skills. These skills are part of the professional competence and necessary tools for learning and professional understanding.

In addition, the curriculum in each individual subject contains so-called core elements. The core elements consist of central concepts, methods, ways of thinking, areas of knowledge and forms of expression. The core elements characterize the content and progression of the curricula and should contribute to the students developing an understanding of the content and connections in the subject over time (Directorate of Education 2019). Examples of core elements included in computational thinking are:

- **Abstraction** : Being able to reduce unnecessary details and focus on elements that are significant. Being able to abstract the essence and ignore irrelevant information
- **Algorithms** : Being able to create instructions by sequencing, selecting, repeating. Being able to follow and explain step-by-step instructions
- **Logic** : Being able to analyze situations, check facts, verify hypotheses, make decisions and draw conclusions
- **Collaboration** : Being able to distribute tasks, roles, build on each other's projects
- **Creativity** : Being able to "think outside the box"
- **Efficiency** : Being able to design something that is easy to use, without unnecessary steps
- **Logic** : Being able to analyze situations, check facts, verify hypotheses, make decisions and draw conclusions
- **Patterns and generalizations** : Being able to identify repetitive patterns based on similarities and differences, assess transfer value. To recognize patterns and relationships and be able to formulate general rules

Programming and coding are subjects that are closely linked to computational thinking, and in LK20 there are examples of competence targets that include both coding and programming. In particular, the subjects mathematics and science have been assigned to take care of teaching students programming and coding.

In the Curriculum LK20, we find computational thinking in various competence targets at the stages in the following ways:

2nd grade:
• *create and follow rules and step-by-step instructions in play and games*

3rd grade:
• *create and follow rules and step-by-step instructions in play and games related to The coordinate system*

4th grade:
• *explore and describe structures and patterns in play and games*
• *create algorithms and express them using variables, conditions and loops*

5th grade:
• *create and program algorithms using variables, conditions and loops*
6th grade:
• *use variables, loops, conditions and functions in programming to explore geometric figures and patterns*

7th grade:
• *use programming to explore data in tables and datasets*

8th grade:
• *explore how algorithms can be created, tested and improved using programming*

9th grade:
• *simulate outcomes in random experiments and calculate the probability that something will occur, using programming*

10th grade:
• *model situations related to real data sets, present the results and argue that the models are valid*
• *explore mathematical properties and relationships using programming*
(Ministry of Education 2019a)

Upper Secondary school, grade 11, Mathematics 1T:

• *formulate and solve problems using algorithmic thinking, various problem-solving strategies, digital tools and programming*
(Ministry of Education (2019b).)

Different ways of implementing algorithmic thinking are often linked to programming and coding. You can work with programming and algorithmic thinking at many levels and grade levels, both with and without a computer. Without a computer, one can e.g. work with sorting algorithms (Gjøvik, Ø & Torkildsen, HA, 2019). With a computer, Scratch, which is a form of block coding, is often used at lower grades since Scratch is considered a digital learning tool that can promote computational thinking and increase students' competence in this area (Gjøvik, Ø & Torkildsen, HA (2019 *)*). At higher grade levels, it is most common to work with problem-solving tasks using coding in Python.

Reference list

Andersen, R (2022). *Algorithmic thinking in LK20 - the Norwegian context* . Digital learning resource . Obtained from: https://kunnskapsfilm.no/wp-content/uploads/2021/11/Algoritmisk-tenkning.pdf

Gjøvik, Ø & Torkildsen, HA (2019 *). Algorithmic thinking.* Tangenten . journal for mathematics education, 30(3). 31-37.

Ministry of Education (2019a). *Curriculum in mathematics* (MAT01-05). Established as a regulation. The Curriculum Agency for the Knowledge Promotion 2020

Ministry of Education (2019b). *Curriculum in mathematics joint subject VG1 theoretical mathematics* (MAT01-05). Established as a regulation. The Curriculum Agency for the Knowledge Promotion 2020. Retrieved from: https://www.udir.no/lk20/mat09-01/kompetansemaal-og-vurdering/kv42

Directorate of Education. (2019, 27 March) *Algorithmic thinking* . Obtained from: https://www.udir.no/kvalitet-og-kompetanse/profesjonsfaglig-digital-kompetanse/algoritmisk-tenkning/

Directorate of Education. (2019, 18 November). Obtained from: https://www.udir.no/laring-og-trivsel/lareplanverket/stotte/hva-er-kjerneelementer/

Computational Thinking in Portugal

Portugal, like many other countries, accepted the incentive from the European Commission, through the Digital Education Action Plan 2021-2027 that considers Computer Education a key element in learning at school. Schools and Universities become aware of the importance of developing virtual cognitive processes in students and how computational thinking allows students to approach problems in a different way. In this sense integrating computational thinking from primary school (programming and robotics) is a good starting point to develop from a very young age abstraction and deductive thinking.

The Digital Training of Schools (Capacitação Digital das Escolas), included in the Action Plan for Digital Transition (Resolution of the Council of Ministers nº 30/2020 of 21 April) foresees, among others, a strong commitment to the digital training of teachers, the digital development of schools and the availability of digital educational resources.

Having in mind the importance of Computational Thinking as a pedagogical practice, this Action Plan aims to provide teachers with teaching tools and strategies that facilitate their work while preparing pedagogical content, to incorporate computational thinking in all years of schooling in order to promote scientific and technological literacy, concepts that are useful in all areas of learning.

In Portugal, the Action Plan for Digital transition aims to promote the development of innovative strategies that can have an impact on improving learning environments and teaching quality.

Computational Thinking in Spain

Computational thinking is not specifically treated in the national curriculum nor in its specification through the Canarian curriculum (as you probably know in Spain we all have a basic national curriculum and those from each Autonomous Community which are based on the previous national curriculum mentioned).

So the treatment of the computational thinking is done through the development of the Digital competence as defined by "Orden ECD/65/2025. relaciones entre las competencias, los contenidos y los criterios de evaluación de la educación primaria, la educación secundaria obligatoria y el bachillerato" (attached file page 6995). The Digital Competence implies a creative, critic and safe use of information and communication technologies to reach aims related with work and employability, learning, the use of spare time, inclusiveness and social participation.

Once the whole competence is analyzed the computational thinking development can be integrated in the Digital Competence dimensions framed by the already mentioned educative standard. These dimensions that can be integrated to are information (analysis, interpretation, evaluation, transformation...), communication, content creation and problem solving.

Here are the links of the proposal through the Educative technology area in the Canary islands where different proposals are shown to the educative community to be shared and developed:

- http://www3.gobiernodecanarias.org/medusa/ecoescuela/ate/2017/06/20/pensamiento-computacional
- http://www3.gobiernodecanarias.org/medusa/ecoescuela/educarobot

From the beginning of the project up to this moment the situation has not changed very much in terms of how the computational thinking is developed through the curriculum even with a change of educational law the treatment still remains as cross curricular t, within the Digital competence although it might also be included in different compulsory subjects like Mathematics in Primary and Secondary Education, Technology in Secondary Education (year 1, 2 and 3) or Informatics in Bachelor's degree.

In the law currently in vigour in our country, computational thinking is not reflected as such in the curriculum. Only in the subjects of Information Technology is the resolution of algorithms sequentially treated. This does not mean that teachers are not including it transversally in compulsory content, especially in Computer Science and Technology subjects. This year a new law comes into force, and with it a new curriculum, which gives hope that it will be included in the future.

Appendix III. Learning Script Template

Part A. General Data	
A.1 Title:	*The title of the learning script, e.g. The enigma machine*
A.2 Author(s):	*Name, Surname, Affiliation*
A.3 Abstract/ Summary:	*Short but informal summary of the scenario. May include the concepts/skills/attitudes it concerns. Some elements of the plot-pretext for the students. The main CT technology it may use (e.g. Python, Arduino etc.). The teaching methods employed and the outcomes-products that the students are expected to obtain or build (e.g. a mobile app, a robotic device). The interdisciplinary subjects it concerns, the educational problem it solves, etc.*
A.4 Keywords:	*Some key concepts or descriptors for indexing purposes*
A.5 Version:	*E.g. 12 and/or draft, and/or revised, and/or final*
A.6 Date:	*The issue date of the version, e.g. 3/7/2020*
A.7 Copyright license:	*Use the creative-commons license scheme (https://creativecommons.org/licenses/?lang=en) e.g.: Attribution ShareAlike CC BY-SA*
Part B. Learning Data	
B.1 Grade(s):	*K-12 e.g.: Grades 6-7 or Age(s): e.g.: 12-13 years old*
B.2 Subject(s):	*Since CompuT learning scenarios aim at the integration of CT in the existing curriculum, several subjects could be mentioned here in addition to CT, e.g., Computer Science, Physics, Language.*
B.3 Topic(s):	*E.g. Data analysis*

B.4 Computational Thinking Dimensions:	*Check or note the dimensions which the scenario involves:*

Algorithmic Thinking (AL)	
Abstraction (AB)	
Generalization (GE)	
Logical reasoning (LR)	
Pattern matching (PM)	
Problem decomposition (PD)	
Problem translation (PT)	
Evaluation (EV)	
Representation (RE)	
Data collection (DC)	
Data representation (DR)	
Data analysis (DA)	
Modeling (MO)	
Simulation – (SIM)	
Automation (AUT)	
Sequencing (SE)	
Testing (TE)	
Understanding People – (UP) /Artificial Intelligence (AI)	

B.5 Computational Thinking Approaches:	*Check or note the CT approaches which the scenario employs*

Tinkering experimenting & playing	
Creating, designing, and making	
Debugging, finding, and fixing errors	
Persevering, keeping going	
Collaborating, working together	

B.6 Thematic in the context of the ComputT Project:	*In the context of the CompuT Project we choose some thematic units to drive the development of the scenario:*		
	Educational Robotics or Physical Computing		
	Computational Science project	Modeling/Simulation	
		Bifocal modelling	
		Sensors use or making	
		Maths and CS	
		Other: …	
	Data science project		
	History of science and technology		
	Digital game, software, or mobile app		
	Digital humanities projects	Digital Storytelling	
		Interactive Fiction	
		Text mining	
		Algorithms in everyday life	
		Other: …	
	Artificial Intelligence Projects		
	Studio approach – Future Classroom projects		
	Unplugged experiential or using manipulatives		
	Other:….		
B.7 Purpose/Aim of the learning scenario:	*What we are trying to obtain with the implementation of the learning scenario in the long run.*		
B.8 Learning outcomes/goals15:	*Specify observable actions and evaluable performance criteria in terms of students' knowledge, skills, and attitudes-affective domains.*		
	B.8.1 Knowledge		
	B.8.2 Skills		
	B.8.3 Attitudes-affective		
B.9 Horizontal competences - 21st century skills:	*Note how the scenario might support the development of general competences and various of the so-called 21st century skills.*		
	B.9.1 Learning and innovation skills:	*4C's: Collaboration, Communication, Critical Thinking, Creativity*	

15 For the effective formulation of learning-instructional goals the works of Mager, who claims for the definition of observable actions and Measurable Criteria of performance evaluation under specific conditions, could be useful. Mager, F. (1975). Preparing Instructional Objectives. (2nd ed.). Belmont, CA: Fearon. & Mager, F. (1997). Preparing instructional objectives: A critical tool in the development of effective instruction. Atlanta: The Center for Effective Performance. The verbs could follow the Bloom's knowledge taxonomy, see for example: https://tips.uark.edu/blooms-taxonomy-verb-chart/. It is important to use higher order thinking verbs. Anderson, L. W., & Krathwohl, D. R. (2001). A taxonomy for learning, teaching, and assessing, Abridged Edition. Boston, MA: Allyn and Bacon

	B.9.2 Digital literacy skills:	*Information literacy, Media literacy, Information and Communication technologies (ICT) literacy, Digital citizenship*
	B.9.3 Career and life skills:	*Flexibility and adaptability, initiative and self-direction, social and cross-cultural interaction, productivity and accountability, leadership and responsibility*
B.10 Modern teaching methods:	*Note how you are making use of modern teaching methods. This field guides the designer to consider and prefer making use of modern effective teaching methods in a balanced manner. Such methods include: Collaborative Learning e.g. group work according to a collaborative inquiry script, Game Based Learning, Gamification e.g. students play an escape game, Project-Based Learning, STEM Learning, Tinkering, Learning by design, Authentic learning in studio or future classroom, Bifocal modeling, Learning by coding, Storytelling.*	
B.11 Integration of CT into the curriculum:	*Explain/analyze the interdisciplinary activities/approach of the scenario that document the CT learning integration in the current curriculum.*	
B.12 Relation to curriculum and/or standards:	*Which specific National or International standards and/or curriculum goals are accomplished through the use of the scenario. E.g. ISTE Standards or your local curriculum sections covered by the scenario.* *e.g. Greek National Curriculum, Grade 7, Geometry Curriculum* *e.g. ISTE, CSTA CT Standards for Data Collection, Grades 6-8: Design survey questions to collect appropriate information to answer questions (e.g. asking fellow students if they were absent from school in the past month and whether they were suffering from the flu).*	
B.13. Prerequisite knowledge:	*Assumed prior knowledge needed to successfully implement the current scenario, e.g. students need to have basic knowledge of python, and wiring, or how to use a compass.*	
B.14. Difficulty Level of the Scenario:	*Easy, intermediate, hard, extra-hard*	
B.15. Social setting of the scenario:	*E.g. individual, pair, small group (3-4 students), large group, whole class*	
B.16 Place of implementation:	*E.g. Classroom, Future classroom, Computer Lab, School yard, other*	
B.17 Teaching time – Duration:	*E.g. 4 x 45' sessions*	
B.18 Educational material, resources,	**B.18.1 Software:**	*E.g. Scratch*
	B.18.2 Hardware:	*E.g. Micro:bit controller, video cam, drone*
	B.18.3 Online resources:	*E.g. Youtube video, online tutorials, etc.*

<table>
<tr><td>instruments, tools, and media:</td><td>B.18.4 Conventional educational material:</td><td>post-it, notebooks, textbook, Whiteboard pens, flip paper, blue tac</td></tr>
<tr><td colspan="3"><u>Part C. Learning Experience Design</u></td></tr>
<tr><td rowspan="2">C.1. Activities-Action-Plot-Storyboard sequence table:</td><td colspan="2">
<table>
<tr><td>Phase 1.</td><td>Phase title (e.g. Introduction)</td><td></td></tr>
<tr><td>Activity/Task</td><td>Description/Procedure</td><td>Duration</td></tr>
<tr><td>A1.1 Descriptive name for the activity/task.
e.g. plan a maze, solve a puzzle, play a role game to feel like the victim etc.</td><td>Describe the actions of teachers and students. Describe their products and their goal. Mention the resources/materials/instruments/media teachers and students use and/or may produce.</td><td>The time needed to complete the activity</td></tr>
<tr><td>A1.2</td><td></td><td></td></tr>
<tr><td>A1.3</td><td></td><td></td></tr>
<tr><td>Phase 2.</td><td>Phase title (e.g. Explore the microbit:cc)</td><td></td></tr>
<tr><td>Activity/Task</td><td>Description/Procedure</td><td>Duration</td></tr>
<tr><td>A2.1</td><td></td><td></td></tr>
<tr><td>A2.2</td><td></td><td></td></tr>
</table>
</td></tr>
<tr><td colspan="2">
Hints-comments for the table specification

• Hint 1. Organize the scenario activities into phases.
If the scenario consists of a big number of activities/tasks, then it is possible to organize them into groups, called phases. E.g. Phase 1. Introduction activities, Phase 2. Exploration activities, Phase 3. Solution design activities, Phase 4. Development and Phase 5. Evaluation and reflection activities. For each such phase a table of activities as the above one should be defined.

• Hint 2. Use of models to structure the scenario
The sequence of activities could follow traditional instructional models or more modern, progressive, and student-centered ones:

a) Traditional instructional models
Such as the nine events of instruction (Gagne, 1985; Gagne et al., 1992)16: Gain Attention, Inform Learners of the Objectives, Stimulate Recall of Prior Knowledge/Learning, Present the Stimulus (content or learning activity), Provide Guidance to the Learners, Elicit Performance from the Learners, Provide Feedback to the Learners, Assess the Performance of the Learners, Enhance the Retention & Transfer of the New Skills, Knowledge, and/or Attitudes. Or the use of similar simpler sequential models e.g. Students cognitive/emotional
</td></tr>
</table>

16 Gagné, R. M., Briggs, L. J., & Wager, W. W. (1992). Principles of instructional design (4th ed.). Forth Worth, TX: Harcourt Brace Jovanovich College Publishers
Gagne, R. (1985). The Conditions of Learning (4th ed.). New York: Holt, Rinehart & Winston

<table>
<tr><td></td><td colspan="2">preparation activities - Teaching activities - Reinforcement Activities - Assessment Activities, or 1. Introduction/ warm-up, 2. Instruction/ presentation, 3. Practice (with feedback)/Application, 4. Review or Summary, 5. Evaluation/Testing etc.

b) Student-centered learning activity models

Alternatively, it is possible to develop the sequence of activities according to student-centered models which are obviously consistent with the constructivist pedagogy and so support the production of corresponding pedagogy learning scenarios. Some well-known such models, for example, are:

• Inquiry learning models: For example, the 5Es model for inquiry instruction: 5E=Engage, Explore, Explain, Elaborate, Evaluate or variations such as Engage, Explore, Reflect, Extend, Discussion etc.

• Experiential models: Using the Kolb's Experiential Learning Cycle: 1.

• Concrete Experience, 2. Reflective Observation of the New Experience, 3. Abstract Conceptualization, 4. Active Experimentation.

• Experiment learning models: Question, Background Research, Hypothesis, Test/Experiment, Analyze Data, Draw Conclusions, Communicate Results

• Collaborative Learning: Using various CSCL-Scripts

• Learning by design and/or making: Analysis, Design, Development, Implementation, Evaluation

• The studio or the Future classroom model17: Organizing the learning activities in two or more of the six learning areas-zones of a Future classroom, namely: Interact, Exchange, Investigate, Create, Present, Develop</td></tr>
<tr><td rowspan="2">C.2 Assessment</td><td colspan="2">How will learning be identified? Provide suggestions and strategies for detecting student learning and performance.</td></tr>
<tr><td>C.2.1 Students feedback and reflection</td><td>How will students get informed about their performance and how is reflection structured</td></tr>
<tr><td>C.3 Homework/ Work with parents-family</td><td colspan="2">Possible homework assignments or proposals for the extension of the activity at home</td></tr>
<tr><td colspan="3"><u>Part D. Information for the Teachers</u></td></tr>
<tr><td>D.1 Adaptation - Differentiation for inclusion of all students</td><td colspan="2"></td></tr>
<tr><td>D.2 Extension</td><td colspan="2"></td></tr>
</table>

17 http://fcl.eun.org

D.3 Resources	
D.4 Experience deriving from the implementation of the scenario	
D.5 Relations to other scenarios	
D.6 Reviews by teachers	
D.7 Assessment of the scenario	*[1=Very Bad – 5=Very Good]*
D.8 References	
Part E. Annexes	
	Annexes may include complementary material of the learning scenario such as: Worksheets, Information Sheets, Questionnaires, Presentations, Code, students' products samples etc. which are essential for the implementation or the understanding of the scenario.

Appendix IV. Exemplar Learning Scenarios

Exemplar Scenario 01: *The history of computation automation*

Part A. General Data	
A.1 Title:	*The history of computation automation*
A.2 Author(s):	*Kefalas Ioannis, University of the Aegean*
A.3 Abstract/ Summary:	*In this scenario, students are traveling in the history of computation automation. During this journey, they are expected to learn about the first machines used to make simple calculations, and the antiquity of them, with a special focus on Pascal's mechanical calculator, the famous Pascaline. They will construct a simplified version of a Pascaline and will then use their model to perform a few calculations. This is a scenario that unites History, Arts and Computer Science in a creative, educational way.*
A.4 Keywords:	*Pascaline, Computation automation, Science History*
A.5 Version:	*Draft*
A.6 Date:	*29/10/2020*
A.7 Copyright license:	*Attribution ShareAlike CC BY-SA*
Part B. Learning Data	
B.1 Grade(s):	*Grades 7-8, Ages 12-13 years*
B.2 Subject(s):	*Computer Science, History, Arts.*
B.3 Topic(s):	*History of computation automation*
B.4 Computational Thinking Dimensions:	(see table below)

Algorithmic Thinking (AL)	✓
Abstraction (AB)	✓
Generalization (GE)	
Logical reasoning (LR)	✓
Pattern matching (PM)	
Problem decomposition (PD)	✓
Problem translation (PT)	
Evaluation (EV)	✓
Representation (RE)	✓
Data collection (DC)	
Data representation (DR)	
Data analysis (DA)	
Modeling (MO)	✓
Simulation – (SIM)	✓
Automation (AUT)	✓
Sequencing (SE)	
Testing (TE)	✓
Understanding People – (UP) /Artificial Intelligence (AI)	

<table>
<tr><td>B.5 Computational Thinking Approaches:</td><td>
<table>
<tr><td>Tinkering experimenting & playing</td><td>✓</td></tr>
<tr><td>Creating, designing, and making</td><td>✓</td></tr>
<tr><td>Debugging, finding, and fixing errors</td><td></td></tr>
<tr><td>Persevering, keeping going</td><td></td></tr>
<tr><td>Collaborating, working together</td><td>✓</td></tr>
</table>
</td></tr>
<tr><td>B.6 Thematic in the context of the CompuT Project:</td><td>
<table>
<tr><td>Educational Robotics or Physical Computing</td><td colspan="2"></td></tr>
<tr><td rowspan="5">Computational Science project</td><td>Modeling/Simulation</td><td>✓</td></tr>
<tr><td>Bifocal modelling</td><td></td></tr>
<tr><td>Sensors use or making</td><td></td></tr>
<tr><td>Maths and CS</td><td>✓</td></tr>
<tr><td>Other: …</td><td></td></tr>
<tr><td>Data science project</td><td colspan="2"></td></tr>
<tr><td>History of science and technology</td><td colspan="2">✓</td></tr>
<tr><td>Digital game, software, or mobile app</td><td colspan="2"></td></tr>
<tr><td>Digital humanities projects</td><td>Digital Storytelling</td><td></td></tr>
<tr><td></td><td>Interactive Fiction</td><td></td></tr>
<tr><td></td><td>Text mining</td><td></td></tr>
<tr><td></td><td>Algorithms in everyday life</td><td></td></tr>
<tr><td></td><td>Other: …</td><td></td></tr>
<tr><td>Artificial Intelligence Projects</td><td colspan="2"></td></tr>
<tr><td>Studio approach – Future Classroom projects</td><td colspan="2"></td></tr>
<tr><td>Unplugged experiential or using manipulatives</td><td colspan="2">✓</td></tr>
<tr><td>Other: ….</td><td colspan="2"></td></tr>
</table>
</td></tr>
<tr><td>B.7 Purpose/Aim of the learning scenario:</td><td>By completing this scenario, students will have gained basic knowledge about the historical evolution of computation automation and have become more familiar with the basic mechanisms of simple computation machines. Thus, the main purpose of the scenario is for them to understand the function of a computing machine, like the Pascaline and build their own machine so that they become engineers and scientists.</td></tr>
<tr><td rowspan="2">B.8 Learning outcomes/goals[18]:</td><td>Note how the scenario might support the development of general competences and various of the so-called 21st century skills.</td></tr>
<tr><td>
<table>
<tr><td>B.8.1 Knowledge</td><td>Recognize some of the mechanisms connected with the history of the</td></tr>
</table>
</td></tr>
</table>

[18] For the effective formulation of learning-instructional goals the works of Mager, who claims for the definition of observable actions and Measurable Criteria of performance evaluation under specific conditions, could be useful. Mager, F. (1975). Preparing Instructional Objectives. (2nd ed.). Belmont, CA: Fearon. & Mager, F. (1997). Preparing instructional objectives: A critical tool in the development of effective instruction. Atlanta: The Center for Effective Performance. The verbs could follow the Bloom's knowledge taxonomy, see for example: https://tips.uark.edu/blooms-taxonomy-verb-chart/. It is important to use higher order thinking verbs. Anderson, L. W., & Krathwohl, D. R. (2001). A taxonomy for learning, teaching, and assessing, Abridged Edition. Boston, MA: Allyn and Bacon

		• *computation automation, such as the Pascaline.* • *Describe how a calculating machine (such as Pascaline) works.*
	B.8.2 Skills	• *Develop Construction skills, by assembling their own Pascaline.*
	B.8.3 Attitudes-affective	• *Acknowledge the importance of the machines to solve everyday life problems.* • *Reflect on the evolution that occurred in science and lead to the modern computers we use nowadays.*
B.9 Horizontal competences - 21st century skills:	*This teaching scenario creates the right conditions in order to develop 21 st century skills such as critical thinking, problem solving, creativity, communication, collaboration, curiosity, initiative, perseverance, adaptability.*	
	B.9.1 Learning and innovation skills:	*4C's: Collaboration, Communication, Critical Thinking, Creativity* *Students will have to collaborate to build their machine, communicating, thinking critically and being creative.*
	B.9.2 Digital literacy skills:	*Information literacy: students will gain knowledge on the first steps of the information revolution.*
	B.9.3 Career and life skills:	*Flexibility and adaptability, social and cross-cultural interaction, productivity and accountability, leadership and responsibility:* *Students will adapt their model to their needs and resources, interacting with their classmates, being productive and responsible on the result.*
B.10 Modern teaching methods:	*The scenario includes modern teaching methods such as:* *Tinkering, as the students will have to assemble a cardboard Pascaline.* *Collaborative Learning, as they must work on teams to complete the tasks.*	
B.11 Integration of CT into the curriculum:	*This scenario includes a variety of disciplines such as history, art and CS, blended with many CT dimensions.*	
B.12 Relation to curriculum and/or standards:	*Greek National Curriculum, Grades 7-8, Computer Science Curriculum*	
B.13. Prerequisite knowledge:	*No prerequisite knowledge required.*	
B.14. Difficulty Level of the Scenario:	*Intermediate*	

B.15. Social setting of the scenario:	*The students will have to work in small groups to complete some of the activities of this scenario.*	
B.16 Place of implementation:	*Classroom, or Computer Lab*	
B.17 Teaching time – Duration:	*3 x 45' sessions*	
B.18 Educational material, resources, instruments, tools, and media:	**B.18.1 Software:**	
	B.18.2 Hardware:	
	B.18.3 Online resources:	*YouTube videos, Search engines*
	B.18.4 Conventional educational material:	*Cardboard pieces of Pascaline, Glue, nails or (Round head) fasteners*

Part C. Learning Experience Design

C.1. Activities-Action-Plot-Storyboard sequence table:

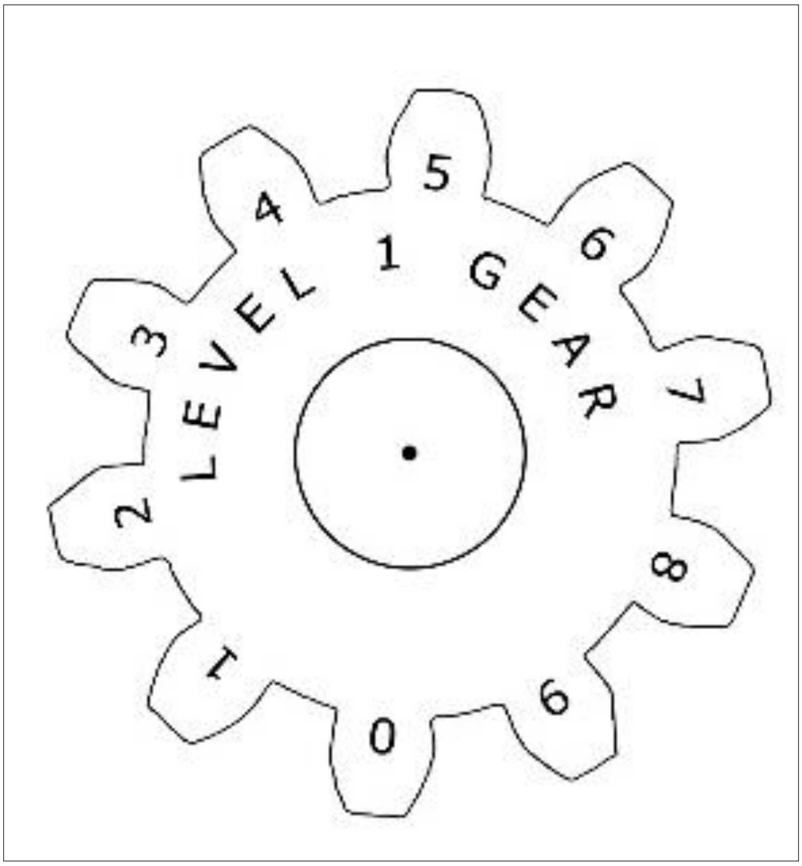
Phase 1.	***The History of Computation Machines***	
Activity/Task	**Description/Procedure**	**Duration**
A1.1 Gain attention – History of computation automation	*The teacher discusses the early steps of computation and projects a relative video to the students* *https://www.youtube.com/watch?v=O5nskjZ_GoI* *Students are asked to try to assume what the utility of what they see is.*	*20'*
A1.2 The Pascaline introduction	*The teacher focuses on the Pascaline and informs the students that this is a model of a mechanism created in 1642-44 by Pascal which operates some simple additions and subtractions, such as 98+6 and 22-5. He/she then projects a video and explains how the Pascaline works:* *https://www.youtube.com/watch?v=SeyMTzKYKqg&t=151s* *Point out that this was an attempt that people made to automate computations.*	*20'*
A1.3 Summary and next phase.	*The teacher sums ups and informs the class that in the next phase, split in groups, they are going to build their own cardboard Pascaline and try to use it to perform a few additions and subtractions.*	*5'*

Phase 2.	***Building a Pascaline Model***	
Activity/Task	**Description/Procedure**	**Duration**
A2.1 Build your Pascaline	*The teacher projects the following video and discusses with the students how they will build their own Pascaline:* • ***Pascaline DIY:*** *https://youtu.be/KgPsTBwn0eM* *Slides from the following presentation could also be exploited. For example, slide #19.* *https://www.cs.cmu.edu/afs/cs/academic/class/15294-f14/lectures/pascaline/pascaline.pdf* *Students are given* ***Worksheet 1****, paper, cardboard, nails and are asked to follow the steps in the Worksheet to build their Pascaline in groups.*	*45'*
Phase 3.	**Phase title (***Performing calculations with our Pascaline Model)*	
A3.1 Compare the groups' Pascaline models	*The groups compare their Pascaline cardboard models to see whether they are all identical. Possible construction errors are identified and corrected*	*5'*
A3.2 Perform calculations with the Pascaline model	*The teacher shares* ***Worksheet 2*** *and asks students to answer the questions on it. Students will have to do some operations to see if their Pascaline functions correctly and then answer general questions to deepen on the subject.* *If there is time left, extra numbers can be given to the students to test their model by performing additions and subtractions with them.*	*35'*
A3.3 Summary and discussion	*The teacher asks the students to evaluate the time it takes to do an operation using Pascal's calculator. Through a relevant discussion he/she tries to point out that the value of*	*5'*

		each invention is related to its time of occurrence.	
C.2 Assessment			
	C.2.1 Students feedback and reflection	*Students will try to add and subtract different numbers and evaluate their machine.*	
C.3 Homework/ Work with parents-family	*No homework needed.*		
Part D. Information for the Teachers			
D.1 Adaptation - Differentiation for inclusion of all students	*All students could implement the scenario*		
D.2 Extension	*Creation of a Pascaline using Lego:* https://youtu.be/olfNFXJEZOA		
D.3 Resources	*YouTube videos, Search engines, Cardboard pieces of Pascaline, Glue, nails or (Round head) fasteners*		
D.4 Experience deriving from the implementation of the scenario			
D.5 Relations to other scenarios			
D.6 Reviews by teachers			
D.7 Assessment of the scenario	*[1=Very Bad – 5=Very Good]*		
D.8 References			
Part E. Annexes			
	Worksheet 1 – Pascaline Assemblage *Worksheet 2 – The Pascaline in action*		

Worksheet 1 - Pascaline Assemblage

You are going to build a machine to do calculations, named Pascaline. Use the model given below, copy and cut 5 gears and follow the steps to build your own Pascaline! Ask your teacher for help if you need so. Good luck!



Following these steps, the Pascaline is built from right to left:

Make a level 1 gear:

1. Connect a circle with a gear using the nail, to make a level 1 gear.
2. Glue the level 1 gear to the lower rightmost predefined spot of the board (Figure 1).
3. Make a second level 1 gear and glue it to the upper rightmost spot (Figure 2).

Make a level 2 gear:

4. First make a level 1 gear and then glue it to a second circle.
5. Glue the level 2 gear to the lower middle spot (Figure 3).
6. Make a second level 2 gear and glue it to the upper left spot (Figure 4).

Make a level 3 gear:

7. First make a level 2 gear and then, glue it to a third circle.
8. Glue the level 3 gear to the lower leftmost spot (Figure 5).
9. Draw three pointers at the bottom of the Pascaline showing to the lower gears (Figure 6).

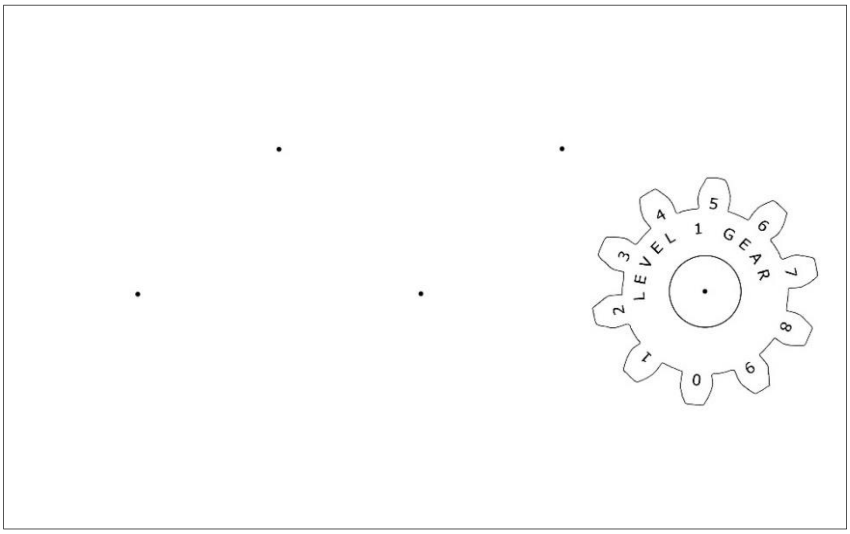


Figure 1

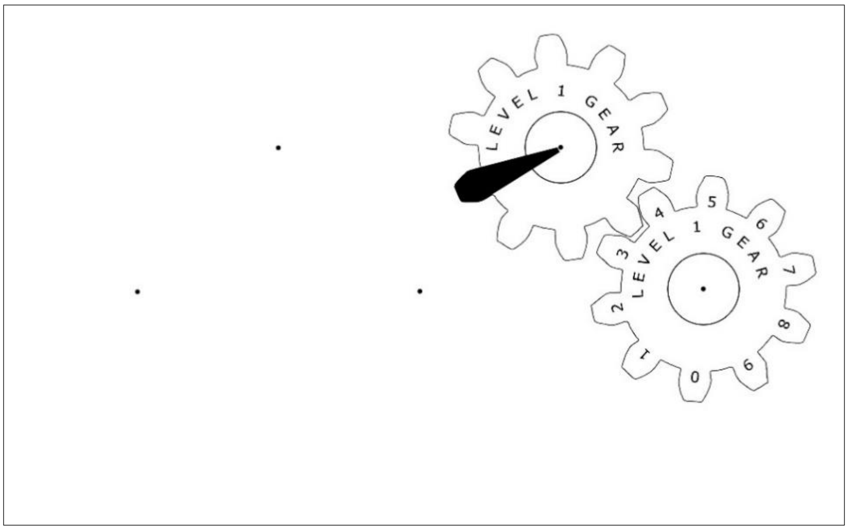


Figure 2

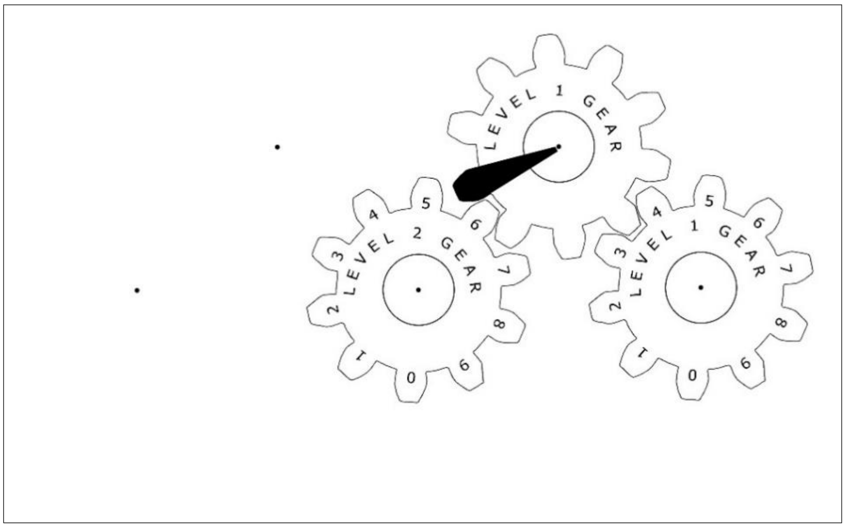


Figure 3

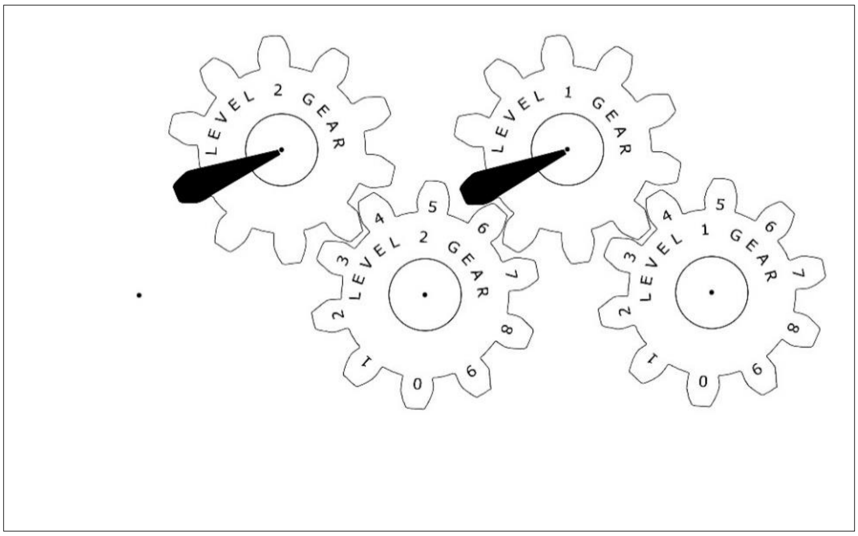


Figure 4

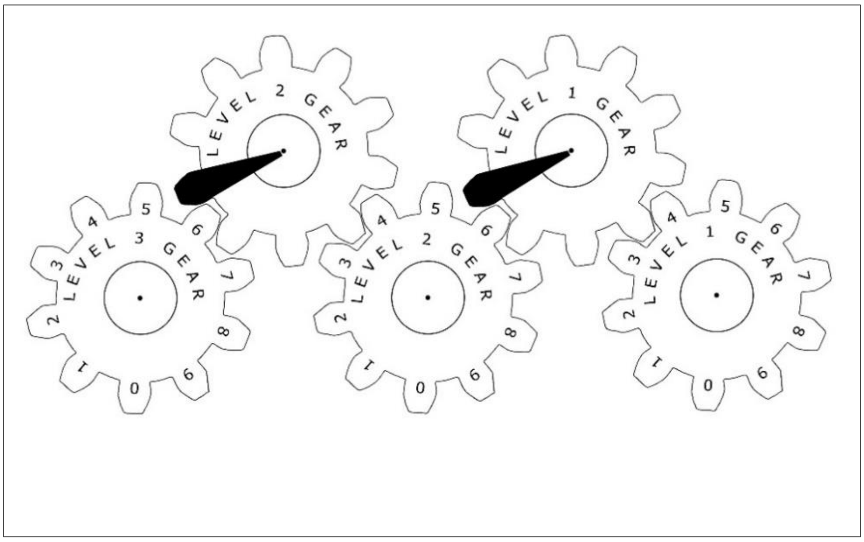


Figure 5

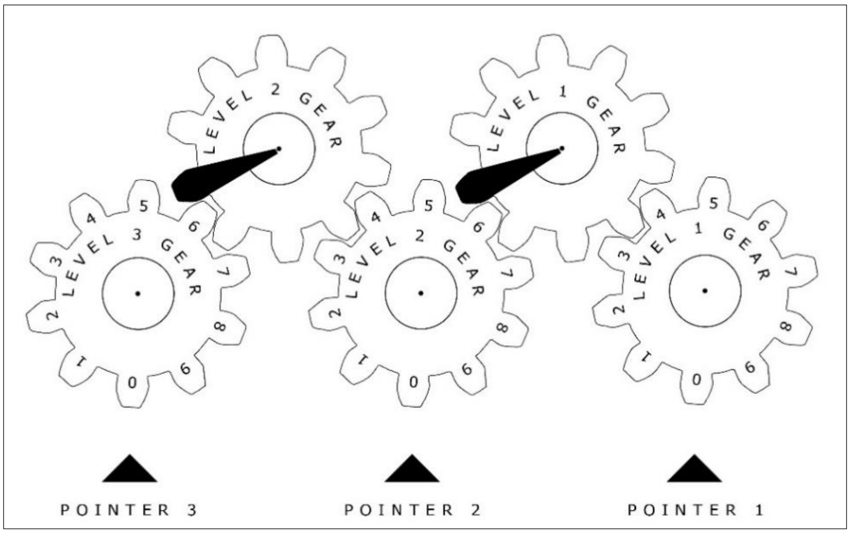


Figure 6

Worksheet 2 – The Pascaline in action

Name(s): ____________________________________

Date: ______________________________________

You have built a machine to do calculations, called Pascaline. Congratulations!
Now, let' s see if your machine functions properly.

1. *Use the Pascaline you built and try to add **87+5**. Is the result correct?*
2. *Now try to calculate **62-4**. Is your result correct?*

Try to answer the following questions:

3. Pascaline's front panel is divided in two distinct areas, an input, and an output. Can you locate these areas?
4. What is the maximum number that Pascaline can output?
5. What kind of arithmetic operations can one perform with Pascaline?
6. Is it possible to add non-integer numbers with Pascaline?
7. How can we inscribe a digit in Pascaline?
8. After the completion of an operation, Pascaline should be reset. How could this be done?
9. What is nines' complement of a number and how is this concept related to Pascaline?
10. What kind of device was Pascaline, analog or digital?

You are now a creator of a computing machine!

Well done!

Exemplar Scenario 02: *Finding Needles in the World's Biggest Haystack*

Part A. General Data	
A.1 Title:	*Finding Needles in the World's Biggest Haystack*
A.2 Author(s):	*Elisavet Mavroudi, University of the Aegean*
A.3 Abstract/ Summary:	*The present scenario deals with some of the core algorithms of the Web search and it is based on the homonymous (second) chapter of the book "The nine algorithms that changed the future" (J. MacCormick, 2012). Through the various activities of the scenario, students are led to a step-by-step discovery of some of the aspects that the indexing and ranking techniques of the search engines, employ. Finally, a first approach to the description of the structure of a web page through HTML, is attempted.*
A.4 Keywords:	*search engines, matching, indexing, nearness, metawords, HTML*
A.5 Version:	*V02*
A.6 Date:	*30/09/2021*
A.7 Copyright license:	*Attribution ShareAlike CC BY-SA*

Part B. Learning Data	
B.1 Grade(s):	*K-12: Grades 6-9 or Age(s): 12-14 years old*
B.2 Subject(s):	*Computer Science*
B.3 Topic(s):	*Algorithms, Search Engines*
B.4 Computational Thinking Dimensions:	*Check or note the dimensions which the scenario involves:*

Algorithmic Thinking (AL)	✓
Abstraction (AB)	✓
Generalization (GE)	✓
Logical reasoning (LR)	✓
Pattern matching (PM)	
Problem decomposition (PD)	
Problem translation (PT)	
Evaluation (EV)	
Representation (RE)	✓
Data collection (DC)	
Data representation (DR)	
Data analysis (DA)	
Modeling (MO)	
Simulation – (SIM)	✓
Automation (AUT)	
Sequencing (SE)	
Testing (TE)	
Understanding People – (UP) /Artificial Intelligence (AI)	

B.5 Computational Thinking Approaches:	*Check or note the CT approaches which the scenario employs*

Tinkering experimenting & playing	✓
Creating, designing, and making	✓
Debugging, finding, and fixing errors	
Persevering, keeping going	
Collaborating, working together	✓

B.6 Thematic in the context of the CompuT Project:	*In the context of the CompuT Project we choose some thematic units to drive the development of the scenario:*

Educational Robotics or Physical Computing		
Computational Science project	Modeling/Simulation	
	Bifocal modelling	
	Sensors use or making	
	Maths and CS	
	Other: …	
Data science project		
History of science and technology		
Digital game, software, or mobile app		
Digital humanities projects	Digital Storytelling	
	Interactive Fiction	
	Text mining	
	Algorithms in everyday life	✓
	Other: …	
Artificial Intelligence Projects		
Studio approach – Future Classroom projects		
Unplugged experiential or using manipulatives		
Other:….		

B.7 Purpose/Aim of the learning scenario:	*The long-term goal of this scenario is for students to be able to explain in simple terms the basic functions of search engines, to become aware of some "smart" ideas behind trivial actions they perform daily on their digital devices and through this engagement, to appreciate the contribution of algorithms to everyday life.*
B.8 Learning outcomes/goals[19]:	*After the completion of the scenario, students are expected to be able to:*

19 For the effective formulation of learning-instructional goals the works of Mager, who claims for the definition of observable actions and Measurable Criteria of performance evaluation under specific conditions, could be useful. Mager, F. (1975). Preparing Instructional Objectives. (2nd ed.). Belmont, CA: Fearon. & Mager, F. (1997). Preparing instructional objectives: A critical tool in the development of effective instruction. Atlanta: The Center for Effective Performance. The verbs could follow the Bloom's knowledge taxonomy, see for example: https://tips.uark.edu/blooms-taxonomy-verb-chart/. It is important to use higher order thinking verbs. Anderson, L. W., & Krathwohl, D. R. (2001). A taxonomy for learning, teaching, and assessing, Abridged Edition. Boston, MA: Allyn and Bacon

	B.8.1 Knowledge	• *distinguish between the two phases of a web search: (a) matching and, (b) ranking.* • *explain the word location trick and demonstrate its contribution in the efficient performance of phrase queries by the search engines.* • *explain how the "nearness" criterion may contribute to the improvement in the ranking of pages* • *recognize html tags*
	B.8.2 Skills	*Use search engines more efficiently*
	B.8.3 Attitudes-affective	• *gain a deeper appreciation of the ideas behind the actions they daily perform on their digital devices* • *appreciate the contribution of algorithms to everyday life*
B.9 Horizontal competences - 21st century skills:	*This learning scenario creates the appropriate conditions for the development of various 21st century skills.*	
	B.9.1 Learning and innovation skills:	*4C's: Collaboration, Communication, Critical Thinking, Creativity* *Throughout this learning scenario, students work in small groups. They are asked, with the help of properly designed questions, to process some data to draw conclusions, which they then present to the plenary. Through this way of working, they can develop and / or improve their Collaboration, Communication and Critical Thinking skills. Finally, their creative potential could be enriched by the very subject of the script, which involves the introduction of some tricks, that is, some clever techniques for accomplishing goals.*
	B.9.2 Digital literacy skills:	*Information literacy, Media literacy, Information and Communication technologies (ICT) literacy, Digital citizenship* *Web searching has become an extremely popular internet activity, an integral part of modern life. The present scenario aims to help internet users use search engines more efficiently, by understanding some aspects of their searching techniques. Pupils are also expected to have a much deeper appreciation of the ideas behind the actions they daily take on their digital devices.*
	B.9.3 Career and life skills:	*Flexibility and adaptability, initiative and self-direction, social and cross-cultural interaction, productivity and accountability, leadership, and responsibility*

B.10 Modern teaching methods:	*The scenario is basically following a discovery learning technique and employs a variety of methods such as work in small groups, a role-playing game and Tinkering.*
B.11 Integration of CT into the curriculum:	*This is not an interdisciplinary scenario. It, however, involves a variety of CT dimensions, within the context of CS discipline.*
B.12 Relation to curriculum and/or standards:	*Greek National Curriculum* *Grade 7 ICT Curriculum (Search Engines)* *Grade 9 ICT Curriculum (Algorithms)*
B.13. Prerequisite knowledge:	*Students need to have basic knowledge of web searching.* *Basic knowledge of Excel would also be desirable.*
B.14. Difficulty Level of the Scenario:	*Intermediate*
B.15. Social setting of the scenario:	*small group (3-4 students), whole class*
B.16 Place of implementation:	*Computer Lab*
B.17 Teaching time – Duration:	*4 x 45' sessions*
B.18 Educational material, resources, instruments, tools, and media:	**B.18.1 Software:** *web browsers, Excel* **B.18.2 Hardware:** *Pcs* **B.18.3 Online resources:** *YouTube video, Search Engines, https://www.w3schools.com/html/* **B.18.4 Conventional educational material**: *copies of book pages, books*

Part C. Learning Experience Design

C.1. Activities-Action-Plot-Storyboard sequence table:

Phase 1.	**Introduction to the concept of indexing**	
Activity/Task	**Description/Procedure**	**Duration**
A1.1 Warming up, engaging the students	*The class is divided in groups of 3-4 students.* *The teacher poses the following questions to the class:* • *Do you know how many websites there are online nowadays?* • *How do search engines get results back to us so quickly?*	*10'*

		• *Do you know what a book index is?* • *If I gave you 4-5 pages from a book and asked you to locate a specific word in them, what method would you follow? How much time do you think you would need for this task?* *5' for the groups to reflect on the questions and a follow – up plenary discussion.* *If the teacher finds it necessary, he/she can proceed with the role game, that is, he/she can distribute a few pages from a book to the groups and ask them to locate a specific word.*	
	A1.2 *Searching with the help of an index*	*As the previous step will have highlighted the difficulty of searching when the information is not organized in some way, the teacher then gives each group an indexed book and asks the groups to study the index and answer the following questions:* 1. *What do the numbers next to the word refer to?* 2. *What* ***attribute*** *of the index makes the search of the word easier?* 3. *Do all the words of a book appear in the index? Why is that?* 4. *Can you think of any other frameworks in which indexing is used for search purposes? (eg libraries, the web etc)* *The groups participate through a representative in the discussion that follows to highlight the value of indexing in the search for information as well as the basic characteristics that an index must have to be useful. But how is an index constructed?*	*15'*

	A1.3 *Try to construct the index for three very short pages (Assessment activity).*	*Each group will be given a copy of three "pages" (Annex 1), each one containing one sentence.* *1. Try to build an index containing all the words that appear in the pages.* *2. Build your index in EXCEL which provides for easy sorting of the entries.* *3. Exchange your index with another group. Are the two indices identical?* *4. Try to perform 1-2 search(es) with the use of your index. Does it work?*	*20'*
	Phase 2.	**How do search engines use the indexing - What other techniques do they use?**	
	Activity/Task	**Description/Procedure**	**Duration**
	A2.1 *Warm up searches*	*Let's move to the web search and try to understand how the search engines work… The groups are asked to perform the following searches and reflect on the results.* *1. Search by the keyword "hospital" - which hospital appears first in the results and why?* *2. Search by the key-phrase "travel to Mars", first without and then with the use of quotation marks. Compare the number of the results in each case. What do the results have to do with, the planet, or the mythical god? How does the search engine undestand the subject?* *3. Do you believe that an index, as the one discussed in the previous step, would be useful in the cases of phrase queries?*	*10'*
	A2.2 *Watch a video and try to understand the basic*	*The students are going to watch a video titled: "The Internet: How Search Works"*	*35'*

	techniques that search engines use, with the guidance of a worksheet.	*(linked provided in Worksheet I- Annex 3).* 1. *Before that, they are prompted to study the questions from* ***Worksheet 1****.* 2. *Each group tries to discuss / answer the questions in the Worksheet, referring to the video if needed.* 3. *All the points of the worksheet will then be discussed in the class.*	
	Phase 3.	**Connecting nearness and metaword tricks with ranking**	
	Activity/Task	**Description/Procedure**	**Duration**
	A3.1 Introducing the nearness trick	*After reminding that the simple index is not effective for phrase-queries search, the groups are given an enriched version of the index, as in the Annex 2, and are asked to study it to answer the following question:* *"What is the role of the new information in the enriched index? How could it be used in answering phrase questions?"* *Note: It has been observed that pages in which the query words appear the one near to the other are more likely to be relevant.*	*15'*
	A3.2 Introducing HTML and the meta words trick	*As it has been highlighted in phase 2, one of the criteria that make a page relevant is for a search term to appear on the title of the page.* *But how can a search engine know which words of the webpage are part of the title?* • *open the https://www.w3schools.com/html/ and try to identify the Title of this page.* • *Now, turn on the source page view. (right-click→ View Page source, in Chrome) and try to locate the same title again.*	

	The teacher makes a brief reference to HTML highlighting the use of tags and metawords. • *Try to use the "Try it yourself" editor, just to experiment a little with HTML (By pressing the "Start learning HTML now").* • *Provided that these metawords become part of the index (the enriched version), what would be the criterion by which the search engine would decide whether a search term is included in the title of the page?*	
Phase 4.	**Assessment activity and investigation of ranking algorithms**	
Activity/Task	**Description/Procedure**	**Duration**
A4.1 *A brief assessment activity*	*The teacher has just added a new entry (page or post) in the class blog. She/he has deliberately put some unusual words in this entry. Students are then asked to:* • *predict whether a keyword search by one of these unusual words would bring this specific page in the results* • *carry out the search to confirm or reject their prediction* • *interpret, based on what they have learned from the current teaching scenario, why the page does not appear in the results*	*20'*
A4.2 *Further experimentation of the ranking algorithms*	*In this step, the groups are invited to experiment with the suggestions provided in Worksheet 2 and make a brief report with their findings. The purpose of this activity is to raise awareness about the problem of search results ranking and to acquaint students with the basic ideas (hyperlink trick, random surfer trick, adaptation through Machine Learning)*	*25'*

	behind the PageRank algorithm. *The teacher guides the process and the final discussion on the basic PageRank ideas as described in MacCormick J. (2011; 2016) and adaptation through Machine Learning.* *Explains the principles with simple schematic examples of linked web pages and hypothetical cases of simple searches.*
C.2 Assessment	***Informal teacher assessment of pupils during the tasks.*** ***Also****, two short tasks are provided for the assessment purposes* **C.2.1 Student's feedback and reflection** *Students will get immediate feedback*
C.3 Homework/ Work with parents-family	*The last phase of the script could alternatively be assigned as homework. In this case, the report with the students' observations / conclusions could be written in a collaborative document, per group of students.*
Part D. Information for the Teachers	
D.1 Adaptation - Differentiation for inclusion of all students	
D.2 Extension	*Students can also be assigned homework based on the questions:* • *Find information about the relationship between PageRank algorithm and search engine evolution and give a brief overview.* • *Is it possible to search exhaustively for something on the internet? How can we search the dark internet? Some websites have been archived over the years. How can we search for the information they contained?* • *How is alphanumeric data compared? Make a program that looks for words in texts.*
D.3 Resources	*MacCormick, J. (2011). Nine Algorithms That Changed the Future. Princeton University Press.* *MacCormick J. (2016). Οι εννέα αλγόριθμοι που άλλαξαν το μέλλον, Πανεπιστημιακές Εκδόσεις Κρήτης* *https://www.semrush.com/blog/pagerank/* *https://en.wikipedia.org/wiki/PageRank*
D.4 Experience deriving from the	

implementation of the scenario	
D.5 Relations to other scenarios	
D.6 Reviews by teachers	
D.7 Assessment of the scenario	*[1=Very Bad – 5=Very Good]*
D.8 References	

Part E. Annexes

Annex 1

The three "pages" sheets for the A1.3 task

Page 1

Page 2

Page 3

Annex 2

Index that includes both page numbers and in-page word location

To be used in the A3.1 task

	A	B	C	D	E	F
1	**a**	3-->6				
2	**cat**	2-->2	3-->7			
3	**couch**	2-->7				
4	**dog**	1-->2	3-->2			
5	**in**	1-->5				
6	**is**	1-->3	2-->3	3-->3	3-->8	
7	**on**	2-->5				
8	**outside**	3-->10				
9	**playing**	1-->4	3-->9			
10	**sleeping**	2-->4	3-->4			
11	**the**	1-->1	1-->6	2-->1	2-->6	3-->1
12	**while**	3-->5				
13	**yard**	1-->7				
14						

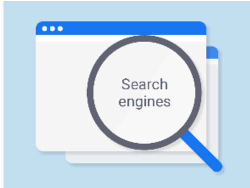
Annex 3

Worksheet 1

To be used in the A2.2 task

Worksheet 1

Finding Needles in the World's Biggest Haystack
Worksheet 1



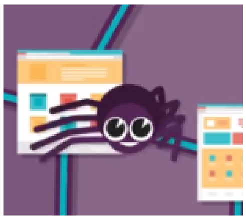
Name(s): ____

Date: _______________

The web is a huge repository of information. Search engines have been a major factor in making the web a widely used information source. You just type one or more words and immediately get back a list of pages that contain your search keyword(s).
The video that you are about to watch will help you understand ***how a search engine turns your request into a result***.

Before watching the video, have a look at the questions you are asked to answer.

1. I guess that you all know what Google is. Do you also know what **Bing** is?
2. How many websites are there on the internet?
3. When a user performs a search, where does the search engine look for the answer? Why is that?



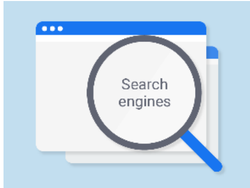
4. What does the spider in the video represent?
5. What helps the spider locate new websites?
6. What is the output of the spider's journey through the web?

7. What is the use of a **ranking** algorithm?
8. What are some basic criteria that the search engines use to rank pages?
9. Which search engine has become very popular because of its ranking algorithm?
10. Could you provide an example to prove that during a search, a search engine may **make use of data that have not been explicitly provided by the user**?
11. In the video (minute 2:50) we hear that "*The search engine's algorithm might check if all the words show up next to each other*"
    Do you think that an index as the one you have seen so far could be useful to such an algorithm?

Watch the video here:
https://www.youtube.com/watch?v=CirQMh7VHc0

Finding Needles in the World's Biggest Haystack

Worksheet 2



Name(s): ____

Date: ______________

Carry out the following searches, record your observations of the results and then - after discussing with each other – write down your conclusions.

1. Carry out a search by deliberately making a mistake (eg wrong spelling, anagram, wrong keyboard language)
2. Do the same search on each of the following search engines, Google, Bing and DuckDuckGo. Make sure to use the same keywords in all three cases.
3. If anyone in the group has a Google account, let him/her sign in and then perform a search. Try the exact same search after s/he's signed out of his/her account.
4. Do another Google search. Then clear your browsing data (history, cookies, etc. – ask your instructor for help with this step, if needed). Repeat the search.

Don't forget to observe the results, at every step. Both in terms of number and the order in which they appear.

Exemplar Scenario 03: *Cats and Dogs*

Part A. General Data	
A.1 Title:	***Cats and dogs***
A.2 Author(s):	*Stavroula Prantsoudi, University of the Aegean*
A.3 Abstract/ Summary:	*Smart devices, that is, devices which show intelligence, are increasingly surrounding students, who should thus be prepared to use such technology in their future social and professional life. These devices use algorithms which automatically improve through experience they build based on sample data. The algorithms can make decisions or predictions without being explicitly programmed to do so and this is called Machine Learning (ML), a subset of Artificial Intelligence (AI).* *The purpose of this scenario is to introduce students to the basic concepts of ML and AI. After an introduction to AI and basic AI concepts, students are asked to build, train, and test a Machine Learning model. They then discuss the AI bias problem and try to find reasons and propose solutions. To extend the scenario, the creation of an application using a ML model is proposed.* *Students are expected to become familiar with basic concepts of AI, learn to create and use ML models and raise their awareness on AI ethics matters, concerning the use of AI applications in everyday life, such as Algorithmic bias. They will be guided to work in a constructive, collaborative way, in groups of 2, while also interacting with the whole class and their teacher.* *The scenario introduces the machine learning concept and could be used in many scientific fields and different subjects, after being properly modified.*
A.4 Keywords:	*Machine learning, Artificial Intelligence, image recognition, AI bias, programming, Scratch*
A.5 Version:	*Version 1*
A.6 Date:	*20/10/2021*
A.7 Copyright license:	*Attribution ShareAlike CC BY-SA*
Part B. Learning Data	
B.1 Grade(s):	*Grades 9-10 or Age(s): 14-15 years old*
B.2 Subject(s):	***Computer Science***
B.3 Topic(s):	***Programming, Machine Learning, Image recognition, Artificial Intelligence, Algorithmic bias***

B.4 Computational Thinking Dimensions:	

Algorithmic Thinking (AL)	✓
Abstraction (AB)	✓
Generalization (GE)	✓
Logical reasoning (LR)	
Pattern matching (PM)	✓
Problem decomposition (PD)	✓
Problem translation (PT)	
Evaluation (EV)	✓
Representation (RE)	✓
Data collection (DC)	✓
Data representation (DR)	✓
Data analysis (DA)	✓
Modeling (MO)	
Simulation – (SIM)	
Automation (AUT)	
Sequencing (SE)	
Testing (TE)	✓
Understanding People – (UP) /Artificial Intelligence (AI)	✓

B.5 Computational Thinking Approaches:	

Tinkering experimenting & playing	✓
Creating, designing, and making	✓
Debugging, finding, and fixing errors	✓
Persevering, keeping going	✓
Collaborating, working together	✓

B.6 Thematic in the context of the CompuT Project:	

Educational Robotics or Physical Computing		
Computational Science project	Modeling/Simulation	
	Bifocal modelling	
	Sensors use or making	
	Maths and CS	
	Other: …	
Data science project	✓	
History of science and technology		
Digital game, software, or mobile app	✓	
Digital humanities projects	Digital Storytelling	
	Interactive Fiction	
	Text mining	
	Algorithms in everyday life	✓
	Other: …	
Artificial Intelligence Projects	✓	
Studio approach – Future Classroom projects		
Unplugged experiential or using manipulatives		
Other: ….		

<table>
<tr><td>B.7 Purpose/Aim of the learning scenario:</td><td colspan="2">The purpose of the learning scenario is to familiarize students with the concept of Machine Learning and Artificial Intelligence in general. Students are surrounded by devices that use machine learning (chatbots, digital platforms, social media platforms, decision making algorithms, prediction algorithms etc.) and educating them in the way that these devices work is a major issue for future citizenship. After completing the scenario, students will have gained understanding on the way that algorithms use the data provided to them to make decisions and predictions, and the intelligence that machines show will be explained and revealed. They will also be aware of the several societal and ethical issues raised due to algorithmic bias.</td></tr>
<tr><td rowspan="4">B.8 Learning outcomes/goals[20]:</td><td colspan="2">The following goals are expected to have been achieved after the completion of the scenario:</td></tr>
<tr><td>B.8.1 Knowledge</td><td>• Students know how artificial intelligence is incorporated in systems.
• Students know how machine learning models are built and used to define the behavior of machines and systems.
• Students know about the importance of their own decisions on the training of the models which the algorithms use.</td></tr>
<tr><td>B.8.2 Skills</td><td>• Students can train a machine learning model (make decisions on the groups of data and categorize data in the proper group).
• Students can test/evaluate a machine learning model.
• Students can import a machine learning model to an algorithm.
• Students can build an algorithm (which makes use of a machine learning model) to make decisions.
• Students can modify an algorithm (which makes use of a machine learning model) to make decisions.</td></tr>
<tr><td>B.8.3 Attitudes-affective</td><td>• Students have developed collaboration skills.
• Students have gained knowledge on machine learning concepts.
• Students have gained understanding on the way that machines and algorithms of everyday life use data to act intelligently (show artificial intelligence).
• Students have gained knowledge on the way that he/she can affect the behavior of an algorithm by providing it with certain data.
• Students have raised awareness on algorithmic bias issues and methods of preventing it.</td></tr>
<tr><td></td><td colspan="2"></td></tr>
</table>

[20] For the effective formulation of learning-instructional goals the works of Mager, who claims for the definition of observable actions and Measurable Criteria of performance evaluation under specific conditions, could be useful. Mager, F. (1975). Preparing Instructional Objectives. (2nd ed.). Belmont, CA: Fearon. & Mager, F. (1997). Preparing instructional objectives: A critical tool in the development of effective instruction. Atlanta: The Center for Effective Performance. The verbs could follow the Bloom's knowledge taxonomy, see for example: https://tips.uark.edu/blooms-taxonomy-verb-chart/. It is important to use higher order thinking verbs. Anderson, L. W., & Krathwohl, D. R. (2001). A taxonomy for learning, teaching, and assessing, Abridged Edition. Boston, MA: Allyn and Bacon

B.9 Horizontal competences - 21st century skills:	**B.9.1 Learning and innovation skills:**	***Collaboration***: *students work in groups of 2 and collaborate* ***Communication***: *students will communicate with other groups to test their results* ***Critical Thinking***: *students need to critically think to make decisions on the images and classes they will use to train their models* ***Creativity***: *students are expected to improve their algorithm by changing costumes, sounds and expressions*
	B.9.2 Digital literacy skills:	***Information literacy***: *students evaluate information to properly train their machine learning model* ***Information and Communication technologies (ICT) literacy***: *students will be able to train a machine learning model and build an algorithm in a popular programming platform (Scratch)* ***Digital citizenship***: *students are aware of the concept of machine learning and the way it is used in various fields of everyday life. They are also aware of the AI bias issue.*
	B.9.3 Career and life skills:	***Flexibility and adaptability***: *students can be flexible and adapt their data to train their model to react in new cases* ***Initiative and self-direction***: *students should make decisions by themselves but also contribute to the group to come up with a result* ***Social and cross-cultural interaction***: *students should interact with other groups and test their results* ***Productivity and accountability***: *students should try to produce the best result in the time given and make their algorithm work for the maximum number of cases.*
B.10 Modern teaching methods:	*Students work in groups of 2 based on a Collaborative inquiry script. They are expected to Learn by coding, in a Project-Based way.*	
B.11 Integration of CT into the curriculum:	*The scenario, depending on the machine learning model used, can be combined with many fields of science in terms of interdisciplinarity. The present implementation is categorizing images, so it could be used to categorize animals, books, recycling material, vehicles, machines etc. to combine with Science, Sociology, Environmental education, History etc.* *A different model could categorize text to combine with Language and Psychology (e.g., categorization of feelings according to the words used). Also, a model categorizing audio could be used to combine with Music, Arts, Dancing, or any other subject.*	
B.12 Relation to curriculum and/or standards:	*Greek National Curriculum, Grades 9-10, Informatics.* *Any other age and/or subject in interdisciplinary implementation.*	
B.13. Prerequisite knowledge:	*Students need to have basic knowledge of web searching and file management. Scratch programming will be needed for the implementation of the extension.*	
B.14. Difficulty Level of the Scenario:	*Medium*	

B.15. Social setting of the scenario:	*Pair (2 students), or individual*	
B.16 Place of implementation:	*Computer Lab*	
B.17 Teaching time – Duration:	*3 x 45' sessions (or 1x45' + 1x90')*	
B.18 Educational material, resources, instruments, tools, and media:	**B.18.1 Software:**	*Scratch, Web browser* *https://teachablemachine.withgoogle.com/* *https://dancingwithai.media.mit.edu/* *https://machinelearningforkids.co.uk/*
	B.18.2 Hardware:	
	B.18.3 Online resources:	*https://teachablemachine.withgoogle.com/* *https://dancingwithai.media.mit.edu/* *https://machinelearningforkids.co.uk/* Payne, B.H. & Breazeal, C. (2019). *An Ethics of Artificial Intelligence Curriculum for Middle School Students*. MIT Media Lab.
	B.18.4 Conventional educational material:	

Part C. Learning Experience Design

C.1. Activities-Action-Plot-Storyboard sequence table:

Phase 1.	**Phase title*: Introduction and Exploration***	
Activity/Task	**Description/Procedure**	**Duration**
A1.1 Warming up – Introduction to AI – the AI definition	*The teacher shares* ***Worksheet 1*** *and follows the guidelines on it with the class.* *They discuss the concept of intelligence in general, the definition of Artificial Intelligence and its presence in everyday life.* *Students answer the questions on the worksheet.* *They watch the video* *https://www.youtube.com/watch?v=nASDYRkbQIY* *(What is artificial intelligence? | The Royal Society) and discuss on it.*	*15 min.*
A1.2 Applications of AI	*The teacher guides the students to list applications of AI and their everyday use, he/she guides them to use some of them and propose others, categorize them*	*30 min*

		based on a conceptual map and search for additional examples of each category. Students also watch a video https://www.youtube.com/watch?v=3wLqsRLvV-c (The Turing test: Can a computer pass for a human?) and discuss on the famous Turing test.	
	Phase 2.	**Phase title: Development and Evaluation**	
	Activity/Task	**Description/Procedure**	**Duration**
	A2.1 AI concepts - machine learning and data collection	*The teacher shares **Worksheet 2**. He /She urges students to wonder if there is a way to teach a machine to recognize **any** photo and distinguish between Cats and Dogs (Discussion). Based on the Worksheet, students collect the data they need to build a model for that reason.*	*10 min*
	A2.2 Build, train, and evaluate a machine learning model	*Following the guidelines, students build a machine learning model in the suggested platform https://teachablemachine.withgoogle.com/. They train, test, and evaluate their model and add new examples/data if necessary.*	*30 min*
	A2.3 Assessment	*The teacher shares the Assessment Worksheet 2.1 and asks students to answer the questions to reflect on the building of ML models*	*5 min*
	Phase 3.	**Phase title: AI ethical issues**	
	Activity/Task	**Description/Procedure**	**Duration**
	A3.1 Raising awareness on AI ethical issues and fighting against them	*The teacher guides a discussion on the ethical and societal issues raising from the use of AI. **Worksheet 3** contains some questions and proposed videos to launch such a discussion. The teacher can adapt the content of the worksheet (videos and questions) to each class, always aiming to raise students' awareness on the*	*45 min*

		critical issues of AI ethics and safety. *The duration of the session and length of the discussion can also be adapted according to the teachers' will.*	
C.2 Assessment	**C.2.1 Student's feedback and reflection**	*Students will test and evaluate their ML model and compare results in real time. They will also fill the assessment worksheet.* *Their models will be evaluated by their classmates and vice-versa.*	
C.3 Homework/ Work with parents-family	*Students can build their ML models at home and test them with real data (like their own pets). They could also discuss with their parents and family to find AI applications they already use and propose new ones.* *The teacher could select and assign an extension to each team as homework.*		

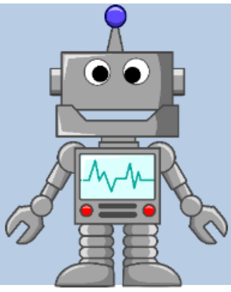
Part D. Information for the Teachers

D.1 Adaptation - Differentiation for inclusion of all students	*The construct can be adapted on the teaching time available. 3 sessions of 45min are proposed. In case this is not possible, it is proposed that teachers implement the scenario in 1 session of 45min, and 1 session of 90min.* *All students in general education could implement the scenario without restrictions.*		
D.2 Extension	*An extension of the scenario could be the building of an application in Scratch which makes use of a ML model. Worksheet 4 can be used for this reason, while not restrictively.*		
	Phase Extension.	**Phase title: Using intelligence to build something useful**	
	AE.1 Build an application (an algorithm to act intelligently) *(35 min)*	*The teacher shares* ***Worksheet 4*** *and students follow the guidelines. Students build an algorithm to embed a ML model they have previously created.* *They use the* *https://machinelearningforkids.co.uk/* *platform and the Scratch programming environment. They are asked to study the examples and try to build a model and an algorithm to play Rock, paper, scissors with the computer.*	
	AE.2 Evaluate your algorithm (test your application) *(10 min)*	*After they build their application students are asked to test it and make possible modifications. They also help to test, evaluate, and modify their classmates' applications.*	

D.3 Resources	*https://teachablemachine.withgoogle.com/* *https://dancingwithai.media.mit.edu/* *https://machinelearningforkids.co.uk/*
D.4 Experience deriving from the implementation of the scenario	
D.5 Relations to other scenarios	Payne, B.H. & Breazeal, C. (2019). *An Ethics of Artificial Intelligence Curriculum for Middle School Students*. MIT Media Lab.
D.6 Reviews by teachers	
D.7 Assessment of the scenario	*[1=Very Bad – 5=Very Good]*
D.8 References	Payne, B.H. & Breazeal, C. (2019). *An Ethics of Artificial Intelligence Curriculum for Middle School Students*. MIT Media Lab.
Part E. Annexes	
	Worksheet 1, Worksheet 2, Worksheet 2.1, Worksheet 3, Worksheet 4

Machine Learning _ Worksheet 1

Introduction to AI - AI Concepts



Students' name(s): ________________________________

Group name: ________________________________

Date: ________________________________

Today you will learn about Artificial Intelligence and its' presence in our everyday lives.

A. Definition of AI

A. Shortly answer the following questions. Then, discuss your answers with your classmates and your teacher:

1. What is intelligence?

____

2. When is a human considered to be intelligent?

____

3. Can other creatures be intelligent? How do you know when that happens?

____

4. Can machines act intelligently? Which machines can do that?

____

5. How do you think any intelligent behavior can be achieved by machines?

____

6. What is **Artificial Intelligence**?

____

7. Watch the video on the following link https://www.youtube.com/watch?v=nASDYRkbQIY (*What is artificial intelligence? | The Royal Society*). Go back to the answer you gave on Question 6 and discuss it with your classmates and teacher.

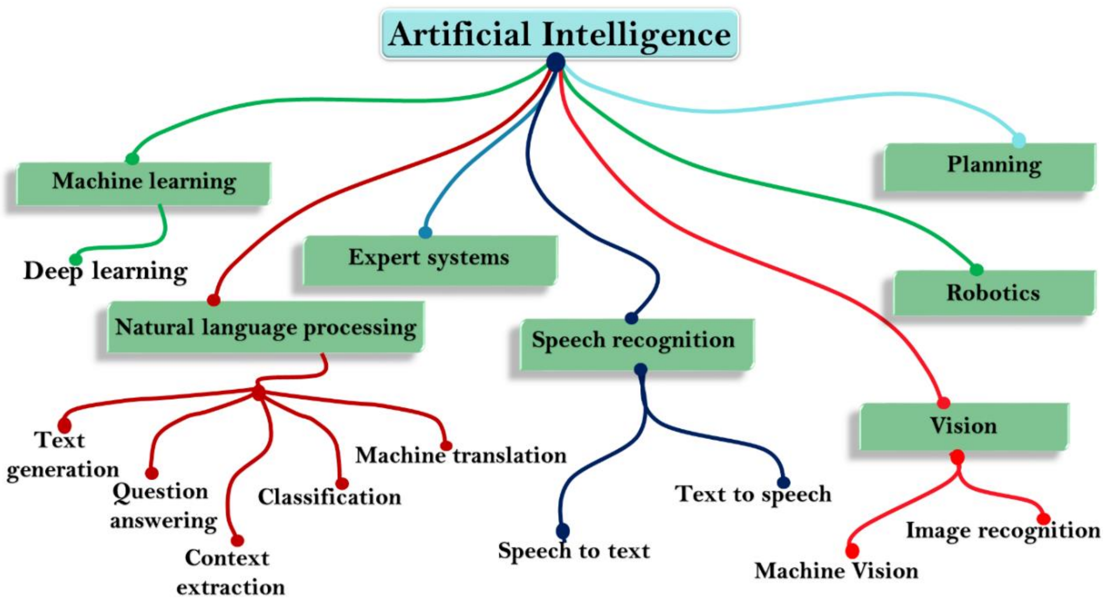
B. Applications of AI

a. Discuss the extent to which the following applications are making use of AI.A chat bot
b. Search engines
c. Autonomous vehicles
d. Robots
e. Social media
f. A translation system

g. Online advertisements
h. Virtual assistants (Siri, Alexa)

1. Use the following applications and discuss their features with your classmates:
   a. Google Chrome's Speech to Text
   b. The WHO Health Alert chat bot, https://www.who.int/
   c. The Photomath application, https://photomath.com

2. Using the following conceptual map, search the Web to find an example of an application in everyday life, for each category (branch) on the map. Discuss the examples you found with your classmates and your teacher.



3. Watch the video on the following link https://www.youtube.com/watch?v=3wLqsRLvV-c (The Turing test: Can a computer pass for a human?). Discuss the Turing test with your classmates and your teacher.

4. Are there any risks caused by using AI? Which can they be?

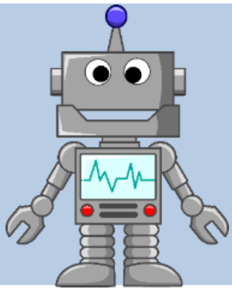
____

5. Suggest ways to eliminate possible dangers (if any) caused by using AI. Discuss your suggestion with your classmates and your teacher.

Good job!

So far, you have learned about the definition of Artificial Intelligence and its' use in everyday life.

Next you will learn about basic AI concepts and focus on Machine Learning.



Machine Learning _ Worksheet 2

Build an AI model

Students' name(s): ______________________________________

Group name: ______________________________________

Date: ______________________________________

Today you will teach a computer to decide whether an image shows a cat or a dog.

Answer the following questions to warm-up:

A. Can a computer recognize animals (**YES** or **NO)**? _________

B. If **YES**, how does that happen?

____

C. If **NO**, can we teach a computer to recognize animals?

____

Computers make decisions using **algorithms** and **data** which people have provided them with. This is called **<u>Machine Learning</u>**.

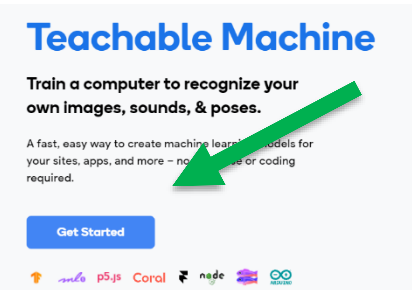
You will now teach a computer to **classify** cats and dogs, by creating a **model**.

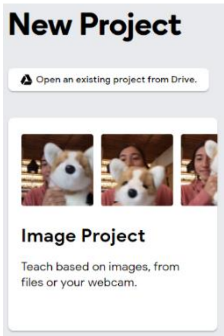
A. Build your model

1. Create two folders on your computer and name them **Cats** and another named **Dogs**. Search the web and collect images from cats and dogs (at least 10-15 of each category) and save them in the appropriate folder. Make sure there is variety and diversity on the images you selected.

2. Open a web browser and visit https://teachablemachine.withgoogle.com/

3. Click on **"Get started"**. You will create a new Image project so Click on it and select **Standard image model** on the popup window.

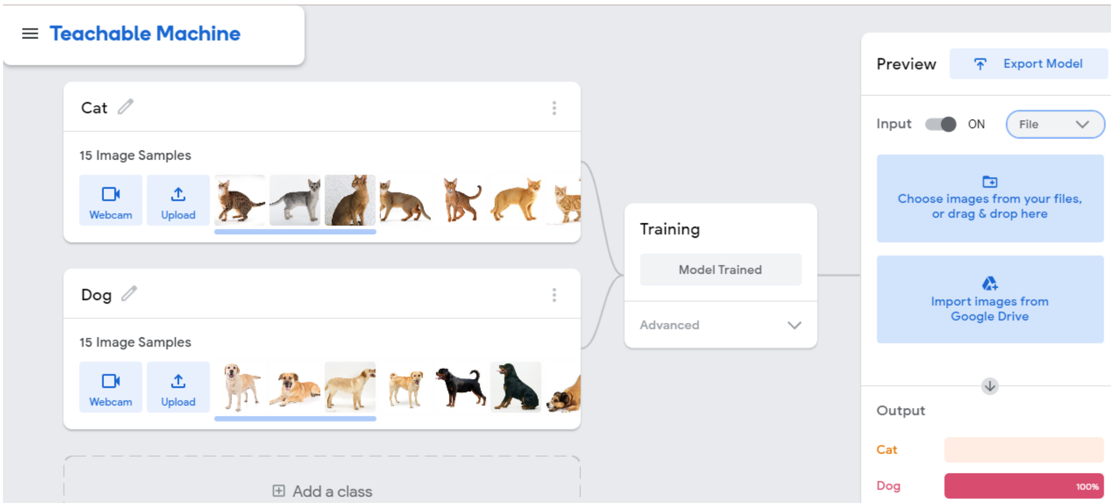




4. Name the two classes **Cat** and **Dog** and upload the images you collected in the appropriate class.

B. Train your model

1. Click on **Train your model** and wait. The computer might need a few minutes to train your model. **Be patient!** After the training is completed, your model should look like the one below:



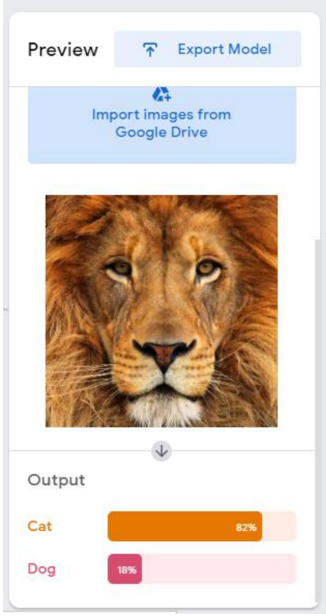
2. To **Preview** the results of your model, use the available options on the right (the webcam or a new file).
   a. On the Cats dataset, which differences and similarities are there between the cats?
   b. On the Dogs dataset, which differences and similarities are there between the dogs?
3. Think of cases of animals you may have not included in your model. You can always go back to your model, add examples and train it again.

B. Test your model

1. Create a new folder and collect some **Test Data**, like images of cats and dogs that you have not included in the examples you used to train the model. Also collect images of other animals (like lion, bear, fox, koala etc.). Create a set of test data similar the one below:

2. Test the images you collected on your model (import or drag & drop each image). The machine will tell you what it recognizes, as well as how confident it is. (You can also turn the webcam on and test the model with printed images). Is the **Output** correct?
3. For each image of your Test Data set write down the results as on the table below. Can you explain each result? For example, why does the model think that the lion is a cat?

Image	Class	Confidence	Result
Lion	Cat	82%	Wrong



4. Ask some of your classmates to help you test your model. Exchange your Test Data set with your classmates' and test their data on your model and vice versa. Are the results similar? Why/Why not?
5. Are you happy with the responses? If not, do not forget that you can go back to the model and add some more examples. Always train your model again, after you have added examples.
6. What do you think should happen so that the model recognizes animals other than dogs and cats? Do you think you can create a model that recognizes any animal on the planet?
7. Click on **Download project as file** and save your project.

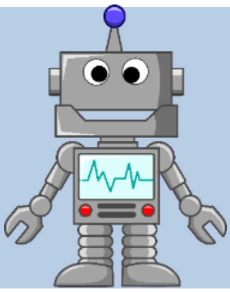
Good job!

So far, you have trained your computer to recognize images as Cats or Dogs, thus, you have trained a **machine learning model** by feeding it with examples.

You can now go on to create something more fun and useful, by embedding your model in an application.

Machine Learning _ Worksheet 2.1

Assessment



Students' name(s): ____

Group name: ____

Date: ____

Since you have learnt how to build a Machine Learning model, you should now be able to predict the behavior of a model based on the data sets used for its' training.
Look at the images and data sets below and try to answer the following questions:

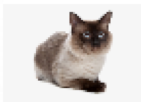
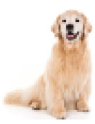
1. A Machine Learning model has been trained with the following training data:

Class	**Images**
Cat	  

What do you think the model will result if you import the following image?

Dog OR **Cat?**

2. A Machine Learning model has been trained with the following training data sets:

Class	**Images**
Cat	     
Dog	  

Which of the following sentence(s) is/are correct, regarding the results of the model:

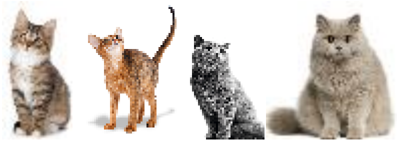
i. The results will be more precise for the Dogs

ii. The results will be more precise for the Cats

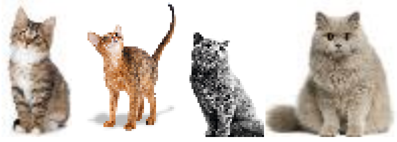
iii. The results will be equally precise for the Dogs and the Cats

3. Which of the following training data sets will give more precise results? Why?

A.

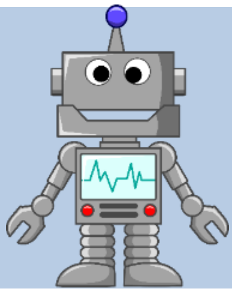
Cat	**Dog**
	

B.

Cat	**Dog**
	

Machine Learning _ Worksheet 3

AI ethics/safety



Students' name(s): ____

Group name: ____

Date: ____

Artificial Intelligence (AI) has conquered human life and its' use is almost inevitable. Along with its' numerous benefits, voices of concern become louder every day. Today you will learn about the societal and ethical issues arising from the use of AI, the potential dangers, and suggestions for always being aware of them.

TIP: Before watching each of the following videos, look at the questions that follow 😉

Ethics and AI

Discuss the following questions with your classmate and your teacher:

1. Is there an Artificial Intelligence system which would work properly in every case?
2. Do you believe ML systems are always right/fair?

Watch the following video: https://www.youtube.com/watch?v=tJQSyzBUAew (Ethics & AI: Equal Access and Algorithmic Bias)

3. What are the potential dangers of using AI? How can they affect people and society?
4. What should people and/or the industry do to avoid such problems?

Watch the following video: https://www.youtube.com/watch?v=BtgcuhQ0cks (Bias in AI is a Problem)

5. Which are the reasons that cause biases on algorithms?
6. Can you give some examples of algorithms who may have been biased?
7. How can such malfunctions be prevented?

Visit https://www.ajl.org/, the website of the Algorithmic Justice League initiation, an effort towards an equitable and accountable AI. Browse the site to:

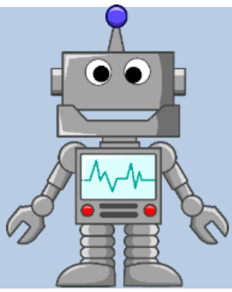
8. List two examples where AI bias affected real people lives.
9. Propose actions for better AI.

Congratulations!

You have officially become an AI expert!

Machine Learning _ Worksheet 4

AI applications



Students' name(s): ____________________________________

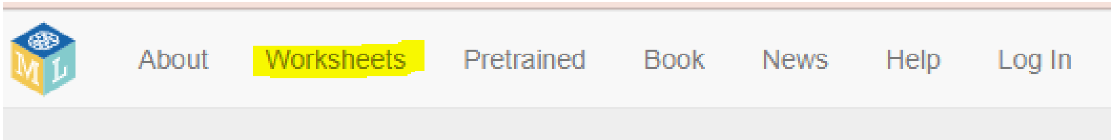
Group name: ____________________________________

Date: ____________________________________

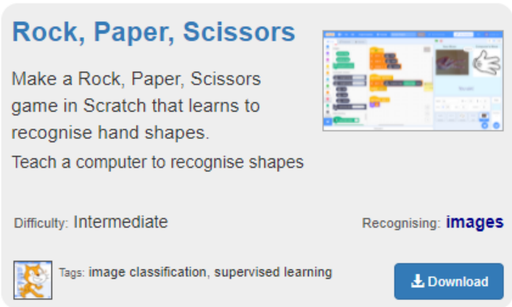
After you have finished **training your model**, it is time that you use it to do something more fun and user friendly. You can think of and create any application which might be useful in your everyday life or modify and use some of the existing ones.

Build an application

1. Visit https://machinelearningforkids.co.uk/, another website where you can build and train a machine learning model. Click on the Worksheets menu and browse the various Machine Learning Projects. Aren't they fantastic?



2. After browsing on the various projects select the **Rock, Paper, Scissors** one and download the worksheets. You will be guided to create a program in Scratch to play the game with the computer.



3. Follow the steps on the Worksheet to train a model to recognize your hand as being rock, paper, or scissors. Then use the model and program an application in Scratch to play the game with the computer.

✓ You can always come back to your model to add more examples.

✓ You can use any project example you wish and modify it to create your own application. Above all, look at the fun side of AI.

Good job!

You can now successfully train a Machine Learning model and build an application to make use of it. **Congratulations!**

Exemplar Scenario 04: *Cryptography*

Part A. General Data	
A.1 Title:	*Cryptography*
A.2 Author(s):	*Zervas Konstantinos, Fesakis Georgios - University of the Aegean*
A.3 Abstract/ Summary:	*The study of techniques used to secure communication, a major necessity these days, is called cryptography. Since ancient times, many cryptography methods have been used to protect communication. Students should be aware of these methods and techniques and be able to use them accordingly, when needed. This scenario is an introduction to the so-called symmetric cryptography methods such as Morse, Braille, and Caesar Cipher. It also introduces students to asymmetric cryptography based on the Public Key Encryption concept. Additionally, through various extensions, students may be given the chance to explore the enigma machine, the RSA algorithm, as well as the various applications of PKE. It intends to teach methods and practices of encrypting and decrypting messages, in both an unplugged and a simulated way through educational software, so that students may gain understanding and knowledge of the concept of cryptography.*
A.4 Keywords:	*Cryptography, encryption, decryption, symmetric/asymmetric cryptography, Caesar cipher, Morse, Braille, Enigma machine, (Public Key Encryption (PKE), RSA, Digital Signature, Certificate Authorities)*
A.5 Version:	*Version 1*
A.6 Date:	*05/11/2021*
A.7 Copyright license:	*Attribution ShareAlike CC BY-SA*
Part B. Learning Data	
B.1 Grade(s):	*Grades 8-10, or Age(s): 13-15 years old*
B.2 Subject(s):	*Computer Science*
B.3 Topic(s):	*Cryptography, security, encryption, decryption*
B.4 Computational Thinking Dimensions:	see table below

Algorithmic Thinking (AL)	
Abstraction (AB)	✓
Generalization (GE)	✓
Logical reasoning (LR)	✓
Pattern matching (PM)	✓
Problem decomposition (PD)	
Problem translation (PT)	
Evaluation (EV)	
Representation (RE)	✓

Data collection (DC)	
Data representation (DR)	
Data analysis (DA)	
Modeling (MO)	
Simulation – (SIM)	
Automation (AUT)	
Sequencing (SE)	
Testing (TE)	✓
Understanding People – (UP) /Artificial Intelligence (AI)	✓

B.5 Computational Thinking Approaches:

Tinkering experimenting & playing	✓
Creating, designing, and making	
Debugging, finding, and fixing errors	✓
Persevering, keeping going	
Collaborating, working together	✓

B.6 Thematic in the context of the CompuT Project:

Educational Robotics or Physical Computing		
Computational Science project	Modeling/Simulation	
	Bifocal modelling	
	Sensors use or making	
	Maths and CS	
	Other: …	
Data science project	✓	
History of science and technology	✓	
Digital game, software, or mobile app		
Digital humanities projects	Digital Storytelling	
	Interactive Fiction	
	Text mining	
	Algorithms in everyday life	✓
	Other: …	
Artificial Intelligence Projects		
Studio approach – Future Classroom projects		
Unplugged experiential or using manipulatives	✓	
Other: ….		

B.7 Purpose/Aim of the learning scenario:	*The purpose of the scenario is to help students become familiar with the concept of cryptography and various methods of encrypting and decrypting messages. Students will then be able to protect their data*

	by using various cryptographic methods to send and receive messages in the ever-evolving age of technology.	
B.8 Learning outcomes/goals[21]:		
	B.8.1 Knowledge	*Students demonstrate understanding about cryptography.* *Students explain the need to encrypt and decrypt messages in this ever-evolving technological era.* *Students illustrate examples of online threats while conducting communication.* *Students compare some basic, widely used cryptography methods.*
	B.8.2 Skills	*Students can apply Morse signals to encrypt/decrypt a message.* *Students can make use of Braille signs to encrypt/decrypt a message.* *Students can apply the Caesar cipher key to encrypt/decrypt a message.* *Students can experiment encrypting /decrypting a message using a simulation of Enigma machine.* *(If the extensions are implemented:* *Students can apply asymmetric methods for encrypting/decrypting messages (RSA, digital signatures).* *Students can create a new method to encrypt/decrypt a message to securely communicate with a friend.)*
	B.8.3 Attitudes-affective	*Students identify the need of protecting messages by encrypting them.* *Students have become conscious on security matters.* *Students can collaborate to find ways to securely communicate with their friends.*
B.9 Horizontal competences - 21st century skills:		
	B.9.1 Learning and innovation skills:	***Collaboration****: students work in groups of 2 and collaborate* ***Communication****: students will communicate with other groups to test their encrypted messages*

21 For effective formulation of learning-instructional goals Mager's work regarding the definition of observable actions and Measurable Criteria of performance evaluation under specific conditions, could be useful. Mager, F. (1975). Preparing Instructional Objectives. (2nd ed.). Belmont, CA: Fearon. & Mager, F. (1997). Preparing instructional objectives: A critical tool in the development of effective instruction. Atlanta: The Center for Effective Performance. The verbs could be in accordance to Bloom's knowledge taxonomy, see for example: https://tips.uark.edu/blooms-taxonomy-verb-chart/. It is important to use higher order thinking verbs. Anderson, L. W., & Krathwohl, D. R. (2001). A taxonomy for learning, teaching, and assessing, Abridged Edition. Boston, MA: Allyn and Bacon

		***Critical Thinking**: students need to think critically to make decisions on the ways they will encrypt their messages* ***Creativity**: students are expected to think of new methods to encrypt/decrypt their messages*
	B.9.2 Digital literacy skills:	***Information literacy**: students evaluate information in order to select the appropriate method for their encryption/decryption method* ***Digital citizenship**: students are aware of the concept of cryptography and the various ways it is used in fields of everyday life*
	B.9.3 Career and life skills:	***Flexibility and adaptability**: students should be flexible and adapt their encryption/decryption method according to the data given* ***Initiative and self-direction**: students should make decisions by themselves but also contribute to the group to come up with the result* ***Social and cross-cultural interaction**: students should interact with other groups and test their results*
B.10 Modern teaching methods:	*Collaborative learning*	
B.11 Integration of CT into the curriculum:	*Cryptography is an example of art combined with science, where Informatics has caused a radical transformation, with social implications for all citizens. The computational problem-solving method is clearly seen in the case of cryptanalysis.* *The scenario can be combined with many subjects depending on the message to be handled each time.*	
B.12 Relation to curriculum and/or standards:	*Greek National Curriculum, Grades 8-10, Computer Science Curriculum*	
B.13. Prerequisite knowledge:	*No prior knowledge needed to successfully implement the current scenario.*	
B.14. Difficulty Level of the Scenario:	*Intermediate*	
B.15. Social setting of the scenario:	*Individual or pair (2 students)*	
B.16 Place of implementation:	*Classroom or Computer Lab*	
B.17 Teaching time – Duration:	*4 x 45' sessions*	
	B.18.1 Software:	For the extensions' purposes:

B.18 Educational material, resources, instruments, tools, and media:		https://travistidwell.com/jsencrypt/demo/, https://www.devglan.com/onlinetools/rsa-encryption-decryption https://8gwifi.org/rsafunctions.jsp https://www.cryptool.org/en/
	B.18.2 Hardware:	
	B.18.3 Online resources:	*Youtube videos*
	B.18.4 Conventional educational material:	

Part C. Learning Experience Design

C.1. Activities-Action-Plot-Storyboard sequence table:

Phase 1.	***Introduction and exploration: Morse code, steganography***	
Activity/Task	**Description/Procedure**	**Duration**
A1.1 The need of cryptography – Warm up	*The teacher discusses the need of protecting personal data from others in various instances of everyday life (e.g. transfer of private data like usernames and passwords, credit card credentials etc.) The danger of unauthorised access to this data is discussed with the students and they are asked to propose methods to protect their data from third parties.* • *Which personal data would you like to protect?* • *Who do you think would want to steal your data?* • *Can you think of a way to protect your communication from third parties?* *They come up with the idea of cryptography.* *They discuss its use since ancient times.*	*10 minutes*
A1.2 Cryptography methods: The Morse code and steganography	*Students are divided in groups of 2.* *They are introduced to Morse code and steganography.* ***Worksheet 1** is shared to them, and the Morse code is discussed. Students are asked to encrypt a message using the Morse code and decrypt one using the same*	*35 minutes*

		technique. They are also asked to decrypt a message from a picture (steganography).	
	Phase 2.	**Exploration: Braille code**	
	Activity/Task	**Description/Procedure**	**Duration**
	A2.1 Warm up – linking to earlier discussed	*Teacher and students deepen the discussion on encryption and decryption and the teacher asks them if they can think of other ways to encrypt their messages.* *Then he/she proposes the Braille code and discusses whether it could be used as a cryptography method*	*10 minutes*
	A2.2 Exploration – Braille code	*Teacher shares* ***Worksheet 2*** *and asks students to collaborate and encrypt/decrypt messages using the Braille code.*	*35 minutes*
	Phase 3.	**Exploration: Caesar cipher**	
	Activity/Task	**Description/Procedure**	**Duration**
	A3.1 Warm up – linking to earlier discussed	*Students are introduced to the Caesar cipher encryption method and the way it is used.* *An introduction to the method can be found here:* https://www.youtube.com/watch?v=sMOZf4GN3oc&feature=emb_title *The teacher can project a way of using it and discuss it with the students.*	*10 minutes*
	A3.2 Exploration – Caesar cipher	*The teacher shares* ***Worksheet 3*** *and introduces students to the Caesar cipher method.* *Students are asked to collaborate to encrypt and decrypt messages using Caesar cipher.*	*25 minutes*
	A3.3 Discussing the weaknesses of symmetric cryptography	*The teacher and students discuss the symmetric encryption methods they have used so far to understand that the methods can be deciphered, especially with the use of computers.*	*10 minutes*
	Phase 4.	***Asymmetric Cryptography***	

	Diffie-Hellman Key Exchange-RSA	
Activity/Task	**Description/Procedure**	**Duration**
A4.1 Warm up – linking to earlier discussed	*The teacher summarizes the course of the lesson so far and reminds students that the main problem of cryptography is the sending of a message from a transmitter to a receiver without being able to be caught-received by a third party interfering with the route of the message. It is also pointed out that the main weakness of symmetric cryptography methods is the secure sending of the key between transmitter and receiver without being perceived by third parties. Students are informed that symmetric cryptographic problems have been addressed with public key cryptographic methods since the 1970s. The teacher connects Public Key Encryption (PKE) to pre-existing knowledge by presenting examples such as secure messaging (email), information transmission over the Internet (Secure http - https) and digital signatures. It is suggested that the relevant video: The Internet: Encryption & Public Keys (Code.org), https://www.youtube.com/watch?v=ZghMPWGXexs is viewed.*	*15 minutes*
A4.2 2 Exploration- Diffie-Hellman Key Exchange algorithm and PKE	*Students are briefly informed that the PKE method was first published in 1976 by Whitfield Diffie and Martin Hellman, although it is known from an earlier time in the state secret service. The teacher shares* ***Worksheet 5*** *and introduces students to Diffie-Hellman Key Exchange algorithm.* *Depending on the readiness of the class, the algorithm*	*30 minutes*

	<table><tr><td></td><td>*can only be shortly demonstrated, or the students can also proceed with the study of the mathematical background of the method, included in the worksheet.* ***Worksheet 6*** *demonstrates the PKE asymmetric cryptography algorithm method with CrypTool software. Students test the PKE process and try out the method with each other. They can also use different free tools and web pages to create key pairs for encryption-decryption.*</td><td></td></tr></table>
C.2 Assessment	<table><tr><td>**C.2.1 Student's feedback and reflection**</td><td>*Students create public and private RSA keys and then exchange encrypted messages and try to decrypt them. If they are able to complete the process, the student is considered to have gained knowledge of the method.*</td></tr></table>
C.3 Homework/ Work with parents-family	*Students are asked to apply the RSA method: key generation, encryption/decryption and exchange of messages with their parents using different online tools and simulation software.*
Part D. Information for the Teachers	
D.1 Adaptation - Differentiation for inclusion of all students	*All students should be able to implement the scenario.*
D.2 Extension	**D.2.1. Enigma machine** ***Worksheet 4:*** *The teacher introduces the use of machines for encryption with the example of the Enigma machine. These machines were extremely difficult to decipher either by humans or by other machines. Alan Turing's attempt to figure out the way the Enigma machine encodes messages, paved the way for the development of computer science.* *Initially how the Enigma machine works is demonstrated and explained with the help of video.* *Next, students practice two Enigma machine simulations:*

	1. Firstly, a simple simulation made with paper that simulates the machine with one rotor. *2. Secondly a simulation with the CrypTool educational software. Students are asked to collaborate to encrypt and decrypt messages using Enigma machine simulations.* *Suggested videos:* *https://www.youtube.com/watch?v=-mdSvGUd0_c* *https://www.youtube.com/watch?v=ASfAPOiq_eQ* **D.2.2. Educational game** *A game can be organized for the students to consolidate the encryption methods. Indicative examples:* 1. *Students are divided into A. The Cryptographers and B. The Hackers. The cryptographers choose a message and a method and hackers try to break their "code" by decrypting the messages. Cryptography methods practiced by students are used.* *2. Students invent a hidden treasure mystery game. Specifically, a series of instructions for accessing the hidden treasure are encrypted and made accessible with QR-Codes placed in different places. Players must decrypt the QR-Code message to find out where the next one is (the first one is given). For decryption they can use paper-pencil, their programs and cryptool.org. The treasure may be the web address of the movie "imitation game".* *3. The students can build an escape room. The escape from which will require the decryption of instructions.* **D.2.3. Reflecting on Cryptography** *Students could:* – *study and discuss the applications of the RSA method. Observe how intractable data security problems are exploited (e.g. calculating large prime numbers).* – *discuss and research cryptography and privacy* – *study cryptography policies and laws. What is the position of the citizens?* ***D.2.4. The biography of A. Turing (movie "imitation game")*** *Students can watch the movie "imitation game" which refers to Alan Turing's biography and his efforts to decipher the algorithm on which the Enigma machine is based. Following this students discuss issues of encryption. Additionally themes which extend from this for example history, language, peace education, human rights and sex education may then be explored in co-operation with other subjects such as art, history, biology and other subjects as inter-thematic projects.* ***D.2.5. Mathematical Background of RSA Method***

	Students are introduced to the method 's mathematical background. ***Worksheet 8*** *illustrates the method with small prime numbers. Students can practice, finding prime numbers mathematically compute private and public keys and encrypt-decrypt messages with the RSA method.* *Mathematical knowledge of powers and mod operation are prerequisites.* *This scenario-extension can be combined with Maths (calculations of powers and application of mod rules).* ***D.2.6. Digital Signatures*** *The teacher connects PKE through examples of secure messaging (email), information transmission over the Internet (Secure http - https) and digital signatures. The digital signature of documents or messages made using the hidden key for encryption and the public key for decryption is also displayed. The problem of pretense and identification is raised, and the role of certification authorities is introduced.* ***Worksheet 7*** *helps students to explore the Digital Signature procedure and practice the signing-verification phase with CrypTool software.*
D.3 Resources	*Youtube*
D.4 Experience deriving from the implementation of the scenario	
D.5 Relations to other scenarios	
D.6 Reviews by teachers	
D.7 Assessment of the scenario	*[1=Very Bad – 5=Very Good]*
D.8 References	Grimm, R., Kempe, T., Löhr, A., & Scholle, O. (2015). *Informatik*. (Schöningh-Schulbuch, 1. Auflage, 4. Druck). Paderborn: Schöningh. *Spioncamp (2019).Bergische Universität Wuppertal, retrieved* from *https://ddi.uni-wuppertal.de/website/repoLinks/v287_Alle-Stationen-hintereinander.pdf*

Part E. Annexes

	Worksheet 1 *Worksheet 2* *Worksheet 3* *Worksheet 4* *Worksheet 5*

	Worksheet 6 *Worksheet 7* *Worksheet 8*

CRYPTOGRAPHY

Worksheet 1

Student name(s): ______________________________________

Group name: ________________________ Date: ____________

Cryptography is the practice of using techniques to securely communicate on the Internet, when trying to exchange private messages. With cryptography you can **encrypt** your messages to avoid third parties from having access to them. The receiver will have to **decrypt** your message to read it.

1. Think of a **message** you would like to send to a friend of yours and write it down:

____

What do you think you should do to **encrypt** your message, so that nobody else understands it? Write down your encrypted message:

____

What does your friend need to know so that he/she can **decrypt** your message?

____

In 1832, before the invention of telephones, American Samuel Morse invented a device called the **Morse telegraph**, which was used to transmit messages over long distances. A network of cables was gradually established throughout the country. The cables did not transmit sound but electrical pulses of long or short duration, according to the table below.

A	● ▬	U	● ● ▬
B	▬ ● ● ●	V	● ● ● ▬
C	▬ ● ▬ ●	W	● ▬ ▬
D	▬ ● ●	X	▬ ● ● ▬
E	●	Y	▬ ● ▬ ▬
F	● ● ▬ ●	Z	▬ ▬ ● ●
G	▬ ▬ ●		
H	● ● ● ●		
I	● ●		
J	● ▬ ▬ ▬		
K	▬ ● ▬	1	● ▬ ▬ ▬ ▬
L	● ▬ ● ●	2	● ● ▬ ▬ ▬
M	▬ ▬	3	● ● ● ▬ ▬
N	▬ ●	4	● ● ● ● ▬
O	▬ ▬ ▬	5	● ● ● ● ●
P	● ▬ ▬ ●	6	▬ ● ● ● ●
Q	▬ ▬ ● ▬	7	▬ ▬ ● ● ●
R	● ▬ ●	8	▬ ▬ ▬ ● ●
S	● ● ●	9	▬ ▬ ▬ ▬ ●
T	▬	0	▬ ▬ ▬ ▬ ▬

Between letters there was a brief pause and between words a longer one. Light signals could also be used for the transmission of Morse code.

2. Based on the table above, can you understand the following message?

-.-.   ---   --   .--.   ..-   -   .   .-.

____

3. What is the Morse signal for **SOS**? (This is the international help signal.)

____

4. In groups of two, try to send a message to another group of your classmates by flashing a lens to represent Morse signals.

Another way to transmit messages is by hiding them in media, e. g. in pictures. This method is called **steganography**. If you look at the picture below, you may not notice that there is a message hidden in it. But the picture contains a message in Morse code. The long and short stems of the grass are the dashes and dots respectively, while each tuft is a letter.

Spioncamp (2019).Bergische Universität Wuppertal, retrieved from *https://ddi.uni-wuppertal.de/website/repoLinks/v287_Alle-Stationen-hintereinander.pdf*

5. Can you find the secret message? ____________________________

6. How would you draw a picture to encrypt a message for your friend?

Well done!

CRYPTOGRAPHY

Worksheet 2

Student name(s): ______________________________________

Group name: ________________________ Date: ____________

BRAILLE CODE

Louis **Braille** was born in France in 1808 and went blind after an accident at the age of 3. At the age of 14 he developed a font which blind people can read. The font consists of raised points that someone can feel with one's fingers. The Braille signs are depicted in Table1.

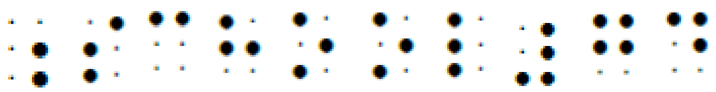
Table 1. Braille signs

A	B	C	D	E	F	G	H	I	J	K	L	M
⠁	⠃	⠉	⠙	⠑	⠋	⠛	⠓	⠊	⠚	⠅	⠇	⠍
N	O	P	Q	R	S	T	U	V	W	X	Y	Z
⠝	⠕	⠏	⠟	⠗	⠎	⠞	⠥	⠧	⠺	⠭	⠽	⠵
1	2	3	4	5	6	7	8	9	0			
⠁	⠃	⠉	⠙	⠑	⠋	⠛	⠓	⠊	⠚			

Words and numbers are discerned by using different signs before them. With these signs the reader knows if what follows is a word, or a number:

⠰ when a **word** follows, or ⠼ when a **number** follows.

For example:

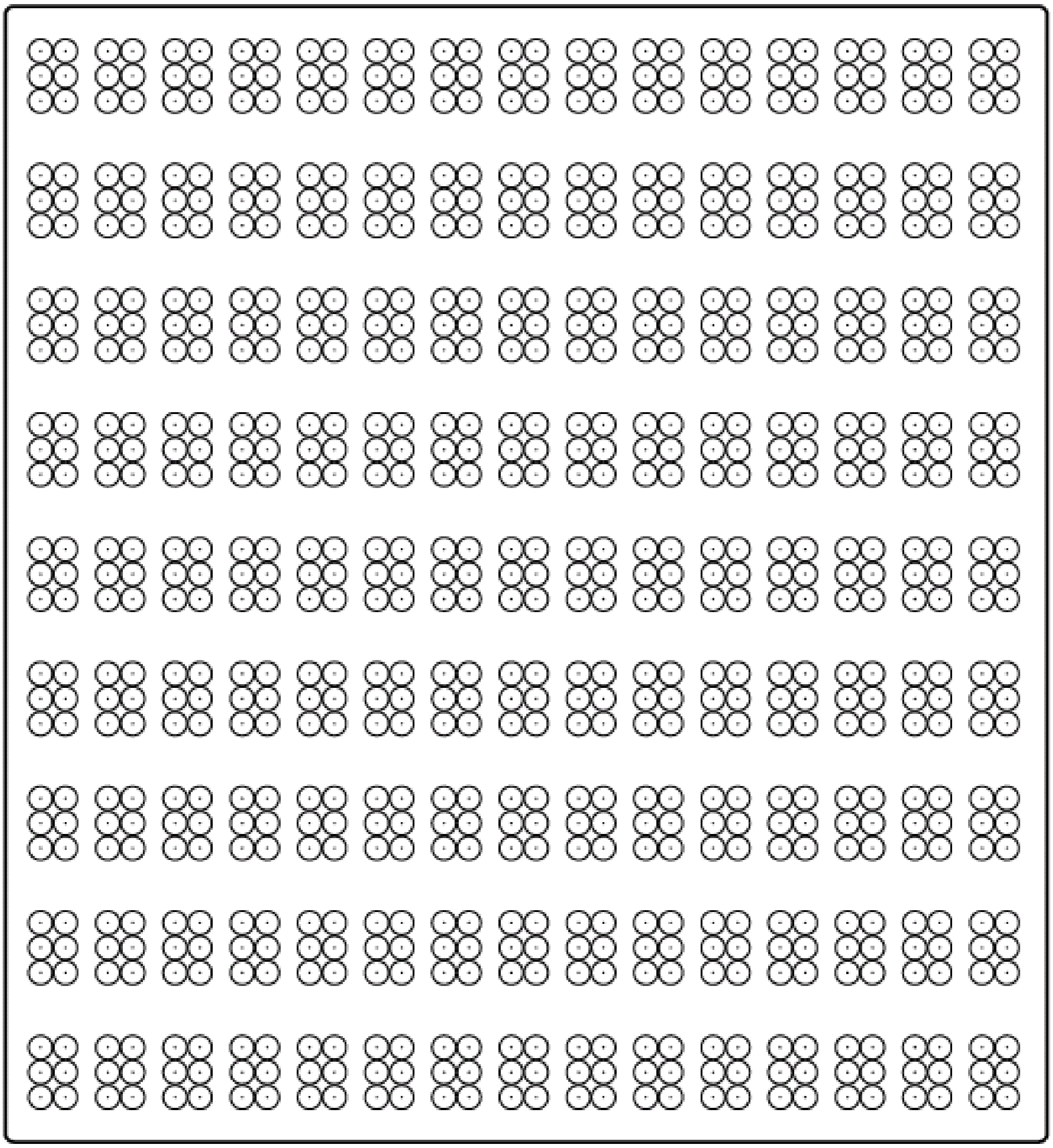
 is the code for **School 74**.

1. Can you decrypt the following message?

____

2. Using the tip of your pencil, try to code your name and age by puncturing on the form below.

   Use the Braille signs table to see which sign corresponds to each letter.



Ask your classmate to read what you wrote with his/her eyes closed, by touch.

GOOD JOB!

CRYPTOGRAPHY

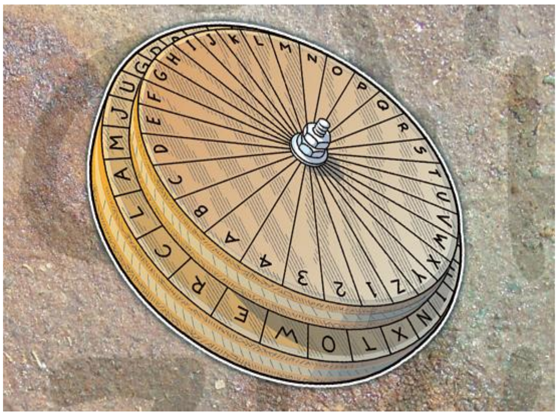
Worksheet 3

Student name(s): ____

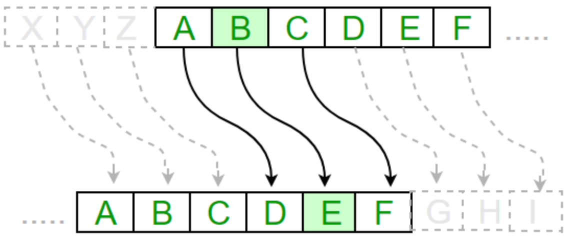
Group name: __________________________ Date: _____________

CAESAR CIPHER

Caesar cipher (or Caesar code) is one of the most famous and easy encryption systems, used by Julius Caesar (100-44 B.C.) for his private messages. According to this method, each letter of a message is substituted by another letter, some fixed number of positions down the alphabet. The number of positions is defined by the **key**, or **Caesar shift**, e. g. left shift of 3 or right shift of 4 etc.



Method: First, you will have to choose a number from 1 to 26, which you will have to share with the receiver. This is called the **key** and the receiver will use it to decrypt your message.



Then you need to write the alphabet in two lines: first the letters from A to Z and then each letter replaced, beginning from the letter in the position right after the key.

For example, in the case where the key is 4, letter A will be replaced by E (the letter after the 4th one), letter B will be replaced by F and so on. The first four letters (ABCD) follow right after Z.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Replaced by	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D

1. Based on the above, if you use Caesar cipher key 4, the word **ANNA** will be encrypted to **ERRE**. Can you encrypt the following message using the above method (Caesar cipher key 4)?

CRYPTOGRAPHY IS FANTASTIC: ________________________________

2. Based on the above, can you also decrypt the following message?

GSQTYXIVW VSGO: ____

Variation:

The method presented can easily be broken, so a variation of it was found. The sender and receiver will have to agree on a **key word**, for example the word **DODEKANISOS** (an island complex in Greece). The key word is written in the beginning of the alphabet (same letters are not repeated). Then you replace each of the other letters with the rest of the letters of the alphabet, beginning from the last letter of the key word. See the example below:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Replaced by	**D**	**O**	**E**	**K**	**A**	**N**	**I**	**S**	T	U	V	W	X	Y	Z	B	C	F	G	H	J	L	M	P	Q	R

This table will be used for coding and decoding.

3. Based on the above variation, if you use the Caesar cipher key **DODEKANISOS**, can you now encrypt the following message?

CRYPTOGRAPHY IS FANTASTIC: ____

4. Also based on the above, can you now decrypt the following message?

GSQTYXIVW VSGO: ____

5. Do you notice any difference?

ACTIVITY:

In groups of two, agree on a key word and create the corresponding table below using Caesar cipher:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Replaced by																										

Send an encrypted message to each other. Did you decrypt the message you received correctly?

You now can encrypt and decrypt messages using the Caesar cipher method!

Homework: Why not try to make your own cipher disk?

Well done!

ENIGMA CRYPTOGRAPHY MACHINE
Worksheet 4

Student name(s): ____

Group name: _____________________________ Date: ____________

Enigma cryptography machine

The "Enigma" machine was invented in 1923 by the German engineer Arthur Scherbius. Its name comes from the Greek word "enigma". This machine was originally used for commercial purposes, it was commercially available before World War II but it was modified into many variants and used to encrypt German army orders in World War II. Historical accounts confer that Alan Turing, an employee of the English counterintelligence, managed to break the code. “The imitation game” is a movie which refers to these events and the tragic fate of Turing.

Encryption/Decryption Method

Next a simplified simulation of the engine is presented. It consists of two wheels, an internal and an external one. The internal wheel rotates while the external wheel stays fixed.

Prerequisite: Both Sender and recipient must possess the machine!

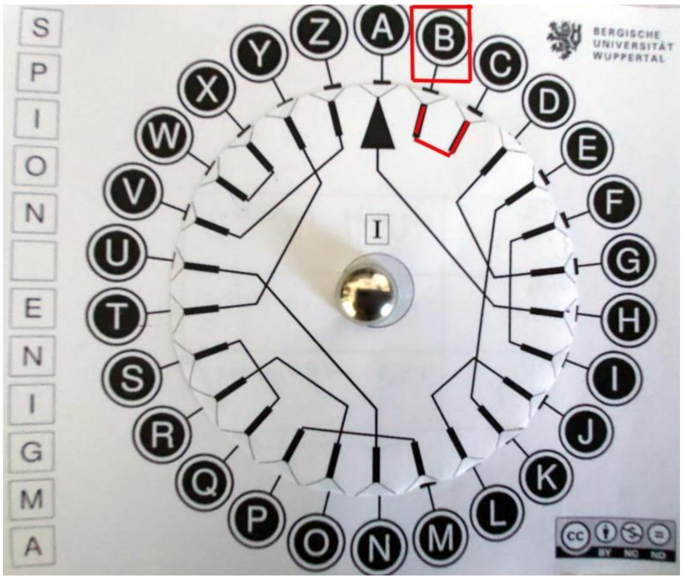
Encryption instructions:

- Place the arrow to point it towards the key.
- Then locate the letter of message you want to encrypt.
- Follow the link. This is the first encrypted letter.
- Then turn the arrow to the right so that it points to one letter down (pointing to the next letter of the key clockwise).
- Follow the link. This is the second encrypted letter.
- Do the same for all the letters in the message to be encrypted. Do not forget to rotate the arrow one letter down each time in a clockwise direction.

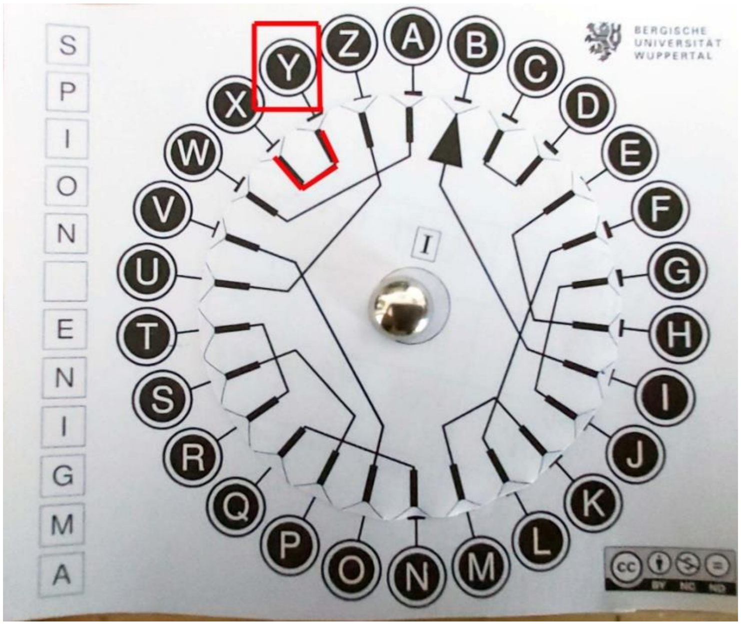
Example

1. A key letter has been agreed upon. For example «A». The big arrow of the internal wheel should point to the key letter, that is letter «A».
2. If for example we want to encrypt the word «BYE»
3. The large arrow on the inner wheel must indicate the key, i.e. «A».

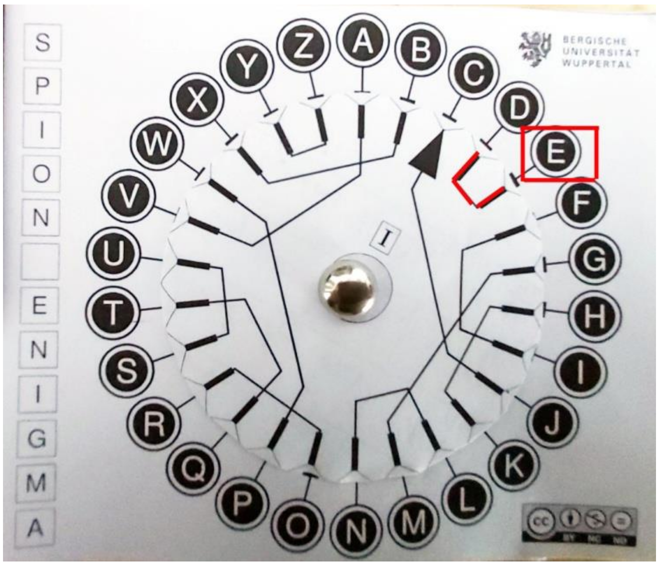
4. To encrypt the first letter B, look at its mapping. The letter B corresponds to the letter C. C is therefore the first encrypted letter.



5. To encrypt the next letter, turn the large arrow one position down clockwise. It should now point to B.



6. To encrypt the letter Y notice that Y is connected to X. The second encrypted letter is therefore X.
7. Turn the arrow one more position clockwise. It should now point to the letter C.



8. To encrypt the letter E notice that E is connected to D. The third encrypted letter is therefore D.

Following the procedure described above, the word **BYE** was encrypted in the ciphertext **CXD**.

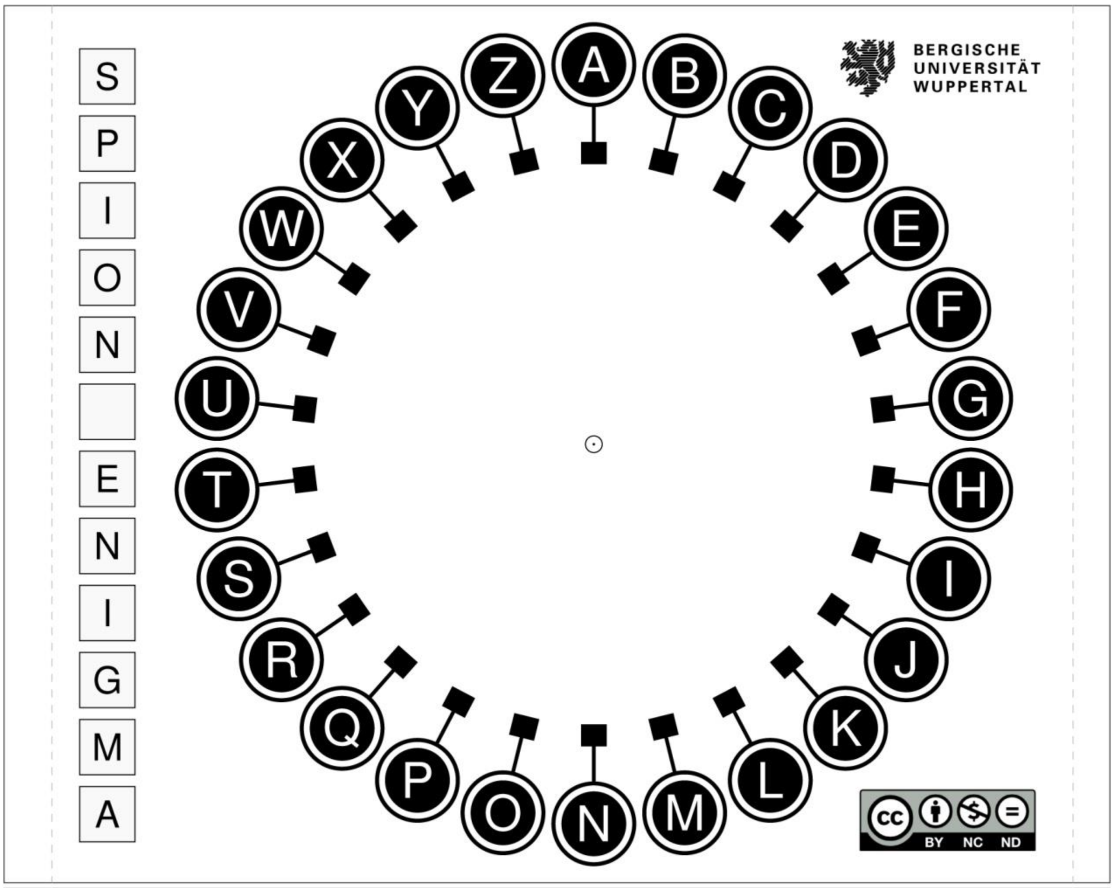
Decryption instructions:

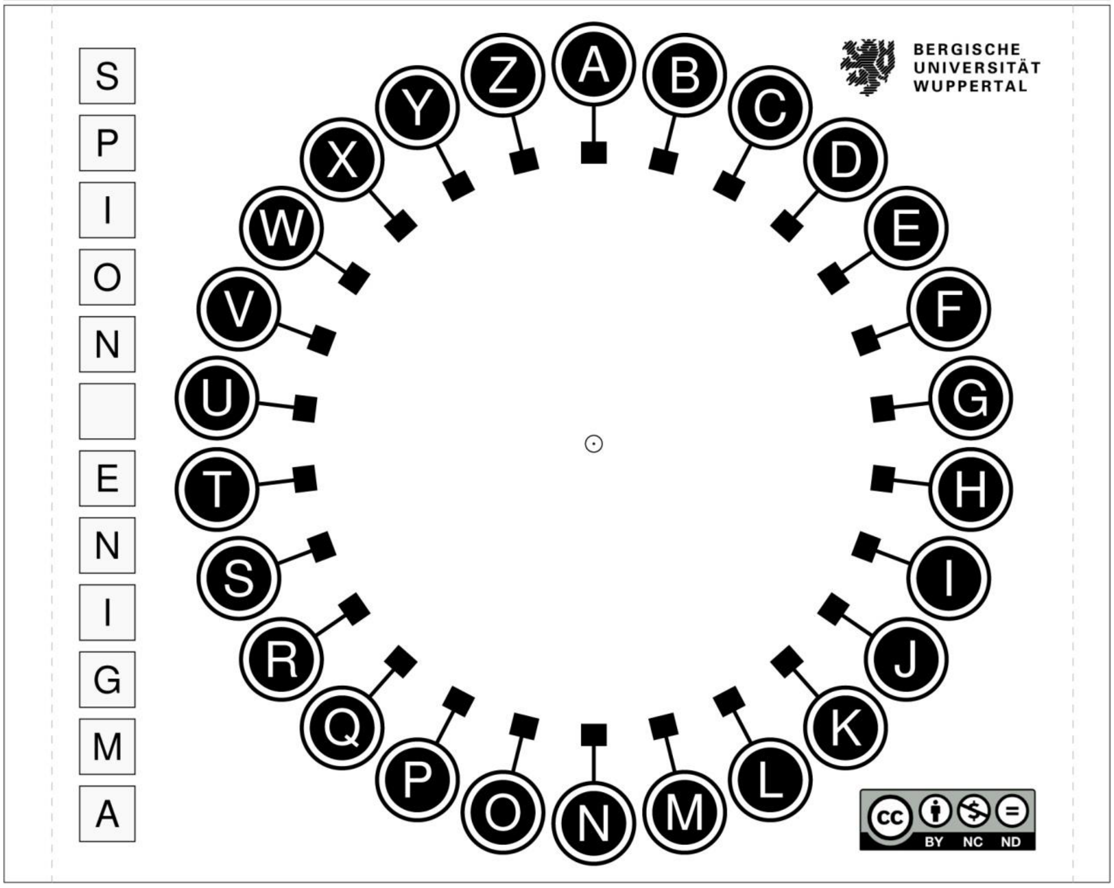
- Place the arrow pointing to the letter that is the key.
- Then locate the letter you want to decrypt.
- Follow the link. This is the first letter of the encrypted message.
- Then turn the arrow one letter down (pointing towards the next letter of the key) clockwise.
- Follow the link. This is the second encrypted letter.
- Do the same for all the letters in the message. Do not forget to rotate the arrow one letter at a time in a clockwise direction.

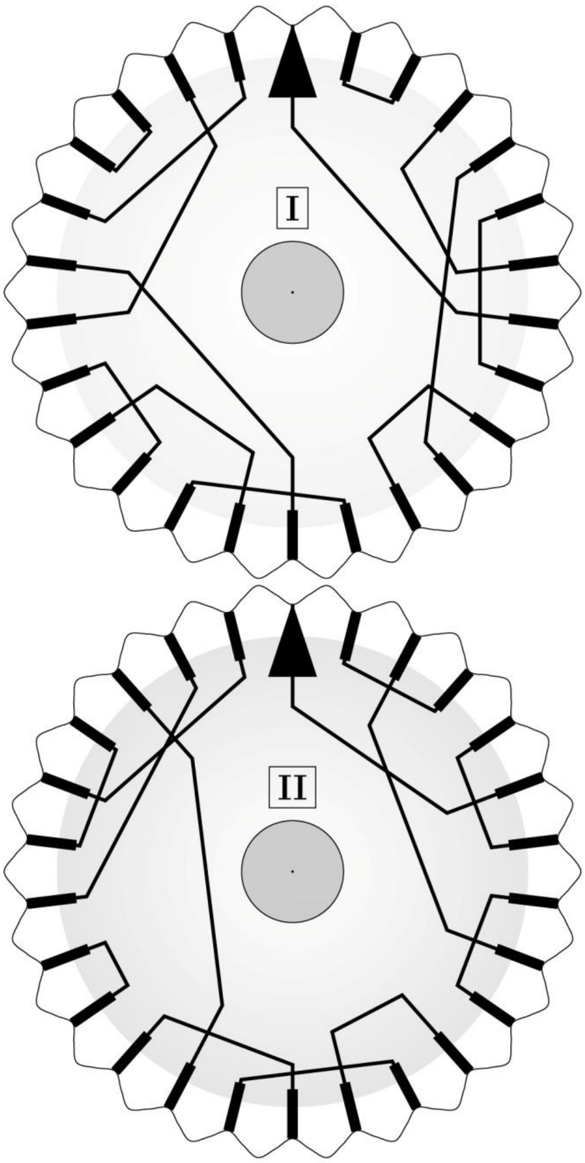
Construction of rotor

Print the two rotor discs.
Use a CD / DVD holder. In this case, cut the inner grey circle.

Alternatively use a  (blister drawing pin)


SPION ENIGMA
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
BERGISCHE UNIVERSITÄT WUPPERTAL
BY NC ND


SPION ENIGMA
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
BERGISCHE UNIVERSITÄT WUPPERTAL
BY NC ND



Spioncamp (2019).Bergische Universität Wuppertal, retrieved from *https://ddi.uni-wuppertal.de/website/repoLinks/v287_Alle-Stationen-hintereinander.pdf*

Extension of Worksheet 4

Activity 1

Simulation with C*rypTool*

The Enigma Machine itself uses three such rotors which are in fact cylinders.
For an introduction to the operation of the Enigma Machine watch the two videos suggested here.
https://www.youtube.com/watch?v=-mdSvGUd0_c
https://www.youtube.com/watch?v=ASfAPOiq_eQ

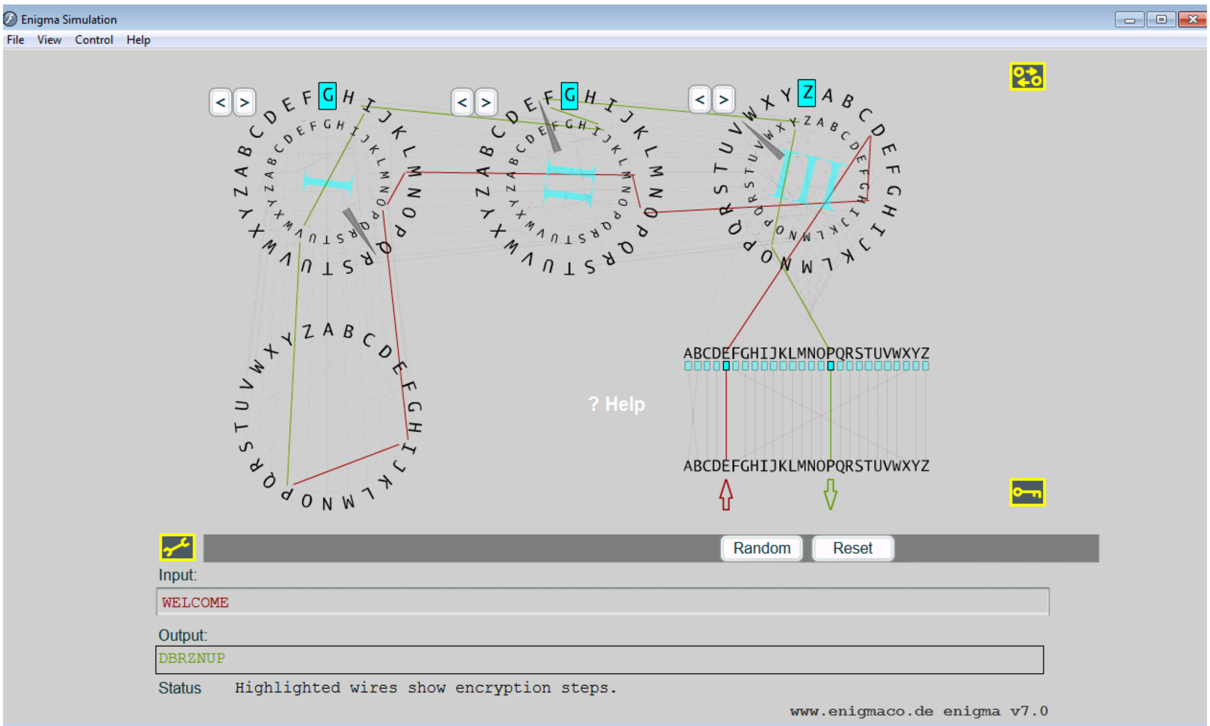
Let's try an example of simulation that is close to reality.

Download the simulation-tool cryptool1.4.41 https://www.cryptool.org/de/cryptool1
From the www.cryptool-online.org site.

Open the menu and choose *Individ. Procedures/Visualisation of algorithms /Enigma*

How can I encrypt a plain text?

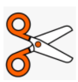
- The first step is to make up a key. In this case, a key consists of two parts.
- The second step is to decide which pairs of letters should be exchanged or trans- positioned in the plugboard, e.g. A to B and also F to X. Notice that rotor settings at the beginning of the text entry, must be chosen for all three rotors e.g. F-E-S.
- The third step is to "RESET" the whole machine to the "initial state" by clicking on "RESET". The machine is now ready to encrypt the first sample.
- The fourth step is to drag the small yellow circle underneath A to B and release the mouse button. Thus, A and B have been exchanged. Please exchange F and X in that same way.
- The fifth step is to set the mentioned rotor settings by pressing the buttons "<" or ">" above each specific rotor. Each click of the mouse puts a rotor one position forward in the indicated direction.
- Finally, the word "welcome" is typed in. The line "Output:" should show the ciphertext i.e."DBRZNUP". The encrypted text looks completely different compared to the original, the only similarity is the same number of letters.



Activity 2

Encrypting –Decrypting with Simulator of Enigma-machine (CryptTool)

Students are divided into two groups: an encryption and a decryption group Using Cryptool software each group respectively encrypts or decrypts messages after having initially agreed on the values that the rotors will have and two letter transpositions.



Cut around the edges of the three text boxes below.

Secret memorandum for encrypting and decrypting groups

1. Set the rotor values (A-Z, English alphabet)

   rotor 1=

   rotor 2=

   rotor3=

2. Set the letter alternation

   … →…

To be kept top secret

Instructions for the encrypting group

Open CrypTool *(Individ. Procedures/Visualisation of algorithms /Enigma*).

Set the rotors as agreed

Set the letter transpostions

Enter the text for encrypting

Send the encrypted text to your decrypting group

Instructions for the decrypting group

Open CrypTool *(Individ. Procedures/Visualisation of algorithms /Enigma*).

Set the rotors as agreed

Set the letter transpositions

Enter the text for decrypting

Check the decrypted message

Asymmetric Encryption: Diffie- Hellman algorithm
Worksheet 5

Student name(s): ____

Group name: ______________________________ Date: ______________

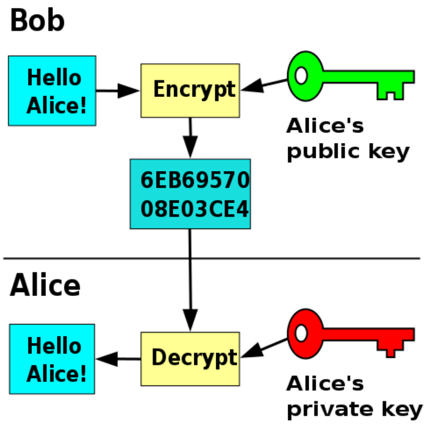
Diffie- Hellman algorithm

Method

Cryptography flourished when it became possible for the sender to encrypt the message with a secret key, send another public key to the recipient, and allow the recipient to decrypt the message using only the public key. Any third party who has access to the public key cannot decrypt the message!!! This is why such a process was called **asymmetric encryption**: But is such a thing possible?

For many years it was considered impossible to exchange a key that even if a third party knew it, it could not decode the encrypted message. In 1976 Martin Hellman, Whitfield Diffie and Ralph Merke developed the Diffie-Hellman algorithm which allows two parties to agree on a key, which even a third party would not know how to decrypt the message.

The diagram below (wikimedia.org) illustrates the steps for sending a message. Two different keys for encryption and decryption are used. Each user freely provides his public key to be sent encrypted messages that only he can decrypt with his secret-private key.



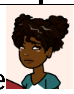
Let's explain it with an example: Bob and Alice agree to use a key number. A third party Ismene can obtain (by eavesdropping !!!) the public key number. Bob and Alice use the key to encode and decode messages which are then exchanged, not secretly, Ismene can see them, but she cannot encrypt them.

Bob and Alice apparently agree at first to use a **prime** number p. They must also agree on a **natural** number, say c. You should c <p.

Bob then chooses a positive integer α (less than p) which he keeps secret.

Alice also chooses a positive integer β (less than p) which she keeps secret.

Bob and Alice can calculate the **key** "**K"** based on the formulas given in the table below. Ismene could know p, c, A and B but cannot calculate the key K because she does not know α and β.

Private space	**Public space**	**Private space**
Bob 	Ismene 	Alice 
	determine p και c	
choose α, α<p		choose β, β<p
compute $A=c^{\alpha}$ mod p		compute $B=c^{\beta}$ mod p
	A	
B ◄	B	► A
compute $K=B^{\alpha}$ mod p		compute $K=A^{\beta}$ mod p

Reference: Spioncamp (2019).Bergische Universität Wuppertal, retrieved from *https://ddi.uni-wuppertal.de/website/repoLinks/v287_Alle-Stationen-hintereinander.pdf*

Here is an example with numbers

Private space	**Public space**	**Private space**
Bob 	Ismene 	Alice 
	p=17 και c=5	
choose α, με α<p		choose β, β<p
α=4		β=7
compute $A=c^{\alpha}$ mod p		compute $B=c^{\beta}$ mod p
$A=5^4$ mod 17		$B=5^7$ mod 17
A= 625 mod 17		B= 78.125 mod 17
A=13	A	B=10
B ◄	B	► A
compute $K=B^{\alpha}$ mod p		compute $K=A^{\beta}$ mod p
$K=10^4$ mod 17		$K=13^7$ mod 17
K=10.000 mod 17		K=62.748.517 mod 17
K=4		**K=4**

The key that Bob and Alice will use is 4. This key can be used to encrypt and decrypt messages.

You can use the Windows calculator in scientific view to calculate powers and divisions with mod.

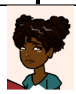
Question: Is it possible for Ismene to find the key K?

Answer: Yes by trying combinations of numbers from 0 to p.

In case p is small, as here, finding the key is easy. But if the numbers to be chosen are large then it is impossible even with the fastest computers available to find the key through number testing.

Activity 1

Compute key K applying Diffie- Hellman algorithm for numbers p=7 και c=4

Private space	**Public space**	**Private space**
Bob 	Ismene 	Alice 
	p=7 και c=4	
choose α, α<p		choose β, β<p
α=…		β=…
compute $A=c^{\alpha}$ mod p		compute $B=c^{\beta}$ mod p
A=………		B=………..
A= ………		B= ………
A=……… →	A	← B=………..
B ←	B	→ A
compute $K=B^{\alpha}$ mod p		compute $K=A^{\beta}$ mod p
K=………..		K=…………….
K=………..		K=……………
K=…..		**K=……**

Asymmetric Encryption: PKE (RSA) Procedure
Worksheet 6

Student name(s): ____

Group name: __________________________ Date: _____________

Activity 1

The operation of the RSA algorithm will be demonstrated in two parts with CrypTool:

a. The generation of an RSA key,

b. The encryption and decryption of messages

According to RSA, encrypted communication between two parties requires:

1. a public key, which consists of a pair of numbers (N, e)

2. a private key, which also consists of a pair of numbers and which remain secret (N, d)

Generation of RSA keys

To create an RSA key select **Individual Procedures \ RSA Cryptosystem \ RSA Demonstration**.

For the RSA key, two different prime numbers, p and q are needed.

Enter two prime numbers into the fields **Prime number p** and **Prime number q**, or generate two random prime numbers, p and q.

As an example we wish to generate a random 256-bit RSA key. To do this, click on the **Generate prime numbers…** button. Similarly to menu selection **Indiv. Procedures \ RSA Demonstration \ Generate Prime Numbers…**, a dialog box opens in which to generate prime numbers p and q. For prime number p, choose 2^127+2^126 as the **lower limit** and 2^128 as the **upper limit**, and activate for the value range the radio button, **Both are equal**. When you click on **Generate prime numbers**, two prime numbers p and q of bit length between 127.5 and 128 are generated. When p and q are multiplied together, the result is RSA modulus N of bit length greater than 2*127.5 = 255, i.e. a 256-bit RSA key.

Prime numbers can be generated as often as you like. If you click on the **Apply primes** pushbutton, prime numbers p and q are passed to the RSA dialog. At the same time RSA modulus N is calculated, also the Euler phi function phi(N).

The next step is to determine the public RSA key e, a number that is coprime to phi(N). Sometimes it is not easy to find such a number. For this reason we offer a small tip: the number e = 2^16+1 = 65537 (= 10000000000000001 binary) is in practice always coprime to phi(N).

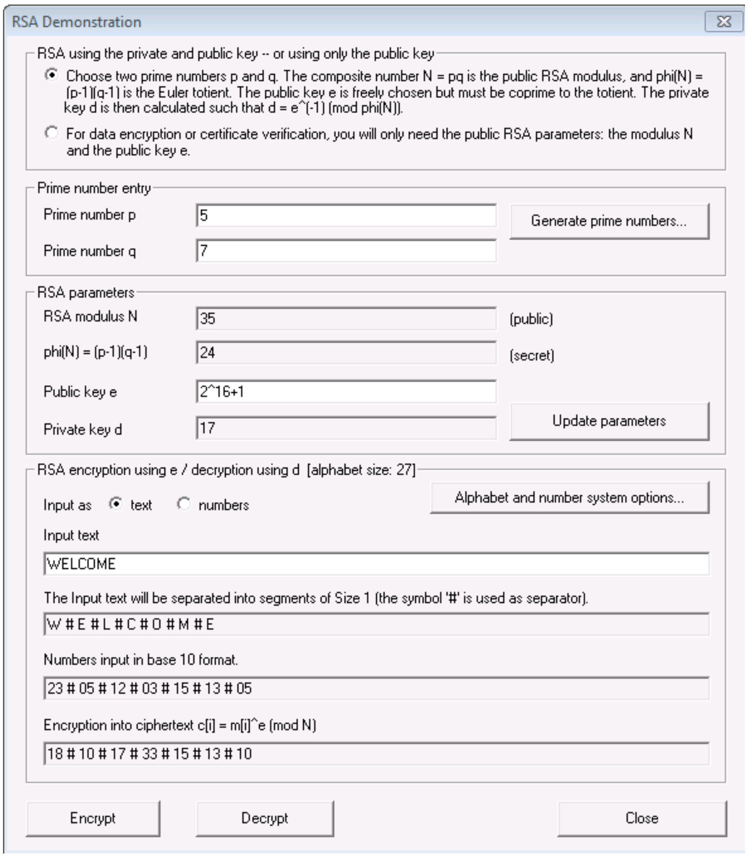
Click on the **Update parameters** pushbutton, and the secret RSA key d will then be calculated from the number e.

You can now encrypt and decrypt messages.

2. Encryption or decryption of messages using the RSA key pair

Once you have generated the RSA key, you can encrypt and decrypt messages.

You can view an example below:



Activity 2

Students are divided into two groups (one group encrypts, the other decrypts).

Step 1
Activity for both groups: the creation of public and private key pairs.

Step 2
The Encryption group encrypts a message.

Step 3

The encrypted message is sent to the decryption group

Step 4
The decryption group decrypts the encrypted message

Activity 3

The operation of the RSA algorithm will be demonstrated alternatively in other simulation software:

- *https://travistidwell.com/jsencrypt/demo/,*
- *https://www.devglan.com/online-tools/rsa-encryption-decryption*
- *https://8gwifi.org/rsafunctions.jsp*

Students can:

1. Create RSA keys
2. Encrypt/Decrypt and exchange messages

Asymmetric Encryption: Digital Signature – Worksheet 7

Student name(s): ____

Group name: __________________________ Date: _____________

Method

Create and verify digital signature

The use of the digital signature involves two procedures: the creation of the signature and its verification. Below, the actions of the sender and the recipient are described step by step in order to facilitate understanding of the digital creation and verification signature mechanism.

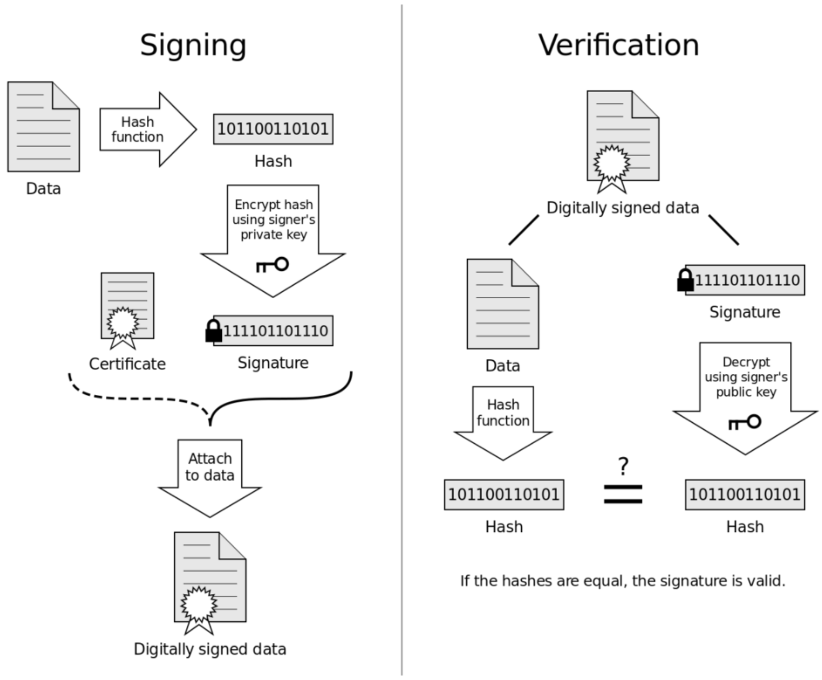
Sender

1. The sender using a hash algorithm (one way hash) creates the summary of the message (message digest) to be sent. A series of digits of a certain length will be generated regardless of the size of the message.
2. The sender encrypts the above using the private key. The digital signature is thus produced and consists of a series of digits.
3. The encrypted summary (digital signature) is attached to the text and the digitally signed message is transmitted over the network (note that message can be encrypted by its sender with the use of the public key).

Recipient

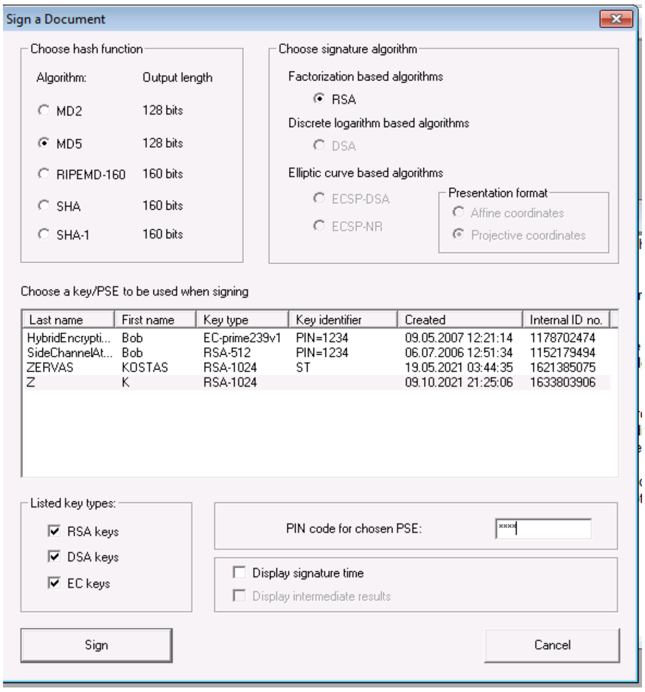
1. The recipient separates the digital signature from the message.
2. The recipient creates the message summary by applying the same hash algorithm as the sender to the message received.
3. The digital signature is decrypted using the sender's public key and a digital signature summary is produced.
4. The message and digital summaries are compared and if they are found to be the same, it means that the message received by the recipient is intact. If on the other hand they are found to be different, then the message sent has been subjected to change.

The diagram below illustrates the signing process (digital signature)



Activity: Practicing the Digital Signature process with CrypTool.

1. The public key pair is created from the menu: Digital signature/PKI/Generate keys (additionally PIN is required)
2. Next the text for encryption is typed in or the file to be encrypted is uploaded.
3. Digital Signatures/Sign Document command is then chosen. It is necessary to specify
   a. The Hash function algorithm (MD2, MD5 etc)
   b. The signature algorithm (RSA etc)
   c. The public key pair
4. Sign



5. Save the produced file and send to recipients. This file contains
    a. The signature
    b. The content to be sent

The team that will receive the file containing the signature and the content can confirm the signature (which guarantees that the text has reached intact), choosing Digital /signature/PKI/Verify Signature

Asymmetric Encryption: RSA Procedure-Mathematical Background

Worksheet 8

Student name(s): ____

Group name: ____________________________ Date: ______________

Method

The table below shows the RSA procedure (prerequisite knowledge: prime numbers, powers)

1	Choose two prime numbers p and q	p=3 και q=11
2	Compute N=p*q	N=3*11=33
3	Compute r=(p-1)*(q-1)	r=(3-1)*(11-1)=2*10=20
4	Choose a number e in such a way that e and r have no common divisor	e=7 e=5 r=20 have no common divisor
5	Determine number d such as e*d mod r=1	d=23 7*23 mod 20=161 mod 20=1
6	Publish N and e, keep secret d	Public key (N,e)=(33, 7) Private key (N, d)=(33, 23)
7	Encrypt message M: Compute C=M^e mod N	For example **M=2** C=2^7 mod 33=128 mod 33 =29
8	Decrypt C Compute M=C^d mod N	Decrypt C=29 M=29^{23} mod 33=2 **M=2**

The philosophy of the algorithm is that calculations in one direction are easy, but much more difficult in another direction. The RSA method is based on the mathematical fact that it is easy to calculate the product of two prime numbers, but it is very difficult to factorize this product, that is, to find the factors from which it is formed. In this case (if we limit ourselves to small numbers, it is possible with tests to calculate the private key d with tests).

But when the numbers are large, the order of 200-300 digits is extremely time-consuming even with the fastest computers to calculate d. It is "computationally impossible" to calculate it. The factorization of small numbers, for example in our example of 33, is easy. We find "by hand that 33" is produced by multiplying 3 by 11. There are also applications that can factorize numbers, such as the one given in the link *https://www.mathpapa.com/factoring-calculator/*

1	Choose two prime numbers p and q	p= και q=
2	Compute N=p*q	N=
3	Compute r=(p-1)*(q-1)	r=
4	Choose a number e in such a way that e and r have no common divisor	e=
5	Determine number d such as e*d mod r=1	d=
6	Publish N and e, keep secret d	Public key (N,e)= Private key (N, d)=
7	Encrypt message M: Compute $C=M^e$ mod N	For example **M=2**
8	Decrypt C Compute $M=C^d$ mod N	Decrypt C

Activity: Mathematical Background of RSA Method

Choose two prime numbers p and q and then apply RSA Method.

You can use the Windows calculator in scientific view to calculate powers and divisions with mod or apply mod rules.

Mod rules

(x+y) mod b = x mod b +y mod b

(x*y) mod b = x mod b * y mod b

This makes it easy to calculate powers modulo a number

(x^{y+z}) mod b = $(x^y * x^z)$ mod b = $(x^y$ mod b * x^z mod b) mod b

References

Grimm, R., Kempe, T., Löhr, A., & Scholle, O. (2016). *Informatik*. (Schöningh-Schulbuch, 1. Auflage, 4. Druck). Paderborn: Schöningh (p. 280-284)

Exemplar Scenario 05: *CompuT Contest – "Be Computationally Intelligent*

Part A. General Data	
A.1 Title:	*CompuT Contest – "Be Computationally Intelligent"*
A.2 Author(s):	*Papamargariti Georgia, Papamargariti Alexandra*
A.3 Abstract/ Summary:	*Nowadays we may find some excellent examples of augmented reality in education worldwide. The ability to connect reality and digital content has been steadily improving, opening more options for teachers and students.* *This scenario demonstrates how augmented reality concepts can be used in real life examples. Students are going to use augmented reality technology in collaboration with mobile learning and the Internet of things to organize a school contest. The purpose of the contest is to find out the most qualified student in computational thinking concepts in their school.* *The contest will be held among students to find out who is the most computational intelligent one. A given pool of questions related to computational thinking problems will be used. Then the questions will be assigned to QR codes. The QR codes will be spread around the school (classrooms, hallways, playground etc.). Students are going to search for the QR codes to answer the questions. The results will be collected into google spreadsheets files. The students will have to process the data registered in the spreadsheets (using functions, filters, and other processing tools) and find out the winner (student/students who have answered correctly in most of the questions of the contest or why not all).* *Although the main goal of this project is to teach students how spreadsheets are used for data processing, this project offers many other educational opportunities that allow us to integrate a variety of other learning tasks, such as mobile learning, internet of things, augmented reality.* *The teaching method employed is the project-based learning method and the students will work in groups.*
A.4 Keywords:	*contest, QR codes, data processing, computational thinking, forms, spreadsheets*
A.5 Version:	*1st version*
A.6 Date:	*29/10/2020*
A.7 Copyright license:	*Attribution ShareAlike CC BY-SA*
Part B. Learning Data	
B.1 Grade(s):	*Grades 8-9, Age 13 – 15 years old*
B.2 Subject(s):	*Computer Science, ICT*
B.3 Topic(s):	*Data analysis*

B.4 Computational Thinking Dimensions:

Algorithmic Thinking (AL)	✓
Abstraction (AB)	
Generalization (GE)	
Logical reasoning (LR)	✓
Pattern matching (PM)	
Problem decomposition (PD)	✓
Problem translation (PT)	
Evaluation (EV)	✓
Representation (RE)	✓
Data collection (DC)	✓
Data representation (DR)	✓
Data analysis (DA)	✓
Modeling (MO)	
Simulation – (SIM)	
Automation (AUT)	
Sequencing (SE)	
Testing (TE)	
Understanding People – (UP) /Artificial Intelligence (AI)	

B.5 Computational Thinking Approaches:

Tinkering experimenting & playing	
Creating, designing, and making	✓
Debugging, finding, and fixing errors	
Persevering, keeping going	
Collaborating, working together	✓

B.6 Thematic in the context of the CompuT Project:

Educational Robotics or Physical Computing		
Computational Science project	Modeling/Simulation	
	Bifocal modelling	
	Sensors use or making	
	Maths and CS	✓
	Other: …	
Data science project	✓	
History of science and technology		
Digital game, software, or mobile app		
Digital humanities projects	Digital Storytelling	
	Interactive Fiction	
	Text mining	
	Algorithms in everyday life	
	Other: …	
Artificial Intelligence Projects		
Studio approach – Future Classroom projects		
Unplugged experiential or using manipulatives		
Other: ….		

<table>
<tr><td rowspan="1">B.7 Purpose/Aim of the learning scenario:</td><td colspan="2">The main goal of this project is to teach students how spreadsheets are used for data processing and learn how to deal with combinational statistic queries. However, this project offers many other educational opportunities that allow us to integrate a variety of other learning tasks, such as mobile learning, Internet of things, augmented reality.

The use of QR codes technology provides students with a deeper connection with the real world. Moreover, it gives them an opportunity to develop their communication skills, interacting with other students, groups of students and the entire school community.</td></tr>
<tr><td rowspan="4">B.8 Learning outcomes/goals[22]:</td><td colspan="2">At the end of the learning scenario students should be able to:</td></tr>
<tr><td>B.8.1 Knowledge</td><td>● Use functions
● Combine data from different spreadsheets
● Sort data
● Illustrate data into graphs
● Breakdown combinational queries
● Answer queries using functions
● Model queries into formulas
● Evaluate results after modeling queries into formulas
● Manage duplicate/multiple records issues encountered in a data set</td></tr>
<tr><td>B.8.2 Skills</td><td>● Practice skills used in scientific research (such as collecting, selecting, processing useful information, comparing and interpreting)
● Develop computational thinking skills</td></tr>
<tr><td>B.8.3 Attitudes-affective</td><td>● Develop a positive attitude towards communication
● Develop a positive attitude towards collaboration
● Develop organizational skills attitude
● Recognize the usefulness of spreadsheets in everyday life applications</td></tr>
<tr><td rowspan="3">B.9 Horizontal competences - 21st century skills:</td><td colspan="2">The teaching scenario helps students develop some very important 21st century skills such as critical thinking, problem solving, creativity, communication, teamwork, analytic reasoning and social awareness.</td></tr>
<tr><td>B.9.1 Learning and innovation skills:</td><td>4C's: Collaboration, Communication, Critical Thinking

Students collaborate to solve the tasks, communicating with their group members, thinking critically and computationally.</td></tr>
<tr><td>B.9.2 Digital literacy skills:</td><td>Information literacy, Information and Communication technologies (ICT) literacy

The scenario enhances Information and ICT literacy while students use technology to participate in a contest and produce cognitive results.</td></tr>
</table>

[22] For the effective formulation of learning-instructional goals the works of Mager, who claims for the definition of observable actions and Measurable Criteria of performance evaluation under specific conditions, could be useful. Mager, F. (1975). Preparing Instructional Objectives. (2nd ed.). Belmont, CA: Fearon. & Mager, F. (1997). Preparing instructional objectives: A critical tool in the development of effective instruction. Atlanta: The Center for Effective Performance. The verbs could follow the Bloom's knowledge taxonomy, see for example: https://tips.uark.edu/blooms-taxonomy-verb-chart/. It is important to use higher order thinking verbs. Anderson, L. W., & Krathwohl, D. R. (2001). A taxonomy for learning, teaching, and assessing, Abridged Edition. Boston, MA: Allyn and Bacon

	B.9.3 Career and life skills:	*Flexibility, initiative and self-direction, social interaction, productivity and accountability, leadership, and responsibility* *To come to the end of the scenario, students will have to be flexible and productive, be responsible and socially interact with their classmates.*
B.10 Modern teaching methods:	*Project-Based Learning,* *Collaborative Learning*	
B.11 Integration of CT into the curriculum:	Computing and data processing concepts are an integral part of CT. Integrating CT into subject areas and curriculum activities is a *one size fits all* solution.	
B.12 Relation to curriculum and/or standards:	*Greek National Curriculum, Grade 8-9, Ages 13-15* *Computer Science Curriculum, ICT Curriculum*	
B.13. Prerequisite knowledge:	*Prior knowledge needed to successfully implement the current scenario. Students should be able to:* ● *use basic spreadsheets tools/features (insert/delete lines/rows/cells etc.)* ● *manage spreadsheets* ● *create formulas using its functions sum, average, min, max, count* ● *use relative and absolute value of a cell* ● *create simple graphs to illustrate various information* ● *browse the internet*	
B.14. Difficulty Level of the Scenario:	*Intermediate*	
B.15. Social setting of the scenario:	*Small groups (3-4 students)*	
B.16 Place of implementation:	*Computer Lab, School yard, Classroom*	
B.17 Teaching time – Duration:	*7 x 45' sessions*	
B.18 Educational material, resources, instruments, tools, and media:	**B.18.1 Software:**	*Google Forms, QR code creator, Google spreadsheets, Microsoft office Word, Browser*
	B.18.2 Hardware:	*Personal computer with internet access, projector, smart board, mobile phones or tablets*
	B.18.3 Online resources:	*Online QR creator tool, Youtube videos*
	B.18.4 Conventional educational material:	*WorkSheets, Evaluation Sheet*

Part C. Learning Experience Design			
C.1. Activities-Action-Plot-Storyboard sequence table:3	**Phase 1.**	***Introduction to the Project***	**45’**
	Activity/Task	**Description/Procedure**	**Duration**
	A1.1 Introduction to the contest philosophy	*Introduction to the project, gaining attention, student activation.* *Teacher introduces the contest that students are going to set up and the organization details.* *Emphasis is given to each stage of the project, describing the goals of the project, the technology and software used, the structure and philosophy of the activities and the impact in the school community.* (Videos to support the teacher: • The magic of QR codes in the classroom https://www.youtube.com/watch?v=NRgWRXFXLQs • What is M-Learning? https://www.youtube.com/watch?v=-EnZca-Te2Y • Mobile Learning: Mobile Tech in the Classroom https://www.youtube.com/watch?v=H2Ly1FOHIa4) *Also, the anonymity issue is discussed. The students’ id (name, surname, nickname) should be hidden for privacy reasons during the contest. A decision is made on how to protect the privacy of the participants. Let students decide on this matter taking into consideration real life examples.* *(A unique code id assigned per each participant student may be a good solution.)*	*15’*
	A1.2 Contest questions	*Students are divided into small groups (3 or 4 students per group). They are given a pool of questions (20 in total- you can find some examples of questions in Annex 1) to discuss. The questions concern different aspects of computational thinking and students are asked to classify them according to their difficulty, defining an easy question compared to a difficult one.*	*25’*

	A1.3 Summary and next phase	*Teacher sums up and sets goals for the next stage.*	*5'*
	Phase 2.	**Using Google Forms**	**45'**
	Activity/Task	**Description/Procedure**	**Duration**
	A2.1 Question selection	*Each group selects two questions from the pool of questions that are going to be used in the contest. An easy and a difficult question are chosen per group.*	*5'*
	A2.2 Modeling in Google Forms	*The questions take a digital form using Google Forms. Teacher shares Worksheet 1 and instructs groups on the creation of the forms and the appropriate settings so that data is collected correctly.* *Except from the question in each google form, students will have to create a text field (short answer question in Google Forms) where participants will insert the unique id code assigned to them. The teacher briefly discusses once more the necessity of anonymity with the groups.*	*35'*
	A2.3 Summary and next phase	*The double record issue arises. What if a candidate answers two or more times the same question?* *What happens when* duplicate/multiple records *are encountered in a data set? How can this affect the accuracy of the result? Briefly discuss ways of solving this problem before moving on to the next phase (food for thought).*	*5'*
	Phase 3.	**Using QR technology**	**45'**
	Activity/Task	**Description/Procedure**	**Duration**
	A3.1 QR introduction	*Introduction to QR technology. Examples from real life. What is a QR code, and how it works, where it is used etc. Application to the project.* Related videos (optional): • https://www.youtube.com/watch?v=zZXCt1Ud_zE, • World's first beacon based Augmented Reality Museum App	*5'*
	A3.2 Create QR codes	*Teacher shows, using the smart board, how students can assign QR codes to demonstrate questions modeled in google forms.*	*35'*

	Sharing Worksheet 2, he/she asks students to generate QR codes for each question and save them in the shared lab folder with specific naming. The teacher will print the QR codes on cards. ***Important note:** In the attached Worksheet, students use the QR codes creation website:* *http://gr.qr-code-generator.com/* *The teacher can properly modify the Worksheet and use any of the QR codes creation sites available.*	
A3.3 Summary and next phase	*We sum up and set goals for the next stage.*	*5'*
Phase 4.	**Testing and evaluating**	**45'**
Activity/Task	**Description/Procedure**	**Duration**
A4.1 Does the process work correctly?	*In this phase students test and evaluate the procedure of the contest themselves. Do the QR codes work, are the data stored right, are the questions modeled and displayed correctly?* *Each team answers the question of another team and monitors the procedure.* *Each team gives feedback to the others. Teams make optimizations before the contest starts.*	*30*
A4.2 Initialization	*Testing data must be deleted and possible last-minute changes are done before the contest starts.*	*10'*
A4.3 Summary and next phase	*We sum up and set goals for the next stage.* *Students are urged to spread the word to their schoolmates. One student from each group will join the advertising team, which takes over the mission of informing the other students in the school about the contest. In particular, the team will be responsible for explaining the contest, announcing the terms of participation, the rules and objectives of the competition and encouraging students to participate in it. They will also place the QR codes in various locations of the school (hallways, boards etc.).*	*5'*

			The contest will take place in a specific period and all students will be welcomed to participate.	
		Phase 5.	**Data processing**	**2 x 45'**
		Activity/Task	**Description/Procedure**	**Duration**
		A5.1 Using spreadsheets	*After the end of the contest, students are going to collect and process the answers of the participants. Students are divided into their initial groups (groups of 3 or 4) and start to process the data collected in the spreadsheets generated for each question of the contest.* *Worksheet 3 is shared, in which each group is asked to answer the research questions and write down the results. Students are expected to use functions, create graphs, and draw complex conclusions through data processing. The multiple records issue is being solved.* *The students are asked to save the outcomes in a word document named by the name of their team.*	*2 x 45'*
		Phase 6.	**Results – Impact - Evaluation**	**45'**
		Activity/Task	**Description/Procedure**	**Duration**
		A6.1 Find the winner	*It is the time to find the winner. The groups compare the results from all other groups to find out the candidate with the most correct answers.* *Guided by the teacher, the groups compare their results (spreadsheets and word files) and combine them to find the winner. Will there be unanimity in the teams? If not, who is right? Teams discuss and work together to reach a correct, valid, and unquestionable result.*	*20'*
		A6.2 Feedback	*At this phase, each group suggests to the plenary ways to improve the contest organization. What went wrong, what needs to be improved, optimized. Then plenary discusses the impact of the contest in the school community.*	*10'*
		A6.3 Evaluation activity	*An evaluation sheet is given to groups with open-ended and closed-ended questions to determine if the desired learning objectives have been achieved (see Annexes). This*	*15'*

		evaluation sheet could be implemented as an online questionnaire.	
C.2 Assessment	*In the final phase (Phase 6) groups answer an evaluation sheet to determine if the desired learning objectives have been achieved.*		
	C.2.1 Students feedback and reflection	*After the contest ends (Phase 5), each group suggests to the other groups ways to improve the procedure. Students detect problems, suggest solutions, and evaluate the efficiency in order to optimize the contest.*	
C.3 Homework/ Work with parents-family	*None*		
Part D. Information for the Teachers			
D.1 Adaptation - Differentiation for inclusion of all students	*All students in general education could implement the scenario. In case of students with special needs, proper adaptations could be done.*		
D.2 Extension	*The subject (questions) of the contest could be transformed to cover various scientific fields or interdisciplinary areas of knowledge.*		
D.3 Resources	*Participants should be provided with smart phones or tablets, so the school should have the equipment.* *Printers and paper to print the QR codes. Materials to stick the codes on walls (if decided to do so).* *Computer lab with Internet connection.*		
D.4 Experience deriving from the implementation of the scenario			
D.5 Relations to other scenarios			
D.6 Reviews by teachers			
D.7 Assessment of the scenario	*[1=Very Bad – 5=Very Good]*		
D.8 References			
Part E. Annexes	**Worksheets and Evaluation sheet**		
	Examples of questions *Worksheet 1* *Worksheet 2* *Worksheet 3* *Evaluation sheet*		

Examples of questions

To implement the scenario, you need some questions concerning Computational Thinking. Here are 5 examples of questions you could use, coming from the International Challenge on Informatics and Computational Thinking Bebras. You may use these questions, other questions from Bebras Challenges which you can find online, create your ones, or even ask students to create theirs.

QUESTIONS

1. Some beavers are allergic to certain types of wood and get sick when they eat them. Beaver George makes snacks for his party and wants to be sure that all the guests will be able to eat something that will not cause them allergies.
Each snack is made from a type of wood:

		
linden	maple	Oak tree
		
birch	poplar	willow

George has a list of his guests and the types of wood that can be eaten without getting sick:
To save time, George does not want to get snacks from all 6 types of wood, if possible.

Name	Type of Wood
Anna	Willow, oak, linden, maple
Veronica	Willow, oak, poplar
Stella	oak
Joan	Linden, birch
Emmanuel	Willow, maple, birch
Frank	Oak, linden
George	Poplar, maple

Question:
How many types of wood can George use to make snacks, so that all the guests can eat without getting sick?

Answers:
A)1 B)2 C)3 D)4 E)5 F)6

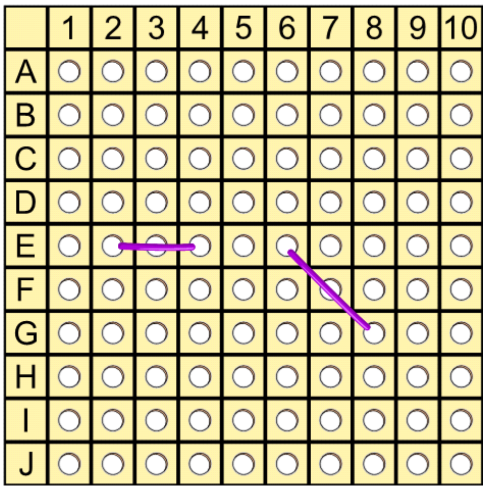
Correct Answer

C)3

2. A beaver tries to make an embroidery pattern by using an embroidery program and a machine.

The embroidery program uses the command OUT(cc)-IN(dd), where cc and dd indicate the position of the needle in the grid. For example, OUT(B2)-IN(A3) is a command to move the needle to the B2 position and pull it out from back to front and then move the needle to the A3 position and pierce it in, from front to back.

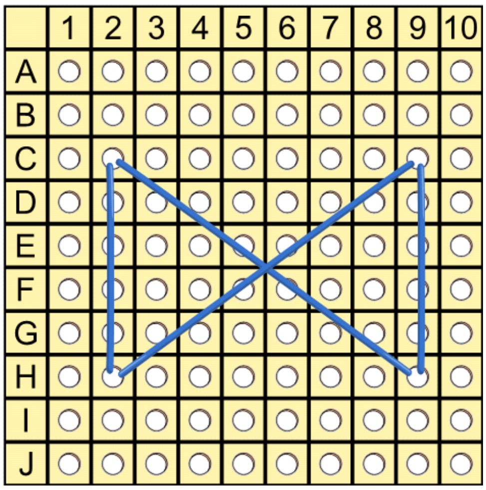
The following two commands create a pattern like below.



OUT(E6)-IN(G8);OUT(E2)-IN(E4)

Question / Challenge

Which commands could be used to create a ribbon pattern like the one in the image?

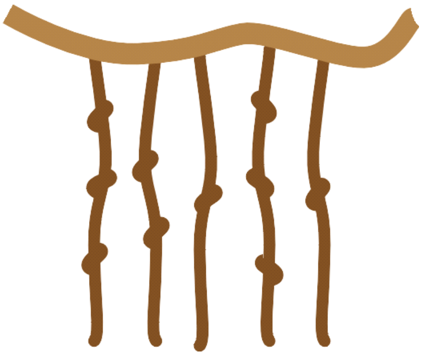


Answers:

A) OUT(H2)-IN(C2);OUT(H9)-IN(C9);OUT(C9)-IN(C2);OUT(H9)-IN(C2)

B) OUT(C2)-IN(H9);OUT(H2)-IN(C9);OUT(C2)-IN(H2);OUT(C9)-IN(H9)

C) OUT(H9)-IN(C9);OUT(H9)-IN(H2);OUT(C2)-IN(H2);OUT(C9)-IN(H2)

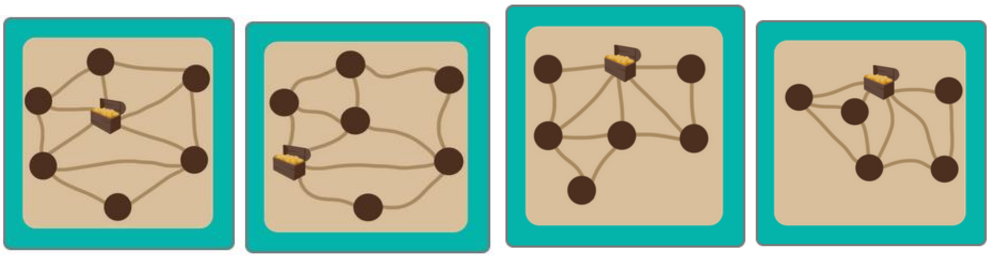
	D) OUT(C2)-IN(C9);OUT(H2)-IN(H9);OUT(C2)-IN(H2);OUT(C9)-IN(H9) **Correct Answer** B) 'OUT(C2)-IN(H9)';'OUT(H2)-IN(C9)';'OUT(C2)-IN(H2)';'OUT(C9)-IN(H9)'
3.	A queen uses knots on hanging ropes (called quipu) to announce news to her kingdom. For example, the following quipu might be the announcement “let’s celebrate”.  All that matters is the order of the ropes and the number of knots on each rope. Each rope has 0, 1, 2 or 3 knots. There are only 50 different possible announcements made by the queen. **Question / Challenge** What is the minimum number of ropes that the queen needs? **Answers** A)2 B)3 C)4 D)5 The correct answer is: B
4.	King of the beavers has hidden his treasure in a country of 7 provinces as shown in the map below. 

	The king created an encoded map. Circles denote provinces and two circles are connected by a line if the corresponding provinces border each other. To confuse the thieves, the king made three more false encoded maps.

<u>Question / Challenge</u>

Which map is real?

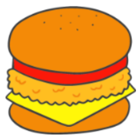
<u>Answers</u>



A B C D

The correct answer is: C

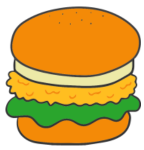
5. BeaverKingWay uses six types of fillings (A, B, C, D, E, and F) in order to make a burger. The following table shows the burgers and their fillings. The fillings are not listed in any particular order.

Burger				
Fillings	C, F	A, B, E	B, E, F	B, C, D

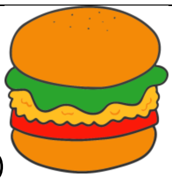
<u>Question / Challenge</u>

Which burger has the fillings A, E, and F?

<u>Answers</u>

A)	B)	C)	D)
			

The correct answer is:

	A) 

Worksheet 1 **Date** ____________________

Team Name ______________

1. In the frames below copy and paste the questions your team selected.

<u>**1st Question**</u>
<u>**2nd Question**</u>

2. Modeling questions in Google Forms

<u>Step 1:</u> Open Google Forms website (https://docs.google.com/forms/) and log in with the account credentials:

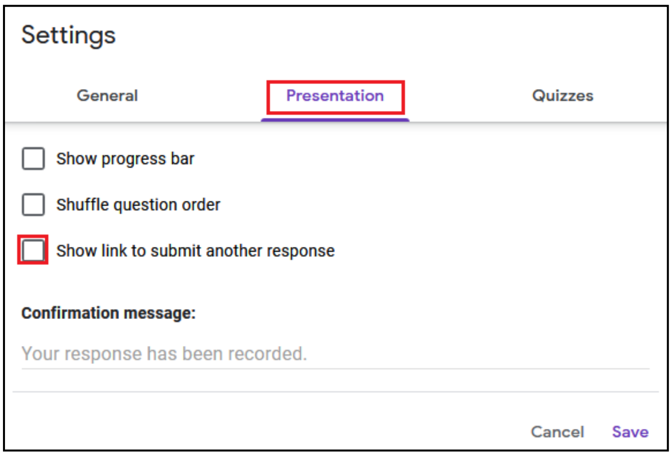
Username→ myschool_ct_contest@gmail.com

Password→ ABC123!!!

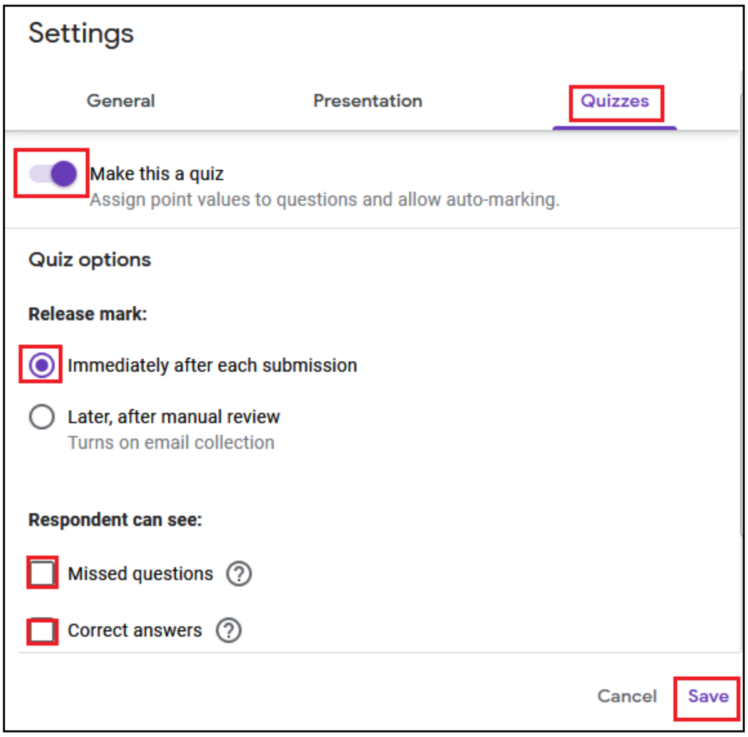
Step 2: Create a new Form for the first question. Name the form "Question X", where X stands for

1	for team 1
3	for team 2
5	for team 3
7	for team 4
9	for team 5

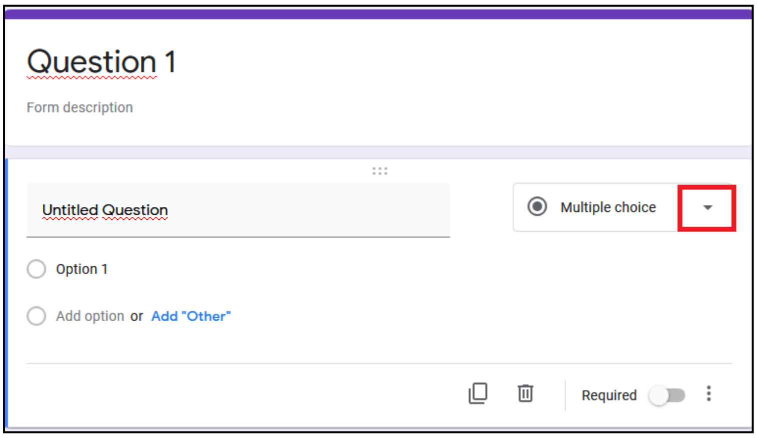
Step 3: Configure your form. Click the  button. In the *Presentation* menu uncheck the checkbox *Show link to submit another response* and click *Save*.

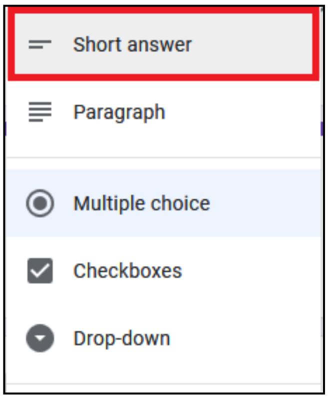


Then in the *Quizzes* menu make this form a quiz and apply the settings shown below and then click *Save*.

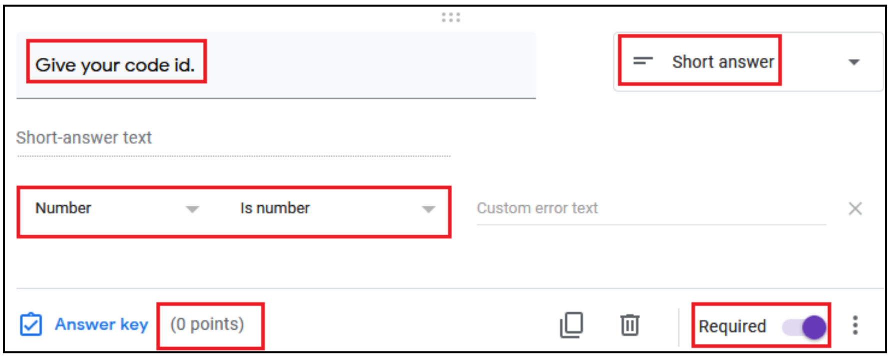


Step 4: Insert a short answer question so each student that participates in the contest can fill in his/her unique code identifier (that question will take 0 points).

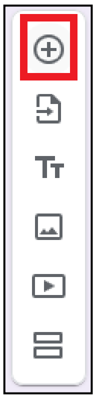


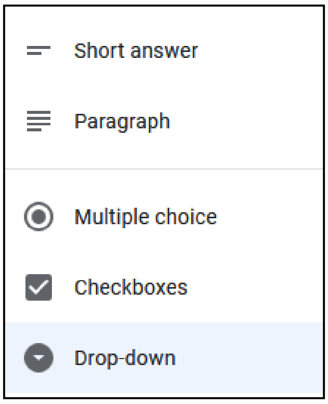


Make the settings shown below (numeric code identifier):



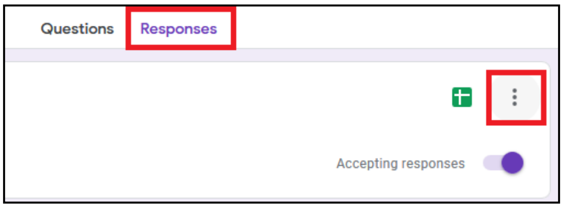
Step 5: Insert your first question. You can choose from multiple choice, checkboxes and dropdown question.

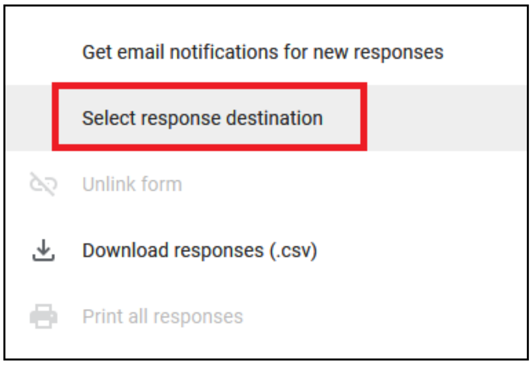




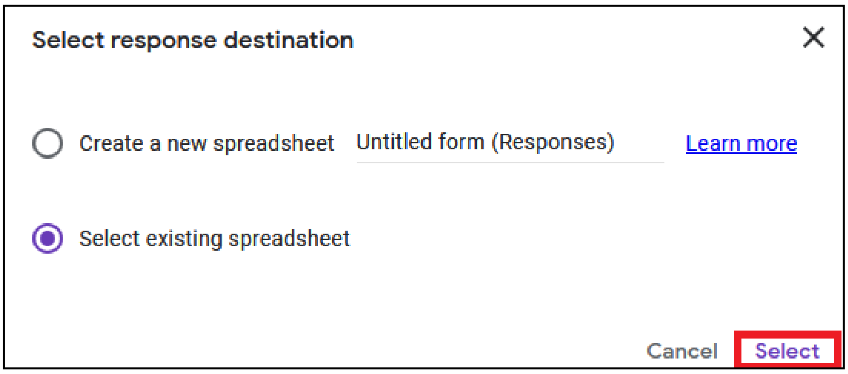
Model your question as you like. Don't forget to activate the *Required* button. 

Step 6: Apply the settings in *Responses* menu in order to collect data correctly. Click *Responses* and then click in  and click *Select response destination.*





Data will be collected in the existing spreadsheet called ***Responses***. Find it and link it with the form.



<u>The form for the first question is ready!</u>

<u>Step 7:</u> Create a new form for the second question. Name the form "Question X", where X stands for

2	for team 1
4	for team 2
6	for team 3
8	for team 4
10	for team 5

<u>Step 8:</u> Repeat from **Step 3** till **Step 6.**

<u>The form for the second question is ready!</u>

Well done! 

Worksheet 2	**Date** ______________
	Team Name ____________

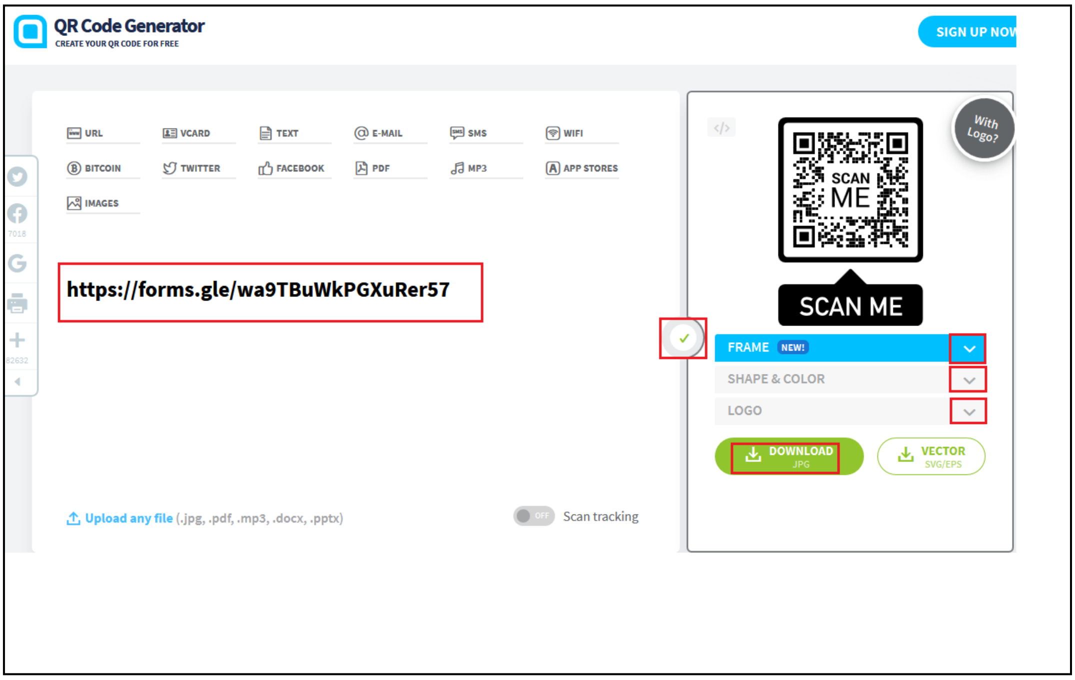
<u>Step 1:</u> Copy link – first question

Open the Google Form for the first question and click the Send button. Then click the button and copy the link that corresponds to the first question.

<u>Step 2:</u> Create a QR code.

Go to the website: http://gr.qr-code-generator.com/

Paste the URL for the online form in the blank space. The QR code will generate automatically. You can change the QR code's shape, color, logo etc.



When you are done download the QR code. Click the 

button and save the jpg file in the shared folder called ***QR Codes***.

Attention: Name your jpg file as "Question X",

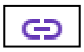
where X stands for

1	for team 1
3	for team 2
5	for team 3
7	for team 4
9	for team 5

The QR code for the first question is ready!

Step 3: Copy link – Second question

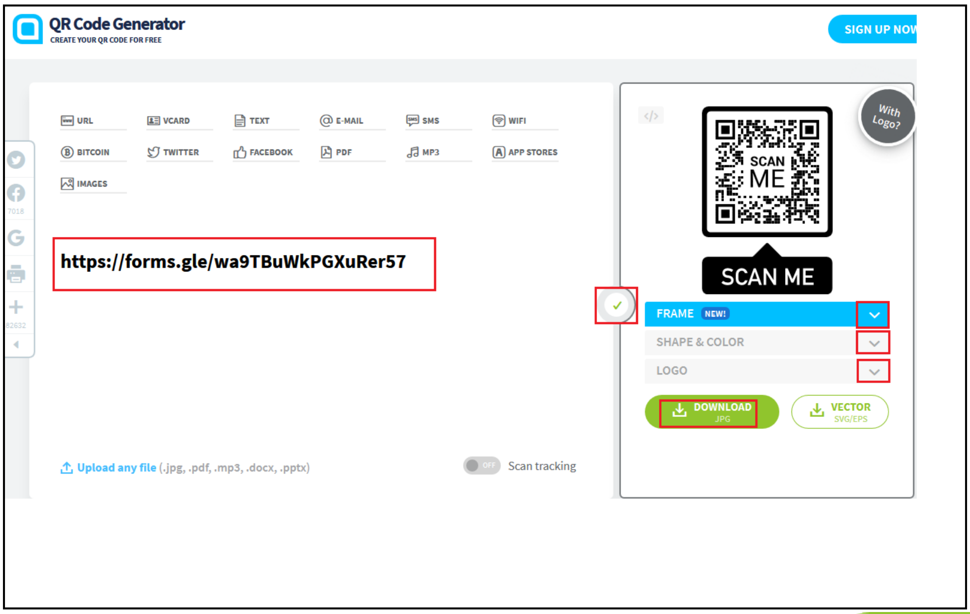
Open the Google Form for the second question and click the 

button. Then click the  button and copy the link that corresponds to the second question.

Step 2: Create a QR code

Go to the website: http://gr.qr-code-generator.com/

Paste the URL for the online form in the blank space. The QR code will generate automatically. You can change the QR code's shape, color, logo etc.



When you are done download the QR code. Click the 

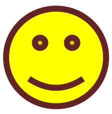
button and save the jpg file in the shared folder called ***QR Codes***.

Attention: Name your jpg file as "Question X",

where X stands for

2	for team 1
4	for team 2
6	for team 3
8	for team 4
10	for team 5

The QR code for the second question is ready!

Well done! 

Worksheet 3 **Date** ____________________

Team Name _____________

<u>Step 1:</u> Open the Google Sheet ***Responses*** and download it to your PC. Open it and look at the content. Check:

- the columns
- the sheets
- the data in each column

<u>Step 2</u>: Find the duplicate/multiple data (if there are any) (use sorting). Decide about the multiple records that correspond to the same candidate. Save the new data set in a new Excel file, named by the name of your team.

<u>Step 3:</u> Make formulas using functions, arithmetic operators, expressions and other excel tools to answer the following questions. Make a document file named by the name of your team to gather and represent information for each question.

1. ***How many students participated in the contest?***
2. ***How many of them answered both the two questions of your team?***
3. ***Which candidates did not answer one, or both questions of your team?*** *(Those candidates should be excluded from the contest)*
4. ***How many candidates answered correctly to the first question of your team?***
5. ***How many candidates answered correctly to the second question of your team?***
6. ***Create a graph to model questions 4 and 5.***
7. ***How many candidates answered correctly to both questions of your team?***

8. ***How many candidates gave a wrong answer to both questions of your team?***

9. ***Create a graph modeling questions 7 and 8.***

10. ***Which candidate / candidates answered correctly one of the two questions of your team?***

11. ***Which candidate / candidates answered correctly both questions of your team?***

Well done!

Evaluation sheet

Date ____________________

Team Name _____________

1. **QR codes are used in**
   - **a.** supermarkets
   - **b.** museums
   - **c.** marketing
   - **d.** all the above

2. **You can make QR codes online.**
   - **a.** True
   - **b.** False

3. **To create an online questionnaire, you need**
   - **a.** Google Forms
   - **b.** Google Slides
   - **c.** Google Docs
   - **d.** All the above

4. **The data collected from a Google Form are registered in a document file.**
   - **a.** True
   - **b.** False

5. **To process data, you may need to use**
   - **a.** Functions
   - **b.** Filters
   - **c.** Operators
   - **d.** Expressions
   - **e.** None of the above
   - **f.** All the above

6. **The multiple entries issue in a data set can be solved**
   - **a.** with unique code identifiers,
   - **b.** with sorting and filtering
   - **c.** with unique code identifiers, sorting and timestamp
   - **d.** with timestamp

7. **Suggest some other use of QR codes in your everyday life.**

8. **What was the most difficult task you issued during this project?**
   - **a.** QR code creation
   - **b.** Google Form creation
   - **c.** Processing of the data
   - **d.** Working in groups
   - **e.** Modeling formulas

   Other ________________________________

Exemplar Scenario 06: *Studying the Skyros Archipelago Lizards*

Part A. General Data	
A.1 Title:	*Studying the Skyros Archipelago Lizards*
A.2 Author(s):	*Elisavet Mavroudi, University of the Aegean*
A.3 Abstract/ Summary:	*This scenario involves students in an authentic data analysis project with the aim of generating scientific knowledge, since it is based on a large set of data which comes from real research. The scenario also falls within the field of CT because it employs several CS practices in solving problems in the field of biology. Students will summarize data sets, interpret them based on simple knowledge in the field of Biology, construct chart graphs, practice spatial reasoning, compare subsets of data based on the values of mean and variance, filter outliers, test hypotheses, and finally, they will suggest the collection of further data to answer questions.* *The scenario constitutes an adaption of (Tally, 2019)*
A.4 Keywords:	*Data analysis, experiment, hypotheses testing, Biological Evolution*
A.5 Version:	*V01*
A.6 Date:	*30/09/2021*
A.7 Copyright license:	*Attribution ShareAlike CC BY-SA*
Part B. Learning Data	
B.1 Grade(s):	*K-12: Grades 7-8 or Age(s): 12-14 years old*
B.2 Subject(s):	*Biology,* *Computer Science,* *Mathematics (Statistics)*
B.3 Topic(s):	*Ecosystem's interactions, Biological Evolution, Adaptation* *Analyzing and interpreting data, constructing explanations* *Measures of location and spread* *Data analysis*
B.4 Computational Thinking Dimensions:	*Check or note the dimensions which the scenario involves:*

Algorithmic Thinking (AL)	
Abstraction (AB)	
Generalization (GE)	✓
Logical reasoning (LR)	✓
Pattern matching (PM)	✓
Problem decomposition (PD)	
Problem translation (PT)	
Evaluation (EV)	

Representation (RE)	✓
Data collection (DC)	
Data representation (DR)	✓
Data analysis (DA)	✓
Modeling (MO)	
Simulation – (SIM)	
Automation (AUT)	
Sequencing (SE)	
Testing (TE)	
Understanding People – (UP) /Artificial Intelligence (AI)	

B.5 Computational Thinking Approaches:

Check or note the CT approaches which the scenario employs

Tinkering experimenting & playing	✓
Creating, designing, and making	✓
Debugging, finding, and fixing errors	
Persevering, keeping going	
Collaborating, working together	✓

B.6 Thematic in the context of the CompuT Project:

In the context of the CompuT Project we choose some thematic units to drive the development of the scenario:

Educational Robotics or Physical Computing		
Computational Science project	Modeling/Simulation	
	Bifocal modelling	
	Sensors use or making	
	Maths and CS	
	Other: …	
Data science project	✓	
History of science and technology		
Digital game, software, or mobile app		
Digital humanities projects	Digital Storytelling	
	Interactive Fiction	
	Text mining	
	Algorithms in everyday life	
	Other: …	
Artificial Intelligence Projects		
Studio approach – Future Classroom projects		
Unplugged experiential or using manipulatives		
Other:….		

B.7 Purpose/Aim of the learning scenario:

The long-term goal of this scenario is for students to get involved in an authentic, comprehensive project of data analysis and application

	of the scientific method on sustainability and biodiversity, thus linking important concepts of data analysis with their applications.	
B.8 Learning outcomes/goals[23]:	*After the completion of the scenario, students are expected to be able to:*	
	B.8.1 Knowledge	• *understand the environment's crucial role in the evolution processes* • *understand how the selective pressure of predation contributes to the diversification of some traits such as body size and alertness* • *understand that islands are isolated places, and the evolution of species there can follow a different course from what happens elsewhere*
	B.8.2 Skills	• *use various CODAP tools to analyze data* • *describe data sets based on the shape of the data distribution and statistical measures* • *read graphs and answer graphs questions about data, between data and beyond data* • *propose and justify data-driven hypotheses and predictions and plan further studies to investigate hypotheses and predictions* • *communicate the results of data analysis clearly and concisely.*
	B.8.3 Attitudes-affective	• *appreciate the value of data in generating claims and reasoning* • *communicate ideas from data* • *appreciate the scientific method* • *realize that research is a collaborative effort carried out by many people*
B.9 Horizontal competences - 21st century skills:	*This learning scenario creates the appropriate conditions for the development of various 21st century skills.*	
	B.9.1 Learning and innovation skills:	*4C's: Collaboration, Communication, Critical Thinking, Creativity* *Throughout this learning scenario, students work in small groups. They are asked, with the help of properly designed questions, to process some data to draw conclusions, which they then present to the plenary. Through this way of working, they can develop and / or improve their Collaboration, Communication and Critical Thinking skills. Finally,*

23 For the effective formulation of learning-instructional goals the works of Mager, who claims for the definition of observable actions and Measurable Criteria of performance evaluation under specific conditions, could be useful. Mager, F. (1975). Preparing Instructional Objectives. (2nd ed.). Belmont, CA: Fearon. & Mager, F. (1997). Preparing instructional objectives: A critical tool in the development of effective instruction. Atlanta: The Center for Effective Performance. The verbs could follow the Bloom's knowledge taxonomy, see for example: https://tips.uark.edu/blooms-taxonomy-verb-chart/. It is important to use higher order thinking verbs. Anderson, L. W., & Krathwohl, D. R. (2001). A taxonomy for learning, teaching, and assessing, Abridged Edition. Boston, MA: Allyn and Bacon

		their creative potential could be enriched by their contact with the scientific methods.
	B.9.2 Digital literacy skills:	*Information literacy, Media literacy, Information and Communication technologies (ICT) literacy, Digital citizenship* *Through the present scenario students are expected to learn how to use a web-based data analysis environment to summarize, visualize, and interpret data, advancing their skills to use data as evidence to support a claim.*
	B.9.3 Career and life skills:	*Flexibility and adaptability, initiative and self-direction, social and cross-cultural interaction, productivity and accountability, leadership, and responsibility*
B.10 Modern teaching methods:	*The scenario includes modern teaching methods such as:* *Collaborative Learning, as students need to work on teams to complete the tasks.* *Project-Based Learning, students will have to complete a project they are assigned with.*	
B.11 Integration of CT into the curriculum:	*This scenario includes a variety of disciplines such as biology, math and CS, blended with many CT dimensions.*	
B.12 Relation to curriculum and/or standards:	*Greek National Curriculum* *Grade 7 Biology Curriculum (Ecosystems: Interactions and Applications)* *Grade 8 ICT Curriculum (Spreadsheets and Data Analysis)* *Grade 8 Mathematics Curriculum (Descriptive Statistics)*	
B.13. Prerequisite knowledge:	*The first phase of the script provides students' familiarity with CODAP data analysis software, introduction to the concept of natural selection as well as a brief introduction to the statistical measures of mean value and standard deviation, while a higher degree of familiarity of students with all the above is expected to be achieved through the scenario. Any relevant prior knowledge / skills however, such as familiarity with spreadsheets, are desirable.*	
B.14. Difficulty Level of the Scenario:	*Intermediate*	
B.15. Social setting of the scenario:	*small group (3-4 students), whole class*	
B.16 Place of implementation:	*Computer Lab*	

<table>
<tr><td>B.17 Teaching time – Duration:</td><td colspan="2">4 x 45’ sessions</td></tr>
<tr><td rowspan="4">B.18 Educational material, resources, instruments, tools, and media:</td><td>B.18.1 Software:</td><td>CODAP (a free educational software for data analysis)</td></tr>
<tr><td>B.18.2 Hardware:</td><td>Pcs</td></tr>
<tr><td>B.18.3 Online resources:</td><td>the downloadable data files, a map of the Skyros Archipelago, a presentation on the Darwin's Finches</td></tr>
<tr><td>B.18.4 Conventional educational material:</td><td></td></tr>
<tr><td colspan="3"><u>Part C. Learning Experience Design</u></td></tr>
<tr><td>C.1. Activities-Action-Plot-Storyboard sequence table:</td><td colspan="2">

Phase 1.	**What happens when populations are separated?**	
Activity/Task	**Description/Procedure**	**Duration**
A1.1 Warming up, engaging the students	*The class is divided in groups of 3-4 students.* *The teacher projects a map of Skyros and the surrounding small islands and reports on how the rising sea level of the Aegean over the last 18,000 years has led to the formation of these small islands and has consequently caused lizard and other animal populations in Skyros to become separated. He/she then poses the following question: “Over those thousands of years, and according to what you have learned in Biology, do you think that the lizards on the small islands might have evolved differently than those on the main island of Skyros?* *5’ for the groups to reflect on the question and a follow–up plenary discussion* *The teacher can use some of the rich material available on the internet (e.g. the power point presentation at https://sciencecases.lib.buffalo.edu/collection/detail.html?case_id=550&id=550) to present the case of*	*15’*

</td></tr>
</table>

		“Darwin's Finches and Natural Selection”	
	A1.2 *Presenting the case of the educational scenario*	*At this point, the teacher presents the case the scenario is about. He/ She displays the picture from Annex 1 and provides the students with all the necessary information. Students are informed that they will be asked to study a small lizard from the Skyros archipelago to examine how the lizards of the surrounding small islands differ from the lizards of the main island of Skyros and why. A key fact for the analysis is that, unlike the main island of Skyros, on the small islands there are no snakes and birds that are the main enemies of the lizard. Finally, the students are informed that the data that will be used throughout this course has been collected by researchers who are investigating the ecological causes of the evolutionary deviation of the population in the Skyros lizard. Specifically, the differences in body size, alertness, and coloration between the lizards of the small islands and the mainland (the island of Skyros) were examined.*	*15’*
	A1.3 *A little bit of statistics*	*Following is a brief and concise reference to the concepts of mean value and standard deviation, with the help of the figure in Annex 2, which is projected by the teacher.* *He/She explains that statistical measures can help us describe changes in the distribution of characteristics and make comparisons between populations.* *After commenting on the usefulness and the way of interpretation of each of the*	*15’*

		above 2 statistical measures, the students are informed that they will use these two statistical measures to analyze the data for the lizards that live on the island of Skyros and the surrounding small islands.	
	Phase 2.	**Getting familiar with CODAP software and the data**	
	Activity/Task	**Description/Procedure**	**Duration**
	A2.1 Informing the class about the source of the data	*First, the way in which the data were collected and the characteristics that will be studied, are briefly presented. The teacher projects and explains the image in Annex 3. For the needs of the research, the lizards were "captured", tagged and then several morphological characteristics of theirs were measured. The present study, however, deals with the measures of weight (in grams) and length (from snout to vent - SVL length). The researchers did not consider the length of the tail as it is common for lizards in capture to lose their tails which then grow back, so any other measurement could be misleading. The researchers also measured the alertness of the lizards, which is expressed by the distance they were able to approach the lizard until it felt the need to move away from the danger. This distance is called the Flight Initiation Distance (FID) and the measurements for all lizards were made during their maximum activity which is between 10:00 am and 4:00 pm.*	*10'*
	A2.2 Getting familiar with CODAP software	*Summarizing the above, the teacher informs the students that, working in groups, they are going to study the data*	*35'*

	collected by the researchers, regarding five characteristics of the lizards and look for differences between the two different habitats, the island of Skyros and the small islands around it. *Before proceeding with their study, it would be useful for the students to familiarize themselves with both the software they will use and the format of the data. In this process they will be assisted by Worksheet I, in Annex 4.*	
Phase 3.	**Application, conduct of the study**	
Activity/Task	**Description/Procedure**	**Duration**
A3.1 *Working with real data*	*At this point, and provided that a satisfactory degree of familiarity with the use of the software and the format of the data has been achieved, the class is divided into groups, 3-5, depending on the number of students and each one can undertake the investigation of an individual trait. As "size" is broken down into two dimensions, weight, and length, and also "coloring" is considered in relation to the environment and to other members of the population, each of these two characteristics can, depending on the number of groups, be assigned to one or two groups.* *Each group shares one computer and is handed the corresponding Worksheet (one version of Worksheet II in Annex 5). In addition, each group is also given access to the corresponding data file in CODAP format, which will be needed.*	*45'*
Phase 4.	**Summarizing, presenting, and reflecting on the findings**	
Activity/Task	**Description/Procedure**	**Duration**
A4.1	*The groups return to the plenary and each in turn is*	*25'*

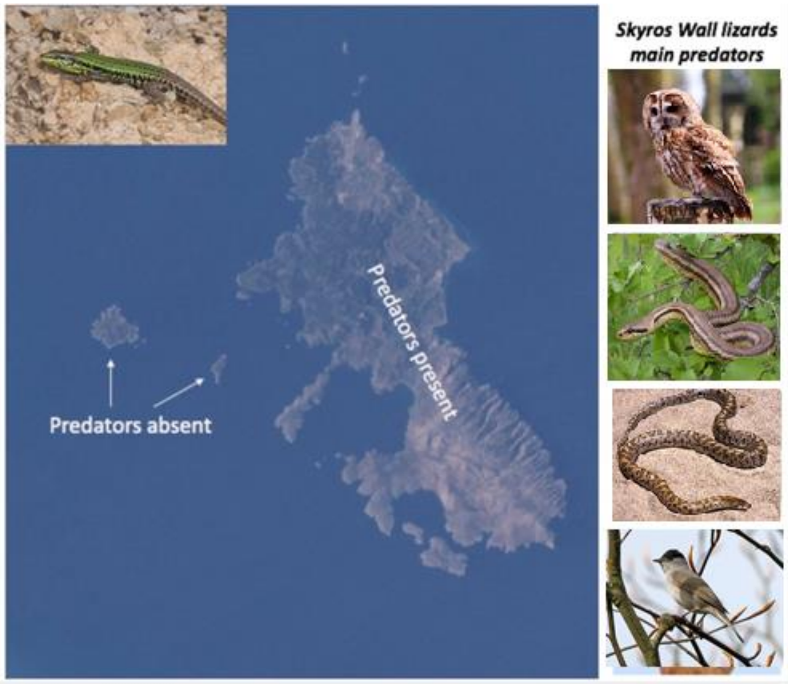
<table>
<tr><td rowspan="3"></td><td>Presenting the findings</td><td>invited to present its findings and the answers it gave in the Worksheet. During these presentations the teacher fills in the data in the corresponding position of the table in Annex 6.</td><td></td></tr>
<tr><td>A4.2
Further discussion on the scientific methods/practices</td><td>At this point it can be emphasized that for both the issues of size and color adaptation, scientists have chosen to investigate more than one dimensions, while the findings on the second dimension each time, confirm and reinforce the findings and conclusions of the findings on the first dimension.
In addition, a presentation on the issue of outliers can be made by the groups invited to negotiate this issue as well as, a relevant debate in plenary.</td><td>5’</td></tr>
<tr><td>A4.3
Summary and homework assignment</td><td>The teacher displays, for completion, the following summary table:<table><tr><th>Trait</th><th>mainland</th><th>islands</th></tr><tr><td>size</td><td></td><td></td></tr><tr><td>alertness</td><td></td><td></td></tr><tr><td>Coloration</td><td></td><td></td></tr><tr><td>predators</td><td></td><td></td></tr></table>After completing the table with the participation of students, the teacher asks the following questions:
Describe how the traits you studied in the lizards of the Skyros archipelago have changed over time.
How does the absence of predators in the small surrounding islands explain the difference in size, alertness, and color adaptation?
The answers to the questions are assigned as a written report at group level.</td><td>15’</td></tr>
</table>

C.2 Assessment	*Informal teacher assessment of pupils during the tasks.* *A final report per group is provided for assessment purposes* **C.2.1 Student's feedback and reflection**: *Students will get immediate feedback*
C.3 Homework/ Work with parents-family	*The last phase of the script could alternatively be assigned as homework. In this case, the report with the students' observations / conclusions could be written in a collaborative document, per group of students.*
Part D. Information for the Teachers	
D.1 Adaptation - Differentiation for inclusion of all students	
D.2 Extension	*It would be interesting to ask the groups of students to design research that will utilize the tools and methods that they had the opportunity to get acquainted with through the current teaching scenario, as well as to suggest how to collect the data.*
D.3 Resources	Finzer, B.,& Kochevar, R. (2019). Monday's lesson: Zoom in! teaching science with data. @Concord, 23(2), 7. Finzer, W., Busey, A., & Kochevar, R. (2018). *Data-driven inquiry in the pbl classroom: Linking maps, graphs, and tables in biology*. The Science Teacher. Tally, B. (2019). *Population Divergence: How are island lizards changing in the Skyros Archipelago?, a learning scenario in zoominscience project*, http://www.zoominscience.edc.org/, http://datascience.zoominmarketing.bbox.ly/wp-content/uploads/2020/05/Diversification_TG_final.pdf
D.4 Experience deriving from the implementation of the scenario	
D.5 Relations to other scenarios	
D.6 Reviews by teachers	
D.7 Assessment of the scenario	*[1=Very Bad – 5=Very Good]*
D.8 References	

Part E. Annexes

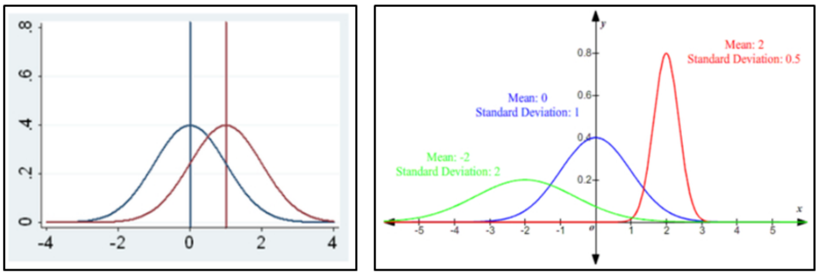
Annex 1

Picture to be displayed in the A1.2 task



Annex 2

To be used in the A1.3 task

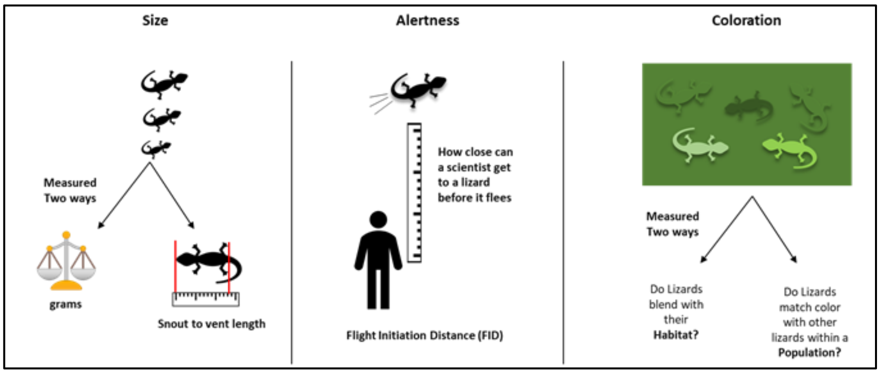


The mean: When comparing the same trait after a change in the environment, different means may indicate an overall change in the trait.

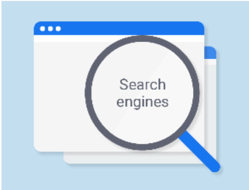
Standard Deviation (SD): When looking at the distribution of a trait in a population, SD can be used to describe the diversity for that trait.

Annex 3

To be used in the A2.1 task



<table>
<tr><td></td><td></td></tr>
<tr><td>Annex 4
Worksheet I
To be used in the A2.2 task</td><td>Worksheet I</td></tr>
<tr><td>Annex 5
Worksheets II
To be used in phase 3</td><td>Worksheets IIa, IIb, IIc, IId, IIe</td></tr>
<tr><td>Annex 6
To be used in the A4.1 task</td><td>
<table>
<tr><td>Habitat Category</td><td>“Mass” mean</td><td>“Mass” SD</td></tr>
<tr><td>Skyros (mainland)</td><td></td><td></td></tr>
<tr><td>Surrounding islands (island)</td><td></td><td></td></tr>
<tr><td>Habitat Category</td><td>“SVL” mean</td><td>“SVL” SD</td></tr>
<tr><td>Skyros (mainland)</td><td></td><td></td></tr>
<tr><td>Surrounding islands (island)</td><td></td><td></td></tr>
<tr><td>Habitat Category</td><td>“FID” mean</td><td>“FID” SD</td></tr>
<tr><td>Skyros (mainland)</td><td></td><td></td></tr>
<tr><td>Surrounding islands (island)</td><td></td><td></td></tr>
<tr><td>Habitat Category</td><td>“Correlation to Habitat” mean</td><td>“Correlation to Habitat” SD</td></tr>
<tr><td>Skyros (mainland)</td><td></td><td></td></tr>
<tr><td>Surrounding islands (island)</td><td></td><td></td></tr>
<tr><td>Habitat type</td><td colspan="2">Percentage (%) of similarity with the population</td></tr>
<tr><td>Skyros (mainland)</td><td colspan="2"></td></tr>
<tr><td>Surrounding islands (island)</td><td colspan="2"></td></tr>
</table>
</td></tr>
</table>



Studying the Skyros Archipelago
Worksheet I

Name(s): ____

Date: ______________

Let's get a little familiar with the program and our data!

1. In a browser, go to: https://codap.concord.org/ and click LAUNCH CODAP
2. Using the option:

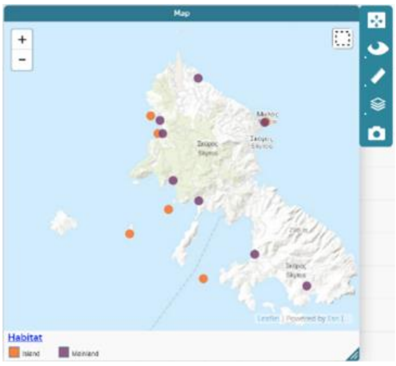
   OPEN DOCUMENT OR BROWSE EXAMPLES

   open the "[Size data.codap]" file (accessible for download at: https://cutt.ly/KbO4hYg).
3. Look carefully at the table and try to answer the following questions:

Questions	Record your answers here
There are three distinct (but interconnected) sections in the table. Which are these and what information does each one contain?	
How many areas of the island of Skyros and how many different islands have the researchers collected data from?	
How many different lizards have been studied?	

Exploring the map

The map shows the main island of Skyros (mainland) and the surrounding small islands (island) while all the areas from which samples were taken have been marked with dots.

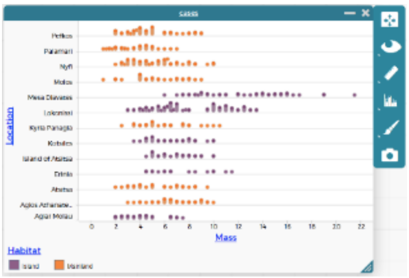


Questions	Record your answers here
Drag the "Habitat" title from the table to the middle of the map. What do you notice?	
Click on any row in the section of the table. What happens on the map;	

Explore the areas on the map of Skyros and the surrounding islands. Zoom In, click on a dot with the mouse. What do you notice about the table?	

Constructing a graph

Use the following tool to build a graph:



Drag the title “Mass” on the X-axis and the title “Location” on the Y-axis from the table.

Then drag "Habitat" in the middle of the chart and notice the change.

Well done! You are now ready to explore the research data to look for possible differences between the two large populations, the lizards that live on the island of Skyros and those that live on the surrounding small islands.

Worksheet IIa – Studying the lizards' weight

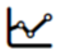
Your group will investigate the weight of the lizards. Remember that lizards from various areas of both the main island of Skyros and the surrounding small islands had been temporarily trapped by the researchers, were then measured and finally, tagged.

Let's make a few hypotheses…

If we take into account that Skyros and the surrounding islands are distinct ecosystems in which the selective pressures are different……

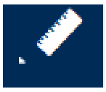
Questions	Record your answers here
Do you expect that the lizard's weight would vary in these two habitats? And if so, how?	
How do you believe the absence or presence of predators would affect any possible difference in size between mainland and island lizards?	

Open the "Size data" file in the CODAP environment



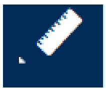
Construct a graph by placing the "**Mass**" field on the X-axis and the "Habitat" field on the Y-axis. Then drag "**Habitat**" to the center of the chart to color the dots.

Observe the graph paying special attention to the outliers.



Use the ruler tool to calculate the **Mean** of the lizard "mass" variable for each environment category.

Questions	Report your findings here
Mean for the Mass of the mainland lizards (island of Skyros)	
Mean for the Mass of the island lizards (surrounding small islands)	
How much heavier are the lizards of the small islands compared to those of the island of Skyros? Express your answer as a difference percentage. (%)	
How could the presence / absence of predators explain the difference you found?	



Use the ruler tool again, this time to calculate the Standard Deviation of the lizard "mass" variable for each environment category.

Questions	Report your findings here
Standard Deviation for the Mass of the mainland lizards (island of Skyros)	
Standard Deviation for the Mass of the island lizards (surrounding small islands)	
Which population, the one from the main island of Skyros or the one from the surrounding islands, shows greater variability in mass? Based on this difference in the value of the standard deviation, what would you conclude about the two populations?	
Remember that the separation of populations between the main island and the small ones around it happened thousands of years ago. How could the presence / absence of predators explain the difference in lizard size?	

Examining the effect of the outliers

On the graph that contains outliers, perform drag-selection of the data, leaving out the outliers. With the help of the tool, hide the unselected values (from the "Hide Unselected Cases" option) and recalculate the Mean Value and the Standard Deviation.

1. In which of the two habitats are the outliers found?
2. What do you observe on the values of the Mean and the Standard Deviation?
3. If you were the researcher, would you choose to include the outliers in your data or would you exclude them and why?

<u>Summarize here your observations and your conclusions about the outliers.</u>

Worksheet IIb – Studying the lizards' body length

Your group will investigate the length of the body of the lizards. Remember that lizards from various areas of both the main island of Skyros and the surrounding small islands had been first temporarily trapped by the researchers, were then measured and finally, tagged. In the case of body length, the snout to vent length was measured.

Let's make a few hypotheses…

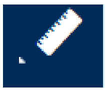
If we take into account that Skyros and the surrounding islands are distinct ecosystems, in which the selective pressures are different……

Questions	Record your answers here
Do you expect that the lizard's body lentgh would vary in these two habitats? And if so, how?	
How do you believe the absence or presence of predators would affect any possible difference in body length between mainland and island lizards?	

Open the "Size data" file in the CODAP environment

Construct a graph by placing the "**Snout_to_Vent Length**" (SNV Length) field on the X-axis and the "**Habitat**" field on the Y-axis. Then drag "Habitat" to the center of the chart to color the dots.

Observe the graph paying special attention to the outliers.



Use the ruler tool to calculate the **Mean** of the lizard "Snout_to_Vent Length" variable for each environment category.

Questions	Report your findings here
Mean for the SNV Length of the mainland lizards (island of Skyros)	
Mean for the SNV Length of the island lizards (surrounding small islands)	
How much longer are the lizards of the small islands compared to those of the island of Skyros? Express your answer as a difference percentage. (%)	
How could the presence / absence of predators explain the difference you found?	

Use the ruler tool again, this time to calculate the Standard Deviation of the lizard SNV Length variable for each environment category.

Questions	Report your findings here
Standard Deviation for the SNV Length of the mainland lizards (island of Skyros)	
Standard for the SNV Length of the island lizards (surrounding small islands)	
Which population, the one from the main island of Skyros or the one from the surrounding islands, shows greater variability in body length? Based on this difference in the value of the standard deviation, what would you conclude about the two populations?	
Remember that the separation of populations between the main island and the small ones around it happened thousands of years ago. How could the presence / absence of predators explain the difference in lizard size?	

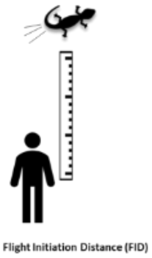
Examining the effect of the outliers

On the graph that contains outliers, perform drag-selection of the data, leaving out the outliers. With the help of the tool, hide the unselected values (from the "Hide Unselected Cases" option) and recalculate the Mean Value and the Standard Deviation.

1. In which of the two habitats are outliers found?
2. What do you observe on the values of the Mean and the Standard Deviation?
3. If you were the researcher, would you choose to include the outliers in your data or would you exclude them and why?

Summarize here your observations and your conclusions about the outliers.

Worksheet IIc – Studying the lizards' alertness



Your group will investigate the lizards' alertness. Which lizards move away from danger faster, those from the main island of Skyros or those from the surrounding small islands? It should be mentioned here that the main predators of lizards are snakes and birds, which, however, do not appear on the small islands around Skyros.

Let's make a few hypotheses…

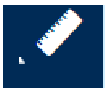
Questions	Record your answers here
Do you think that alertness is an important trait for a lizard? Why is that;	
Taking into account that Skyros and the surrounding islands are distinct ecosystems, in which the selective pressures are different… What differences in alertness (if any) would you expect to see between the lizards of Skyros and the small islands around it?	

Open the file "Flight Initiation Distance Data.codap" (available for downloading at https://cutt.ly/XbO4GFV) in the CODAP environment. Exactly as you did with the "Size data" file before, take some time to study the table and its three distinct sections, to get acquainted with the data it contains.

Construct a graph by placing the "**Flight Initiation Distance - FID**" field on the X-axis and the "**Habitat**" field on the Y-axis. Then drag "Habitat" to the center of the chart to color the dots.

Observe the graph carefully.

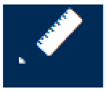
Keep in mind that the FID distance indicates how far away from the lizard the researcher was when the lizard started running.



Use the ruler tool to calculate the Mean of the lizards' "FID" variable for each environment category.

Questions	Report your findings here
Mean for the FID of the mainland lizards (island of Skyros)	
Mean for the FID of the island lizards (surrounding small islands)	
In which of the two environments were the researchers able to get closer to the lizards?	

Which lizards are more alert or more careful? Use data in your answer and explain what that data shows. Comment on the populations mean values.	
How could the absence of predators explain the difference in the alert levels you observed between the two populations (mainland vs island)?	



Use the ruler tool again, this time to calculate the Standard Deviation of the FID variable for each environment category.

Questions	Report your findings here
Standard Deviation for the FID of the mainland lizards (island of Skyros)	
Standard Deviation for the FID of the island lizards (surrounding small islands)	
What is the difference in variability between the lizards of Skyros and those of the surrounding islands? What would this difference be due to?	
Does this finding surprise you? Justify your answer.	

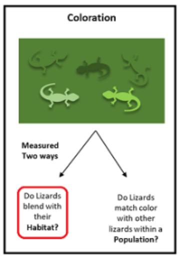
Examining the effect of the outliers

On the graph that contains outliers, perform drag-selection of the data, leaving out the outliers. With the help of the  tool, hide the unselected values (from the "Hide Unselected Cases" option) and recalculate the Mean Value and the Standard Deviation.

1. In which of the two habitats are the outliers found?
2. What do you observe on the values of the Mean and the Standard Deviation?
3. If you were the researcher, would you choose to include the outliers in your data or would you exclude them and why?

Summarize here your observations and your conclusions about the outliers.

Worksheet IId – Investigating the lizards’ coloration to habitat



Your group will investigate the coloration of the lizards to the habitat. The researchers investigated the lizards’ camouflage or how well they blend with their environment. They analyzed the color from the RGB images both, of the lizards' backs and squares from their surroundings (1m X 1m). **The higher the ratio between the lizard's dorsal surface and their habitat, the better the lizards are covered.** The degree of similarity in the data is given by a number called “correlation to habitat”.

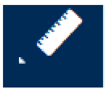
Let’s make a few hypotheses…

Questions	Record your answers here
How would the color of an animal be important in avoiding predators?	
Taking into account that Skyros and the surrounding islands are distinct ecosystems, in which the selective pressures are different… What differences in coloration do you predict there will be between island and mainland lizards?	

Open the file “Coloration Data.codap” (available for downloading at https://cutt.ly/3bO4TS2) in the CODAP environment. Exactly as you did with the "Size data" file before, take some time to study the table and its three distinct sections, to get acquainted with the data it contains.

Construct a graph by placing the “**Correlation to Habitat**” field on the X-axis and the “Habitat” field on the Y-axis. Then drag "Habitat" to the center of the chart to color the dots.

Observe the graph paying special attention to the outliers.



Use the ruler tool to calculate the Mean of the lizard "Correlation to Habitat " variable for each environment category.

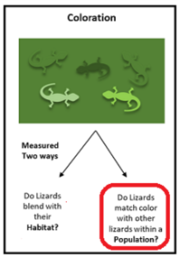
Questions	Report your findings here
Mean for the Correlation to Habitat of the mainland lizards (island of Skyros)	
Mean for the Correlation to Habitat of the island lizards (surrounding small islands)	
Describe what each graph (Skyros Island and surrounding small islands) tells you about how well the lizards match in color with their habitat.	

Which lizards blend better with their environment? Explain your reasoning in relation to the presence / absence of predators.	

Use the ruler tool again, this time to calculate the Standard Deviation of the lizard "Correlation to Habitat" variable for each environment category.

Questions	Report your findings here
Standard Deviation for the Correlation to Habitat of the mainland lizards (island of Skyros)	
Standard Deviation for the Correlation to Habitat of the island lizards (surrounding small islands)	
Comparing the two populations, the lizards of Skyros and those of the surrounding islands, where do you find more diversity in color? What is the proof of this?	
How would you explain your remarks? Take into account the different selective pressures in these habitats.	

Worksheet IIe – Investigating the lizards' coloration to each other

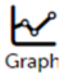


Your group will study how lizards blend in their own population by displaying a similar coloration. The researchers examined whether the lizards from the island of Skyros are more similar to each other than the lizards on the surrounding small islands. The degree of similarity in the data is given by a number called "correlation to population".

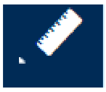
Let's make a few hypotheses…

Questions	Report your answers here
What, do you believe, is the cause of this investigation?	
What does it tell you about lizards' ways of hiding from their enemies?	

Open the file "Coloration Data.codap" (available for downloading at https://cutt.ly/3bO4TS2) in the CODAP environment. Exactly as you did with the "Size data" file before, take some time to study the table and its three distinct sections, to get acquainted with the data it contains.



Construct a graph by placing the "**Correlation to Population**" field on the X-axis and the "Habitat" field on the Y-axis. Then drag "Habitat" to the center of the chart to color the dots.



Use the ruler tool to calculate the Mean of the lizard "Correlation to Population" variable for each environment category

Estimate the percentage of lizards that are similar in color to each other at about 80% or more.
Hint: Add the percentage to boxes .8-.9 and .9-1.

Questions	Report your findings here
Percentage of lizards that are similar in color by 80% or more on the island of Skyros. (mainland)	
Percentage of lizards that are similar in color by 80% or more on the surrounding small islands (island)	
According to your analysis, the lizards on the small islands around Skyros are more or less similar to each other than those on the main island of Skyros.	
Try to interpret the difference between the two populations. (mainland vs island) found above.	

Exemplar Scenario 07: *Studying Cam Carpets to learn mathematics and computational thinking*

Part A. General Data	
A.1 Title:	*Studying Cam Carpets to learn mathematics and computational thinking*
A.2 Author(s):	*Evangelia Stamatarou, Maths Teacher , 2nd Lyceum of Rhodes*
A.3 Abstract/ Summary:	*The students experiment with* **Cam Carpet** *idea first using everyday material and light sources and progressively more formal tools to mathematise and make sense of the optic phenomena involved. First, students try a simple projection using light source and, pen and pencil to experiment with the optic illusion behind Cam Carpets. Then, they use Geogebra for the geometric analysis of simple cases of cam carpet phenomena (e.g. they will compute the cam carpet for simple letters) progressively they are introduced to the analytical model behind the cam carpets using equation systems for key point coordinates and finally, they model the optics using matrices. Finally, they can apply the new knowledge in an optional outdoor activity in which they represent the name of their school three-dimensionally as a Cam Carpet in the school yard. Thus, through the sequence of the various learning tasks, they better comprehend the maths related to the use of computing technology and improve their Computational Thinking skills. During this project, students will use their knowledge in Maths, Science and Arts.*
A.4 Keywords:	*digital technology, geometric analysis, outdoor activities*
A.5 Version:	*V2*
A.6 Date:	20/6/2022
A.7 Copyright license:	CC BY-SA 3.0
Part B. Learning Data	
B.1 Grade(s):	*Grades 10-11, Ages: 16-17*
B.2 Subject(s):	*Maths, Computer Science, Physics, English Language, Arts*
B.3 Topic(s):	

B.4 Computational Thinking Dimensions:	*Check or note the dimensions which the scenario involves:*

Algorithmic Thinking (AL)	
Abstraction (AB)	X
Generalization (GE)	
Logical reasoning (LR)	X
Pattern matching (PM)	
Problem decomposition (PD)	X
Problem translation (PT)	
Evaluation (EV)	
Representation (RE)	X
Data collection (DC)	
Data representation (DR)	
Data analysis (DA)	
Modeling (MO)	X
Simulation (SIM)	X
Automation (AUT)	
Sequencing (SE)	
Testing (TE)	
Understanding People – (UP) /Artificial Intelligence (AI)	X

B.5 Computational Thinking Approaches:	*Check or note the CT approaches which the scenario employs*

Tinkering experimenting & playing	X
Creating, designing, and making	X
Debugging, finding, and fixing errors	
Persevering, keeping going	X
Collaborating, working together	X

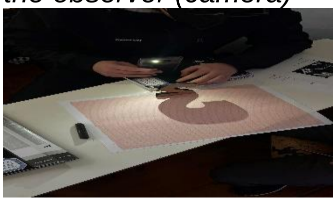
<table>
<tr><td>B.6 Thematic in the context of the CompuT Project:</td><td>In the context of the CompuT Project we choose some thematic units to drive the development of the scenario:
<table>
<tr><td>Educational Robotics or Physical Computing</td><td colspan="2"></td></tr>
<tr><td rowspan="5">Computational Science project</td><td>Modeling/Simulation</td><td>X</td></tr>
<tr><td>Bifocal modelling</td><td></td></tr>
<tr><td>Sensors use or making</td><td></td></tr>
<tr><td>Maths and CS</td><td>X</td></tr>
<tr><td>Other: …</td><td></td></tr>
<tr><td>Data science project</td><td colspan="2"></td></tr>
<tr><td>History of science and technology</td><td colspan="2"></td></tr>
<tr><td>Digital game, software, or mobile app</td><td colspan="2"></td></tr>
<tr><td>Digital humanities projects</td><td>Digital Storytelling</td><td></td></tr>
<tr><td></td><td>Interactive Fiction</td><td></td></tr>
<tr><td></td><td>Text mining</td><td></td></tr>
<tr><td></td><td>Algorithms in everyday life</td><td></td></tr>
<tr><td></td><td>Other: …</td><td></td></tr>
<tr><td>Artificial Intelligence Projects</td><td colspan="2"></td></tr>
<tr><td>Studio approach – Future Classroom projects</td><td colspan="2"></td></tr>
<tr><td>Unplugged experiential or using manipulatives</td><td colspan="2"></td></tr>
<tr><td>Other:….</td><td colspan="2"></td></tr>
</table></td></tr>
<tr><td>B.7 Purpose/Aim of the learning scenario:</td><td>Hopefully, mathematics will become an enjoyable and fun subject for all the students, even for those intimidated by it. Students will realize that Mathematics isn’t something abstract but it is closely related to experiences in the real world. They will connect Mathematics with an insight into human abilities like eyesight and they will see how Mathematics is used within the interdisciplinary approach to the creation of a model. In addition, students will appreciate the use of computational methods and tools in doing mathematics by solving real mathematical problems.</td></tr>
<tr><td rowspan="3">B.8 Learning outcomes/goals[24]:</td><td>At the end of the learning scenario students should be able to:</td></tr>
<tr><td><table><tr><td>B.8.1 Knowledge</td><td>✓ realize the real application of geometric analysis
✓ define the sense of space and develop geometrical thinking</td></tr></table></td></tr>
<tr><td><table><tr><td>B.8.2 Skills</td><td>✓ produce optical images.
✓ understand mathematical concepts applying mathematics outdoors help.</td></tr></table></td></tr>
</table>

[24] For the effective formulation of learning-instructional goals the works of Mager, who claims for the definition of observable actions and Measurable Criteria of performance evaluation under specific conditions, could be useful. Mager, F. (1975). Preparing Instructional Objectives. (2nd ed.). Belmont, CA: Fearon. & Mager, F. (1997). Preparing instructional objectives: A critical tool in the development of effective instruction. Atlanta: The Center for Effective Performance. The verbs could follow the Bloom’s knowledge taxonomy, see for example: https://tips.uark.edu/blooms-taxonomy-verb-chart/. It is important to use higher order thinking verbs. Anderson, L. W., & Krathwohl, D. R. (2001). A taxonomy for learning, teaching, and assessing, Abridged Edition. Boston, MA: Allyn and Bacon

		Additionally there is an implementation of mathematics in the real environment ✓ *use computational method and tools*
	B.8.3 Attitudes-affective	✓ *arouse enthusiasm and interest in their work, throughout the school community* ✓ *enhance their self-esteem, satisfaction and adopt a more positive attitude towards knowledge.* ✓ *work collaboratively*
B.9 Horizontal competences - 21st century skills:	*This learning scenario creates the appropriate conditions for the development of various 21st century skills*	
	B.9.1 Learning and innovation skills:	***Collaboration:*** *students collaborate as they work in groups of 2* ***Communication****: students will communicate with other groups to test their results* ***Critical Thinking****: students need to critically think to make decisions on the projections of the objects* ***Creativity****: students are expected to improve their projection of a three-Dimensional Object by changing points*
	B.9.2 Digital literacy skills:	***Information literacy****: students evaluate information to properly create a three-dimensional object for the observer (camera)* ***Information and Communication technologies (ICT) literacy****: students will be able to train a computational model and create their projections in a popular software (Geogebra)* ***Digital citizenship****: students will be aware of the use of CAM CARPET and the its applications in various fields in everyday life.*
	B.9.3 Career and life skills:	***Flexibility and adaptability****: students can be flexible and adapt their data to train their model to react in new cases* ***Initiative and self-direction****: students should make decisions by themselves but also contribute to the group to come up with a result* ***Social and cross-cultural interaction****: students should interact with other groups and test their results* ***Productivity and accountability****: students should try to do their best in the time given*

		Leadership and responsibility *students should cooperate and make decisions for the best result*
B.10 Modern teaching methods:	*Students work in groups of 2 based on a Collaborative inquiry script. They will learn by Project-Based Learning, STEM Learning, Learning by design, Authentic learning in the school yard.*	
B.11 Integration of CT into the curriculum:	*Creation of computational models in order to solve mathematical problems.*	
B.12 Relation to curriculum and/or standards:	*Greek National Curriculum, Grades 10 &11, Geometry Curriculum and Analytic Geometry Curriculum*	
B.13. Prerequisite knowledge:	*Students need to have basic knowledge of geometry and drawing.*	
B.14. Difficulty Level of the Scenario:	*Intermediate*	
B.15. Social setting of the scenario:	*A large group of students (8-10), working also in groups of 2-3*	
B.16 Place of implementation:	*Classroom, computer lab and may be school yard*	
B.17 Teaching time – Duration:	*7 x 45' sessions*	
B.18 Educational material, resources, instruments, tools, and media:	**B.18.1 Software:**	*Geogebra, Excel*
	B.18.2 Hardware:	*Video camera or smartphone, tripod, light source preferable led type flash.*
	B.18.3 Online resources:	https://www.gesamtschule-schinkel.de/camcarpet-ein-projekt-des-mathe-kurs-ma1-der-aktuellen-q1 https://www.youtube.com/watch?v=kHrp85-ekoI https://3dsportsigns.com/ https://www.youtube.com/watch?v=YMXsVACiwwo https://www.geogebra.org/search/cam%20carpets?fbclid=IwAR0m_Fy7OBjndBRN0Spk3xMjsDOhzEww86wspehKme05afUlwneCOKmEtMs
	B.18.4 Conventional educational material:	*Notebooks, color pencils, markers, geometrical instruments, millimetre paper, cartons, lego type building blocks,* piece *of string*

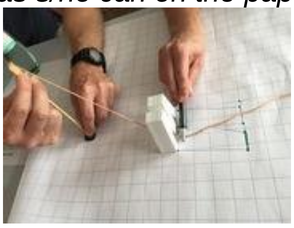
Part C. Learning Experience Design			
C.1. Activities-Action-Plot-Storyboard sequence table:	***Phase 1.***	***Introduction to the Cam Carpet idea***	
	Activity/Task	***Description/Procedure***	***Duration***
	A1.1 Introducing Cam Carpets	*The teacher distributes* ***Worksheet 1*** *to the students. By visiting the links provided in the worksheet and by answering the supportive questions, students are guided to discover what a cam carpet is and what context it usually finds application in.* *The goal is for students to familiarize themselves with the concept of cam carpets as well as to come up with ideas for creating their own cam carpet. Their ideas are written down on a piece of paper.* *The students may decide on the size and the place where the two-dimensional projection of the 3-D object of their choice, will be drawn.*	*45 ‘*
	Phase 2.	**Exploring the central projection**	
	Activity/Task	***Description/Procedure***	***Duration***
	A2.1 Discovering the projection of a three-dimensional Object	*A two dimensional Cam Carpet image creates a three-dimensional image for the observer (camera) However, this three-dimensional image can only be seen from a specific viewpoint. From another position it seems to be neither upright nor legible. The three-dimensional letter object is not physically present but due to the representation it is created by our eyes when located in the camera position.* *The teacher introduces the Cam Carpets principle via*	*45’*

		shadowing. S/he distributes ***Worksheet 2****, for this purpose, along with the necessary material. Worksheet 2 guides the students to shed light on an object so that its shadow appears on a sheet of paper. After drawing it on the paper they are asked to remove the object so that the students can see its projection as well as the optical 3-D illusion that applies under the same viewpoint. The light source should be suitable. A led /smartphone source on a tripod would serve.* *The students are given millimetre paper to create the projection of letters intuitively. The teacher supervises so that the students project the shadow correctly on the paper. So, they can realize how a two-dimensional Cam Carpet image creates a three-dimensional image for the observer (camera)* 	
	A2.2 Creating ***the*** *projection of an object using pieces of string*	*The teacher places a letter object on the graph paper. With the help of a piece of string he shows exactly how to create the projection of a three-dimensional object on the paper observing it from a certain point* 	*45’*

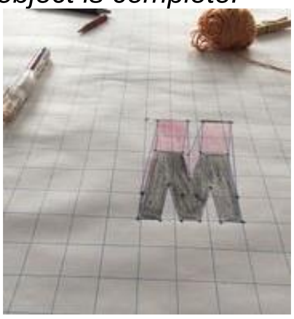
More specifically, with the help of his students, the teacher…

1. Puts a letter object on the graph paper.
2. Ties the one edge of a piece of string to the tripod.
3. S/he stretches the rope until it touches first, a point of the object and then, the paper. S/he, then, marks the point on the paper.

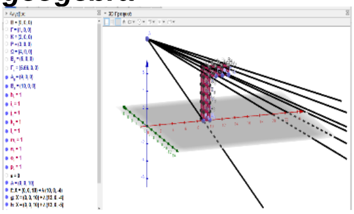
4. S/he continues making as many and suitable points as s/he can on the paper.

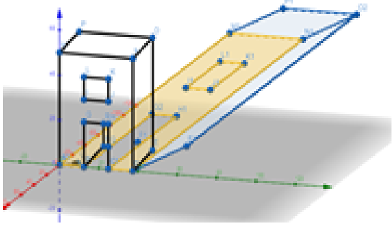


5. S/he then joins the points until the projection of the object is complete.



6. S/he calls the students to see the projection of the three-dimensional object letter with the help of a piece of a string which supports the observation from a certain point.

Phase 3.	**Creating the projection of a 3D-object with GEOGEBRA**	
A3.1 Exploring the projection of a 3D-object in ***GEOGEBRA***	*Through the guidance of* ***Worksheet 3*** *and an appropriate Geogebra applet, the students, first experiment with the projection of a three-dimensional letter in* ***Geogebra*** *(ensuring a specific camera position) and, vice versa, with the 3D-impression of the Cam Carpet viewed from a fixed camera position. Special controls allow for the height of the camera position to be shifted as well as to show/hide the trackpoints, the projection of the 3-D letter and of the letter itself.* *Then, the teacher showcases the projection of a letter made in GEOGEBRA.* *He/she also conveys the projection on graph paper in scale.*	*45'*
A3.2 Creating *the projection of a three-dimensional Object with* ***GEOGEBRA***	*The students, in turn, practice by creating a projection of a three-dimensional letter with* ***geogebra***  *The students are also given millimetre paper to create the projection of a letter like the projection in the* ***geogebra environment****. The teacher supervises so that the students implement the*	*45'*

		modelling project correctly. 	
	Phase 4.	**Creating the projection of a three-dimensional object with vectors**	
	Activity/Task	***Description/Procedure***	***Duration***
	A4.1 Analytical general solution of the cam carpet problem	*The teacher helps the students recall related key points from analytical geometry. Assuming a specific camera position (point K) and the projection of the 3D-object on the xy-plane, the teacher distributes **Worksheet 4** and helps students obtain the equation of the line that is defined by point K and by any given point A of the 3D-object. The coordinates of the corresponding track point on the xy-plane can then be calculated by setting the z coordinate equal to zero. S/he then asks students to produce an excel spreadsheet to automate the solution* *Students apply the spreadsheet in a case study problem e.g. the short name of the school.* *Students are assigned to make their own cam carpet analytically to demonstrate it at school*	*45'*
	A4.2 Drawing all the letters of the name of our school (optional)	*The students use a large piece of carton to draw the whole name of the school in the size they have agreed*	*45'*
	Phase 5.	**Evaluation**	
	Activity/Task	***Description/Procedure***	***Duration***

	A5.1 Evaluate and reflect on the project	*Students will be given* ***Worksheet 5*** *to describe and evaluate their experience*	*45'*
C.2 Assessment	*Informal teacher assessment of students during the tasks.* *Students will also fill the assessment worksheet. So, the teacher will get know the students' reflection.*		
	C.2.1 Students feedback and reflection	*Students get immediate feedback*	
C.3 Homework/ Work with parents-family	*Students can build their CAM CARPETS at home. They could also discuss with their parents and family to find out the use and propose of CAM CARPETS. The teacher could select and assign an extension to each team as homework.*		

Part D. Information for the Teachers

D.1 Adaptation - Differentiation for inclusion of all students			
D.2 Extension	*A4.2 Create the final product*	*They project it in the school yard.* 	*45'*
D.3 Resources			
D.4 Experience deriving from the implementation of the scenario			
D.5 Relations to other scenarios			
D.6 Reviews by teachers			
D.7 Assessment of the scenario	*[1=Very Bad – 5=Very Good]*		
D.8 References	*Reit,X.R.(2020). Cam carpets as outdoor STEM education activity. Research on Outdoor STEM Education in the digiTal Age,139. Online accessible at: https://www.wtm-verlag.de/DOI-Deposit/978-3-95987-144-0/978-3-95987-144-0-17.pdf*		

Part E. Annexes

	Worksheet 1, Worksheet 2, Worksheet 3, Worksheet 4, Worksheet 5

2O GEL RODOU

Worksheet 1   CAM CARPETS

DURATION : 1 SESSION

A1.1 INTRODUCING CAM CARPETS

ACTIVITY A1.1

GROUP #: ……………………………………………………………..
NAME/SURNAME: ……………………………………..……………..
CLASS…../ … DATE …..………………….…………………………..

1. **Visit the following links :**

   https://www.youtube.com/watch?v=kHrp85-ekoI
   https://3dsportsigns.com/

2. **What is the video about?**

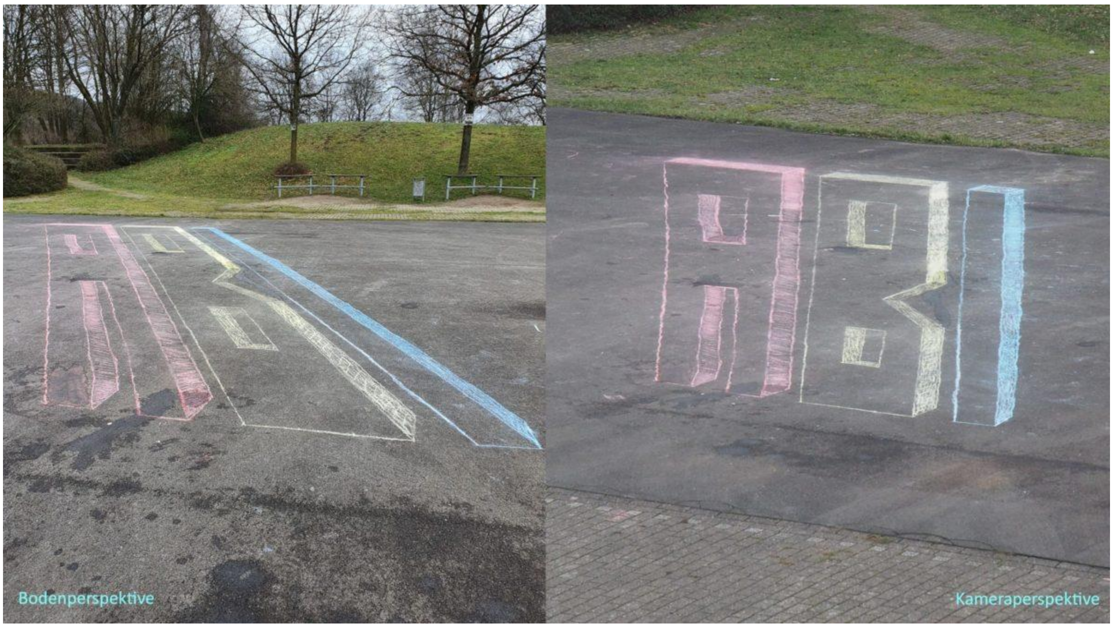
   …………………………………………………………………………………………….

   …………………………………………………………………………..……………………

3. **Visit the following link and watch the video**

   https://www.gesamtschule-schinkel.de/camcarpet-ein-projekt-des-mathe-kurs-ma1-der-aktuellen-q1/

   Pay special attention to the following screenshot:



4. **What was the issue of the video?**

   ……

   …………………………………………………………………………..……………………………

5. **What do you think a CAM CARPET is?**

   ……

   …………………………………………………………………………..…………………………..

6. **Where do you think we can find CAM CARPETS?**

   ……..

   ……..

7. Do you think it is possible for us to make our own CAM CARPETS?

……

……

8. Suggest an idea for a Cam Carpet of ours!

Object: ……………………………………………………………………

Size: ………………………………………………………………………

Location: ………………………………………………………………...

2^{O} GEL RODOU

Worksheet 2   CAM CARPETS

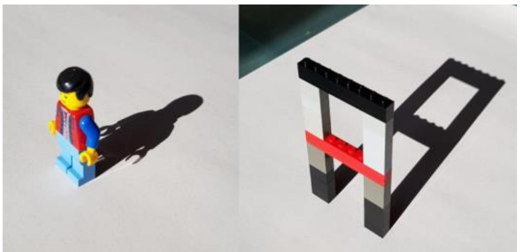
DURATION : 1 SESSION

A2.1 DISCOVERING THE PROJECTION OF A THREE-DIMENSIONAL OBJECT

GROUP #: **……………………………………………………………..**
NAME/SURNAME: **……………………………………..……………..**
CLASS…../ **… DATE …..…………………..…………………………..**

Students will be in groups of 2-3 and handed out an object, graph paper, tripod and smartphone

1. **What do you see in the photo?**



………………………………………………………………………………………………………

………………………………………………………………………………………………………

2. **Now we are going to make our projection of the three-dimensional object on the ground from a particular point.**
   a. **Put the object on the graph paper.**
   b. **Then put the tripod in front of it.**
   c. **Put the smartphone on the tripod and turn the light on.**
   d. **Look the projection of the object on the ground from a particular point.**
   e. **Turn the light on. (You may move your smartphone a little bit so that this point changes and see how the projection changes.)**

f. **Fix the "particular point" and draw the projection which is created on the paper from this point.**

g. **Turn off the light, remove the physical object, turn the camera of the smartphone on and watch the 3-D impression of the object. You should take care as to not change the location of the smartphone.**

h. **Notice that, when viewed from a different point, the two-dimensional projection of the object, does not give the 3-D impression of the object.**

So far ...So nice!!!
You have learned that you can obtain a 3-D illusion of an object by creating its shadow on the ground, when light is being shed from a particular point.

2^{O} GEL RODOU

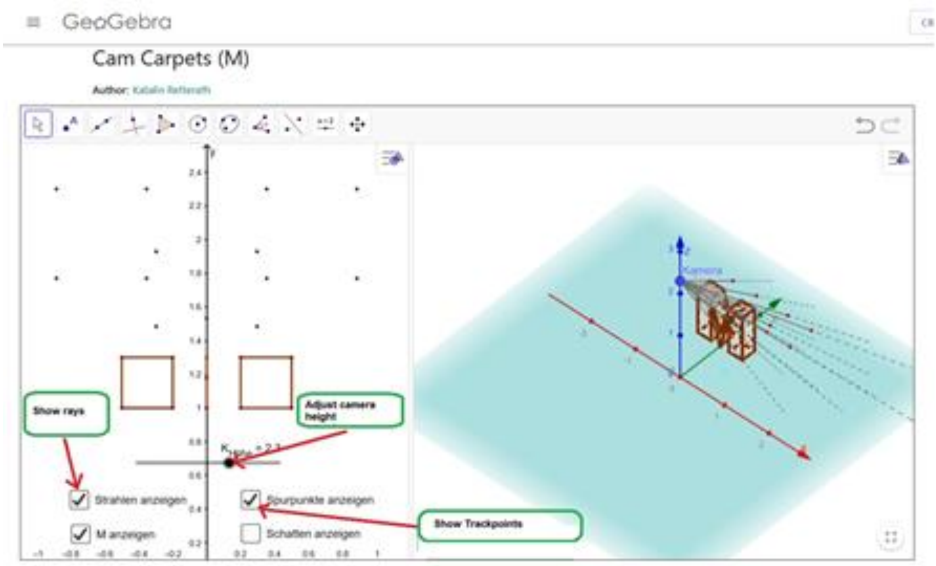
Worksheet 3   CAM CARPETS

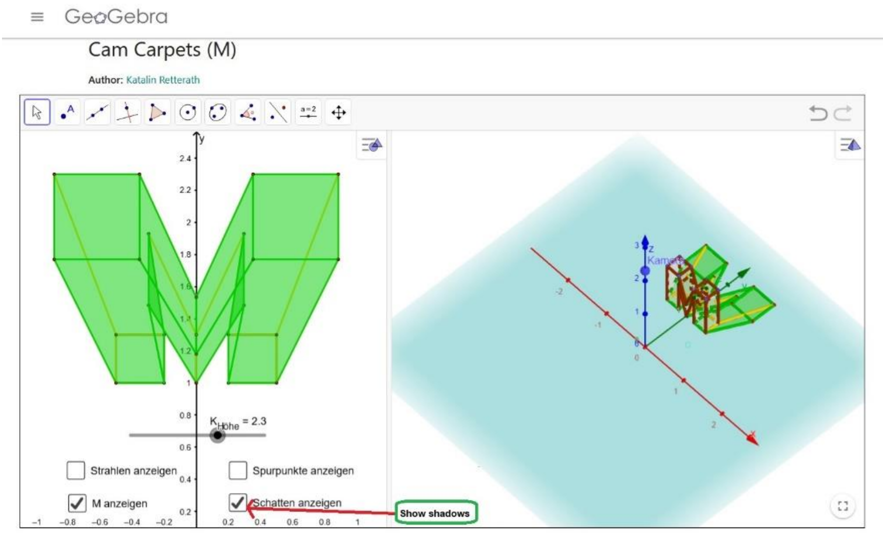
DURATION : 1 SESSION

A3.1 EXPLORING THE PROJECTION OF A 3D-OBJECT IN GEOGEBRA

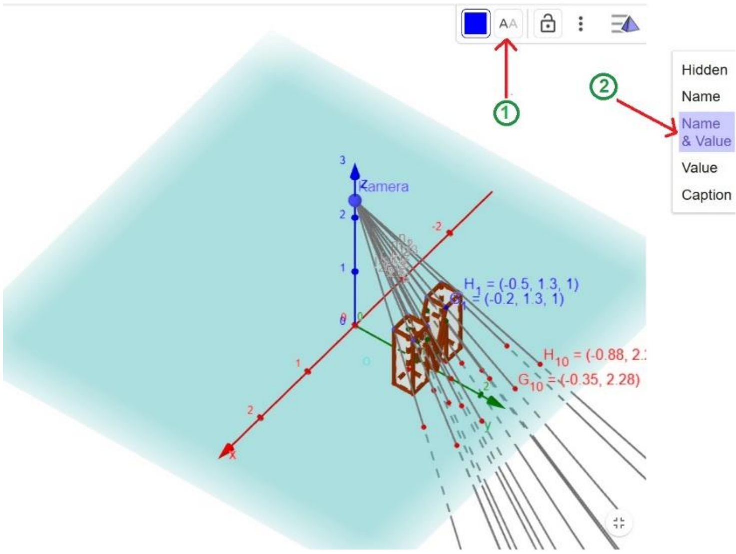
GROUP #: **………………………………………………………………..**
NAME/SURNAME: **…………………………………..……………..**
CLASS…../ **… DATE …..…………………..………………………..**

1. **Visit the link [https://www.geogebra.org/m/TYt3mxdQ.](https://www.geogebra.org/m/TYt3mxdQ) Experiment for a while with this geogebra applet. You can rotate the xy level in the right pane of the application and use the controls on the left to show/disappear the rays, the trackpoints of the object itself and/or its shadow. The following illustrative images may be helpful:**

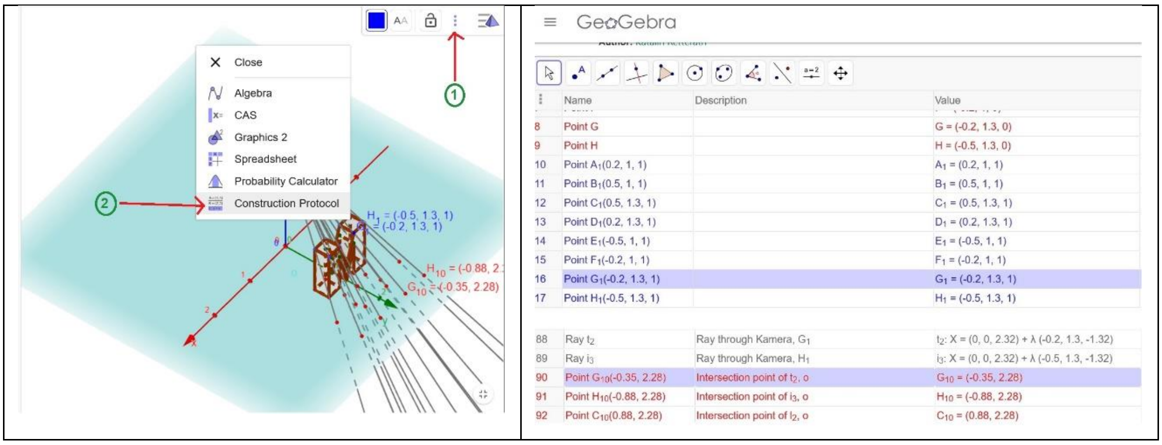




2. **Select a few points (vertices, preferably) of the 3-D letter as well as their corresponding track points and display their coordinates. The following screenshot might help:**



3. **You can get the coordinates of all the track points corresponding to the vertices of the 3-D model of the letter, by following the next steps:**



4. **Let's try to create the projection of a 3D object in Geogebra, from scratch. Watch carefully what your teacher will do in GEOGEBRA and do the same in order to draw the projection of your own object in GEOGEBRA.**

5. **Transfer the projection of your letter to the graph paper (scale will be needed).**

WONDERFUL WORK!!
Now it's the time for the geometric analysis!

2O GEL RODOU

Worksheet 4 CAM CARPETS

DURATION : 1 SESSION

A 4.1 ANALYTICAL GENERAL SOLUTION OF THE CAM CARPET PROJECT

GROUP #: ***……………………………………………………………..***
NAME/SURNAME: **…………………………………...……………..**
CLASS…../ **… DATE ….…………………..…………………………..**

Let's assume the camera position at point K:

K CAMERA $(X_{CAM}, Y_{CAM}, Z_{CAM})$

And a point A of our 3D-object:

A POINT (X,Y,Z)

The vector *AK* represents the direction vector of the line g_{AK}:

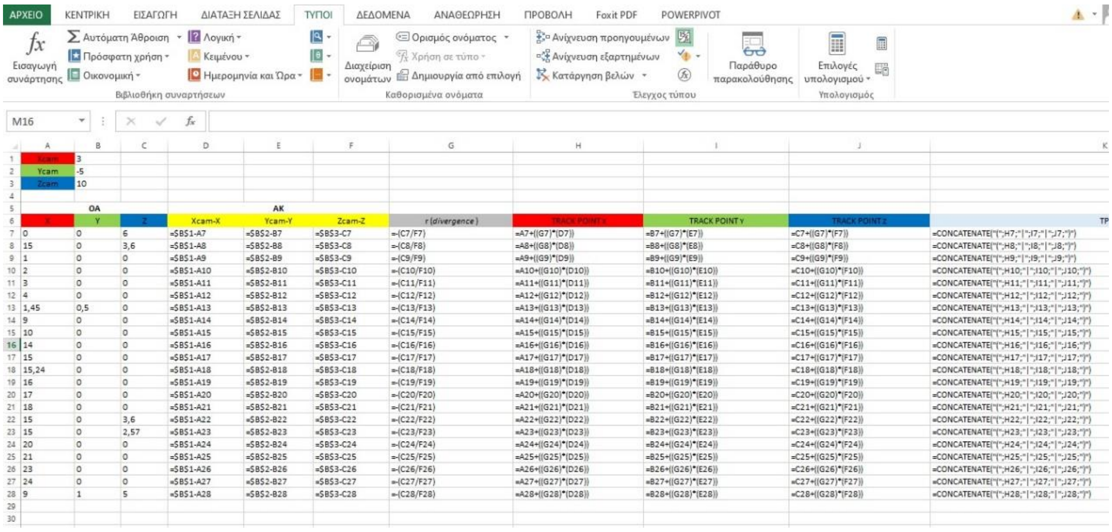
$$g_{AK} = \overrightarrow{OA} + r\overrightarrow{AK}$$

In the xy-plane z=0 and so we have: $0 = z + (z_{CAM} - z)r$

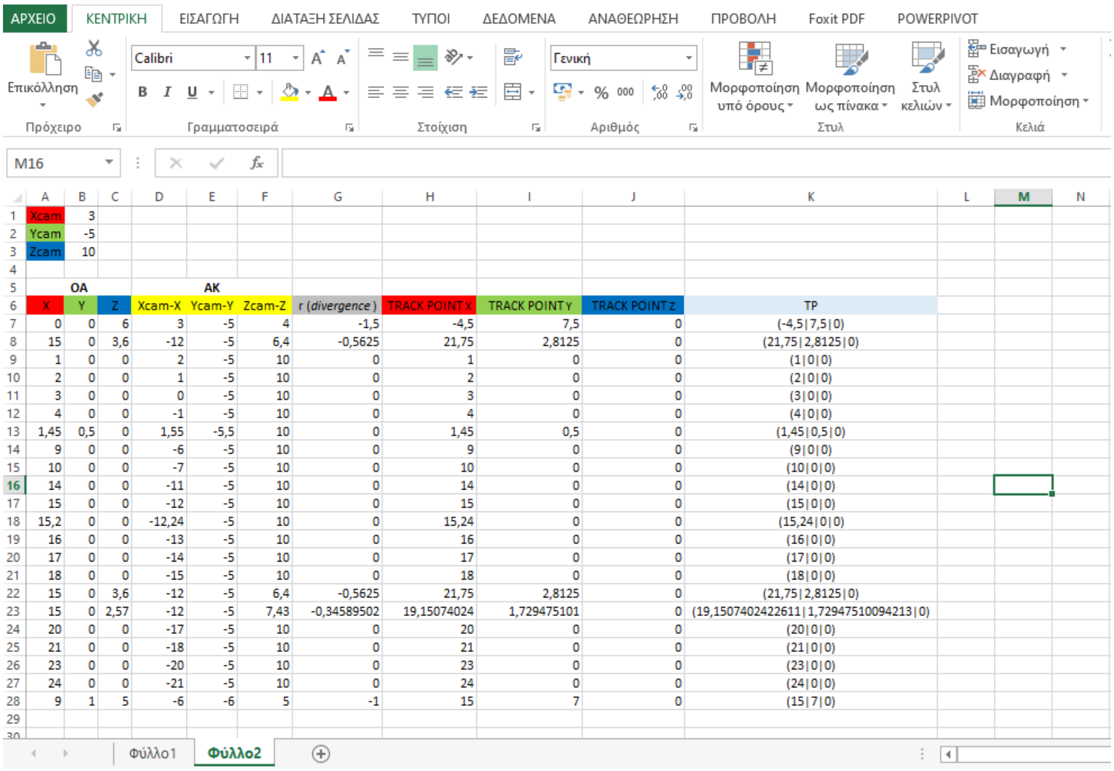
This gives

$$r = -\frac{z}{z_{cam} - z}$$

Now it's time to select as many points of the 3D-object as you need for an accurate projection and try to automate the process of gaining the coordinates of the track points with the help of Excel. The following examples might prove helpful:



	A	B	C	D	E	F	G	H	I	J	K
1	Xcam	3									
2	Ycam	-5									
3	Zcam	10									
4											
5		OA			AK						
6	X	Y	Z	Xcam-X	Ycam-Y	Zcam-Z	r (*divergence*)	TRACK POINT x	TRACK POINT Y	TRACK POINT z	TP
7	0	0	6	=$B$1-A7	=$B$2-B7	=$B$3-C7	=-(C7/F7)	=A7+((G7)*(D7))	=B7+((G7)*(E7))	=C7+((G7)*(F7))	=CONCATENATE("(";H7;"|";I7;"|";J7;")")
8	15	0	3,6	=$B$1-A8	=$B$2-B8	=$B$3-C8	=-(C8/F8)	=A8+((G8)*(D8))	=B8+((G8)*(E8))	=C8+((G8)*(F8))	=CONCATENATE("(";H8;"|";I8;"|";J8;")")
9	1	0	0	=$B$1-A9	=$B$2-B9	=$B$3-C9	=-(C9/F9)	=A9+((G9)*(D9))	=B9+((G9)*(E9))	=C9+((G9)*(F9))	=CONCATENATE("(";H9;"|";I9;"|";J9;")")
10	2	0	0	=$B$1-A10	=$B$2-B10	=$B$3-C10	=-(C10/F10)	=A10+((G10)*(D10))	=B10+((G10)*(E10))	=C10+((G10)*(F10))	=CONCATENATE("(";H10;"|";I10;"|";J10;")")
11	3	0	0	=$B$1-A11	=$B$2-B11	=$B$3-C11	=-(C11/F11)	=A11+((G11)*(D11))	=B11+((G11)*(E11))	=C11+((G11)*(F11))	=CONCATENATE("(";H11;"|";I11;"|";J11;")")
12	4	0	0	=$B$1-A12	=$B$2-B12	=$B$3-C12	=-(C12/F12)	=A12+((G12)*(D12))	=B12+((G12)*(E12))	=C12+((G12)*(F12))	=CONCATENATE("(";H12;"|";I12;"|";J12;")")
13	1,45	0,5	0	=$B$1-A13	=$B$2-B13	=$B$3-C13	=-(C13/F13)	=A13+((G13)*(D13))	=B13+((G13)*(E13))	=C13+((G13)*(F13))	=CONCATENATE("(";H13;"|";I13;"|";J13;")")
14	9	0	0	=$B$1-A14	=$B$2-B14	=$B$3-C14	=-(C14/F14)	=A14+((G14)*(D14))	=B14+((G14)*(E14))	=C14+((G14)*(F14))	=CONCATENATE("(";H14;"|";I14;"|";J14;")")
15	10	0	0	=$B$1-A15	=$B$2-B15	=$B$3-C15	=-(C15/F15)	=A15+((G15)*(D15))	=B15+((G15)*(E15))	=C15+((G15)*(F15))	=CONCATENATE("(";H15;"|";I15;"|";J15;")")
16	14	0	0	=$B$1-A16	=$B$2-B16	=$B$3-C16	=-(C16/F16)	=A16+((G16)*(D16))	=B16+((G16)*(E16))	=C16+((G16)*(F16))	=CONCATENATE("(";H16;"|";I16;"|";J16;")")
17	15	0	0	=$B$1-A17	=$B$2-B17	=$B$3-C17	=-(C17/F17)	=A17+((G17)*(D17))	=B17+((G17)*(E17))	=C17+((G17)*(F17))	=CONCATENATE("(";H17;"|";I17;"|";J17;")")
18	15,24	0	0	=$B$1-A18	=$B$2-B18	=$B$3-C18	=-(C18/F18)	=A18+((G18)*(D18))	=B18+((G18)*(E18))	=C18+((G18)*(F18))	=CONCATENATE("(";H18;"|";I18;"|";J18;")")
19	16	0	0	=$B$1-A19	=$B$2-B19	=$B$3-C19	=-(C19/F19)	=A19+((G19)*(D19))	=B19+((G19)*(E19))	=C19+((G19)*(F19))	=CONCATENATE("(";H19;"|";I19;"|";J19;")")
20	17	0	0	=$B$1-A20	=$B$2-B20	=$B$3-C20	=-(C20/F20)	=A20+((G20)*(D20))	=B20+((G20)*(E20))	=C20+((G20)*(F20))	=CONCATENATE("(";H20;"|";I20;"|";J20;")")
21	18	0	0	=$B$1-A21	=$B$2-B21	=$B$3-C21	=-(C21/F21)	=A21+((G21)*(D21))	=B21+((G21)*(E21))	=C21+((G21)*(F21))	=CONCATENATE("(";H21;"|";I21;"|";J21;")")
22	15	0	3,6	=$B$1-A22	=$B$2-B22	=$B$3-C22	=-(C22/F22)	=A22+((G22)*(D22))	=B22+((G22)*(E22))	=C22+((G22)*(F22))	=CONCATENATE("(";H22;"|";I22;"|";J22;")")
23	15	0	2,57	=$B$1-A23	=$B$2-B23	=$B$3-C23	=-(C23/F23)	=A23+((G23)*(D23))	=B23+((G23)*(E23))	=C23+((G23)*(F23))	=CONCATENATE("(";H23;"|";I23;"|";J23;")")
24	20	0	0	=$B$1-A24	=$B$2-B24	=$B$3-C24	=-(C24/F24)	=A24+((G24)*(D24))	=B24+((G24)*(E24))	=C24+((G24)*(F24))	=CONCATENATE("(";H24;"|";I24;"|";J24;")")
25	21	0	0	=$B$1-A25	=$B$2-B25	=$B$3-C25	=-(C25/F25)	=A25+((G25)*(D25))	=B25+((G25)*(E25))	=C25+((G25)*(F25))	=CONCATENATE("(";H25;"|";I25;"|";J25;")")
26	23	0	0	=$B$1-A26	=$B$2-B26	=$B$3-C26	=-(C26/F26)	=A26+((G26)*(D26))	=B26+((G26)*(E26))	=C26+((G26)*(F26))	=CONCATENATE("(";H26;"|";I26;"|";J26;")")
27	24	0	0	=$B$1-A27	=$B$2-B27	=$B$3-C27	=-(C27/F27)	=A27+((G27)*(D27))	=B27+((G27)*(E27))	=C27+((G27)*(F27))	=CONCATENATE("(";H27;"|";I27;"|";J27;")")
28	9	1	5	=$B$1-A28	=$B$2-B28	=$B$3-C28	=-(C28/F28)	=A28+((G28)*(D28))	=B28+((G28)*(E28))	=C28+((G28)*(F28))	=CONCATENATE("(";H28;"|";I28;"|";J28;")")



	A	B	C	D	E	F	G	H	I	J	K
1	Xcam	3									
2	Ycam	-5									
3	Zcam	10									
4											
5		OA			AK						
6	X	Y	Z	Xcam-X	Ycam-Y	Zcam-Z	r (*divergence*)	TRACK POINT X	TRACK POINT Y	TRACK POINT Z	TP
7	0	0	6	3	-5	4	-1,5	-4,5	7,5	0	(-4,5|7,5|0)
8	15	0	3,6	-12	-5	6,4	-0,5625	21,75	2,8125	0	(21,75|2,8125|0)
9	1	0	0	2	-5	10	0	1	0	0	(1|0|0)
10	2	0	0	1	-5	10	0	2	0	0	(2|0|0)
11	3	0	0	0	-5	10	0	3	0	0	(3|0|0)
12	4	0	0	-1	-5	10	0	4	0	0	(4|0|0)
13	1,45	0,5	0	1,55	-5,5	10	0	1,45	0,5	0	(1,45|0,5|0)
14	9	0	0	-6	-5	10	0	9	0	0	(9|0|0)
15	10	0	0	-7	-5	10	0	10	0	0	(10|0|0)
16	14	0	0	-11	-5	10	0	14	0	0	(14|0|0)
17	15	0	0	-12	-5	10	0	15	0	0	(15|0|0)
18	15,2	0	0	-12,24	-5	10	0	15,24	0	0	(15,24|0|0)
19	16	0	0	-13	-5	10	0	16	0	0	(16|0|0)
20	17	0	0	-14	-5	10	0	17	0	0	(17|0|0)
21	18	0	0	-15	-5	10	0	18	0	0	(18|0|0)
22	15	0	3,6	-12	-5	6,4	-0,5625	21,75	2,8125	0	(21,75|2,8125|0)
23	15	0	2,57	-12	-5	7,43	-0,34589502	19,15074024	1,729475101	0	(19,1507402422611|1,72947510094213|0)
24	20	0	0	-17	-5	10	0	20	0	0	(20|0|0)
25	21	0	0	-18	-5	10	0	21	0	0	(21|0|0)
26	23	0	0	-20	-5	10	0	23	0	0	(23|0|0)
27	24	0	0	-21	-5	10	0	24	0	0	(24|0|0)
28	9	1	5	-6	-6	5	-1	15	7	0	(15|7|0)

2^O GEL RODOU

Worksheet 5   CAM CARPETS

DURATION : 1 SESSION

A5.1 EVALUATION

GROUP #: ***…………………………………………………………..***
NAME/SURNAME: **…………………………………..……………..**
CLASS…../ **… DATE …..……………….……………………….**

1. **Your friend asks you what is CAM. What would you answer?**

   ……………………………………………………………………………………

   ……………………………………………………………………………………

   ……………………………………………………………………………………

   ……………………………………………………………………………………

   ……………………..…………………………………………………………….

   During the scenario :

2. **I liked**

   ……………………………………………………………………………………

   …………………………………………...…………………………………………

   ……………………………………………………………………………………

   ……………………………………………………………………………………

   ………………………………………………………….…………………………..

3. **I didn't like**

   ……………………………………………………………………………………

   ……………………………………………………………………………………

   ……………………………………………………………………………………

   ……………………………………………………………………………………

   ……………………………………………………………………………………

   ……………………………………………………………………………………

Exemplar Scenario 08: *Let´s talk to the machines*

Part A. General Data	
A.1 Title:	*Let´s talk to the machines*
A.2 Author(s):	*Manuel Toro Casaucao, IES El Sobradillo*
A.3 Abstract/ Summary:	*In this scenario, students will learn how to decompose simple algorithms sequentially and how to express and communicate them through flowcharts.*
A.4 Keywords:	*Flowcharts, sequential thinking, robotics, programming languages.*
A.5 Version:	*Draft*
A.6 Date:	*15/09/2021*
A.7 Copyright license:	*Attribution ShareAlike CC BY-SA*
Part B. Learning Data	
B.1 Grade(s):	*Grage 10 or Ages 15-16 years*
B.2 Subject(s):	*Technology*
B.3 Topic(s):	*Programmable control systems. Robotics.*

B.4 Computational Thinking Dimensions:

Algorithmic Thinking (AL)	✓
Abstraction (AB)	✓
Generalization (GE)	
Logical reasoning (LR)	✓
Pattern matching (PM)	
Problem decomposition (PD)	✓
Problem translation (PT)	✓
Evaluation (EV)	✓
Representation (RE)	✓
Data collection (DC)	
Data representation (DR)	
Data analysis (DA)	
Modeling (MO)	✓
Simulation – (SIM)	✓
Automation (AUT)	✓
Sequencing (SE)	✓
Testing (TE)	✓
Understanding People – (UP) /Artificial Intelligence (AI)	✓

B.5 Computational Thinking Approaches:

Tinkering experimenting & playing	✓
Creating, designing, and making	✓
Debugging, finding, and fixing errors	✓
Persevering, keeping going	✓
Collaborating, working together	✓

<table>
<tr><td>B.6 Thematic in the context of the CompuT Project:</td><td colspan="2">
<table>
<tr><td>Educational Robotics or Physical Computing</td><td colspan="2">✓</td></tr>
<tr><td rowspan="5">Computational Science project</td><td>Modeling/Simulation</td><td>✓</td></tr>
<tr><td>Bifocal modelling</td><td></td></tr>
<tr><td>Sensors use or making</td><td></td></tr>
<tr><td>Maths and CS</td><td>✓</td></tr>
<tr><td>Other: …</td><td></td></tr>
<tr><td>Data science project</td><td colspan="2"></td></tr>
<tr><td>History of science and technology</td><td colspan="2"></td></tr>
<tr><td>Digital game, software, or mobile app</td><td colspan="2"></td></tr>
<tr><td>Digital humanities projects</td><td>Digital Storytelling</td><td></td></tr>
<tr><td></td><td>Interactive Fiction</td><td></td></tr>
<tr><td></td><td>Text mining</td><td></td></tr>
<tr><td></td><td>Algorithms in everyday life</td><td></td></tr>
<tr><td></td><td>Other: …</td><td></td></tr>
<tr><td>Artificial Intelligence Projects</td><td colspan="2"></td></tr>
<tr><td>Studio approach – Future Classroom projects</td><td colspan="2"></td></tr>
<tr><td>Unplugged experiential or using manipulatives</td><td colspan="2">✓</td></tr>
<tr><td>Other: ….</td><td colspan="2"></td></tr>
</table>
</td></tr>
<tr><td>B.7 Purpose/Aim of the learning scenario:</td><td colspan="2">By completing this scenario, students will have developed a basic understanding of how programmable systems work, and will understand the need to decompose the solution of a problem into a sequence of simple steps. They will also learn an efficient way to communicate these solutions through flowcharts. Across the board, students will understand the importance of knowing the machine (hardware) to design the solution (software).</td></tr>
<tr><td rowspan="3">B.8 Learning outcomes/goals[25]:</td><td colspan="2">Note how the scenario might support the development of general competences and various of the so-called 21st century skills.</td></tr>
<tr><td>B.8.1 Knowledge</td><td>Understand the importance of decomposing the solution of a problem into sequential steps.
Understand the importance of knowing the capabilities of the machine (hardware) to design the solution to a problem.
Know the rules of the basic flowchart symbols.</td></tr>
<tr><td>B.8.2 Skills</td><td>Know how to decompose a simple algorithm into sequential steps.
Know how to represent algorithms using</td></tr>
</table>

25 For the effective formulation of learning-instructional goals the works of Mager, who claims for the definition of observable actions and Measurable Criteria of performance evaluation under specific conditions, could be useful. Mager, F. (1975). Preparing Instructional Objectives. (2nd ed.). Belmont, CA: Fearon. & Mager, F. (1997). Preparing instructional objectives: A critical tool in the development of effective instruction. Atlanta: The Center for Effective Performance. The verbs could follow the Bloom's knowledge taxonomy, see for example: https://tips.uark.edu/blooms-taxonomy-verb-chart/. It is important to use higher order thinking verbs. Anderson, L. W., & Krathwohl, D. R. (2001). A taxonomy for learning, teaching, and assessing, Abridged Edition. Boston, MA: Allyn and Bacon

		flowcharts.
	B.8.3 Attitudes-affective	• *Recognize the importance of machines in solving everyday problems.*
B.9 Horizontal competences - 21st century skills:	*This teaching scenario creates the right conditions in order to develop 21 st century skills such as critical thinking, problem solving, creativity, communication, collaboration, curiosity, initiative, perseverance, adaptability.*	
	B.9.1 Learning and innovation skills:	*Critical thinking: finding solutions to problems. Students have to look for solutions to each problem that appears during the learning situation.* *Creativity: thinking outside the box. Students must be original in finding solutions to problems.* *Collaboration: students will be able to share their proposals with the rest of the students in order to outline the solution.* *Communication: express solutions using flowchart language.*
	B.9.2 Digital literacy skills:	*Information literacy: students will search for information about the different programming languages.*
	B.9.3 Career and life skills:	*Flexibility and adaptability, social and cross-cultural interaction, productivity and accountability, leadership and responsibility:* *Students will adapt their model to their needs and resources, interacting with their classmates, being productive and responsible on the result.*
B.10 Modern teaching methods:	*The scenario includes modern teaching methods such as:* *Learning by coding, as students will have to sequence solutions to problems.* *Collaborative learning, as students will have to work as a team to complete the task.*	
B.11 Integration of CT into the curriculum:	*This learning situation is related to programming languages and sequential problem solving.*	
B.12 Relation to curriculum and/or standards:	*This learning situation is related to the topic of Programmable Control Systems, of the subject Technology of 4th ESO. It is also related to the curriculum of Information and Communication Technologies I and II of 1st and 2nd baccalaureate.*	
B.13. Prerequisite knowledge:	*No prerequisite knowledge required.*	
B.14. Difficulty Level of the Scenario:	*Intermediate*	
B.15. Social setting of the scenario:	*The students will have to work in small groups to complete some of the activities of this scenario.*	
B.16 Place of implementation:	*Classroom or Computer Lab*	

B.17 Teaching time – Duration:	*3 x 45' sessions*	
B.18 Educational material, resources, instruments, tools, and media:	**B.18.1 Software:**	
	B.18.2 Hardware:	
	B.18.3 Online resources:	*https://www.areatecnologia.com/diagramas-de-flujo.htm*
	B.18.4 Conventional educational material:	*Whiteboard and marker. Paper and pencil+-69+.*

Part C. Learning Experience Design

C.1. Activities-Action-Plot-Storyboard sequence table:

Phase 1.	***Understand problem sequencing.***	
Activity/Task	**Description/Procedure**	**Duration**
A1.1 Let's get to know the hardware	*Students are presented with the idea that the teacher is a state-of-the-art "robot" with the following capabilities:* *- Take a number of steps.* *- Turn a number of degrees to the left or right.* *- Detect if it sees the classroom door.* *- Detect if it can touch the classroom door.* *- Open the door.*	*10'*
A1.2 We have a problem	*Students will be divided into groups, and asked to explain to the teacher how they can get out of the class.* *NOTE: Normally students will pose non-sequential solutions in human language, practically in one sentence. "E.g.: Find the door and go outside."* *Then the teacher will point out the need to explain it only by using the actions understood by the machine.*	*15'*
A1.3 Let's program the teacher.	*The different groups will design their solution and test it with the teacher, performing the actions indicated by each group, inviting reflection if the algorithm fails.*	*20'*
Phase 2.	***Understanding loops.***	
Activity/Task	**Description/Procedure**	**Duration**
A2.1 We do not know how he is doing.	*Now the groups are asked to test their algorithms, but the teacher will change their position and/or orientations,*	*10'*

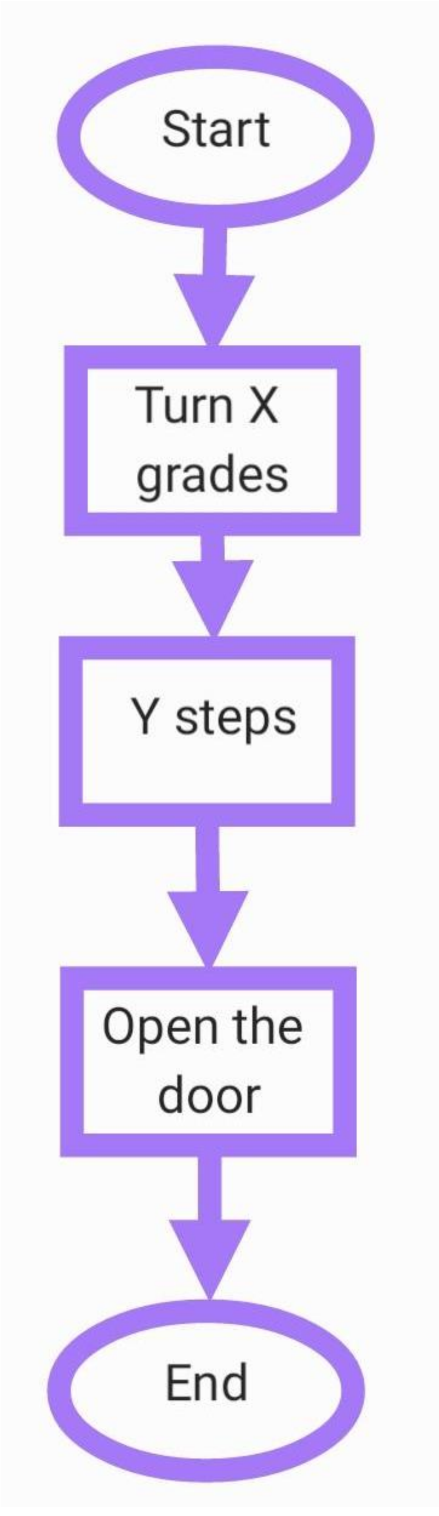
		letting them find out that these no longer work.	
	A2.2 Flow charts.	*The teacher will explain the rules of flowcharts (optionally they may be asked to consult https://www.areatecnologia.com/diagramas-de-flujo.htm) Worksheets 1 and 2 could be exploited at this point.*	*20'*
	A2.3 We program our solution	*The teacher will give an example of a flowchart with an error for the students to find a solution.*	*15'*
	Phase 3.	**We program**	
	A3.1 We raise the level.	*The teacher will place tables in the center of the classroom to serve as obstacles. Now you will have to get out avoiding obstacles. In this way, students will understand than with the previous "hardware" we don't have the possibility to avoid them. So we will have a teacher 2.0 who has a new ability:* *- Detect obstacles.* *Note: The starting position is unknown.*	*10'*
	A3.2 We program	*Each group will look for a solution*	*20'*
	A3.3 Summary and discussion	*The different solutions are tested, compared and their structure analyzed.*	*15'*
C.2 Assessment			
	C.2.1 Students feedback and reflection	*Students will test and correct their algorithms.*	
C.3 Homework/ Work with parents-family	*No homework needed.*		

Part D. Information for the Teachers

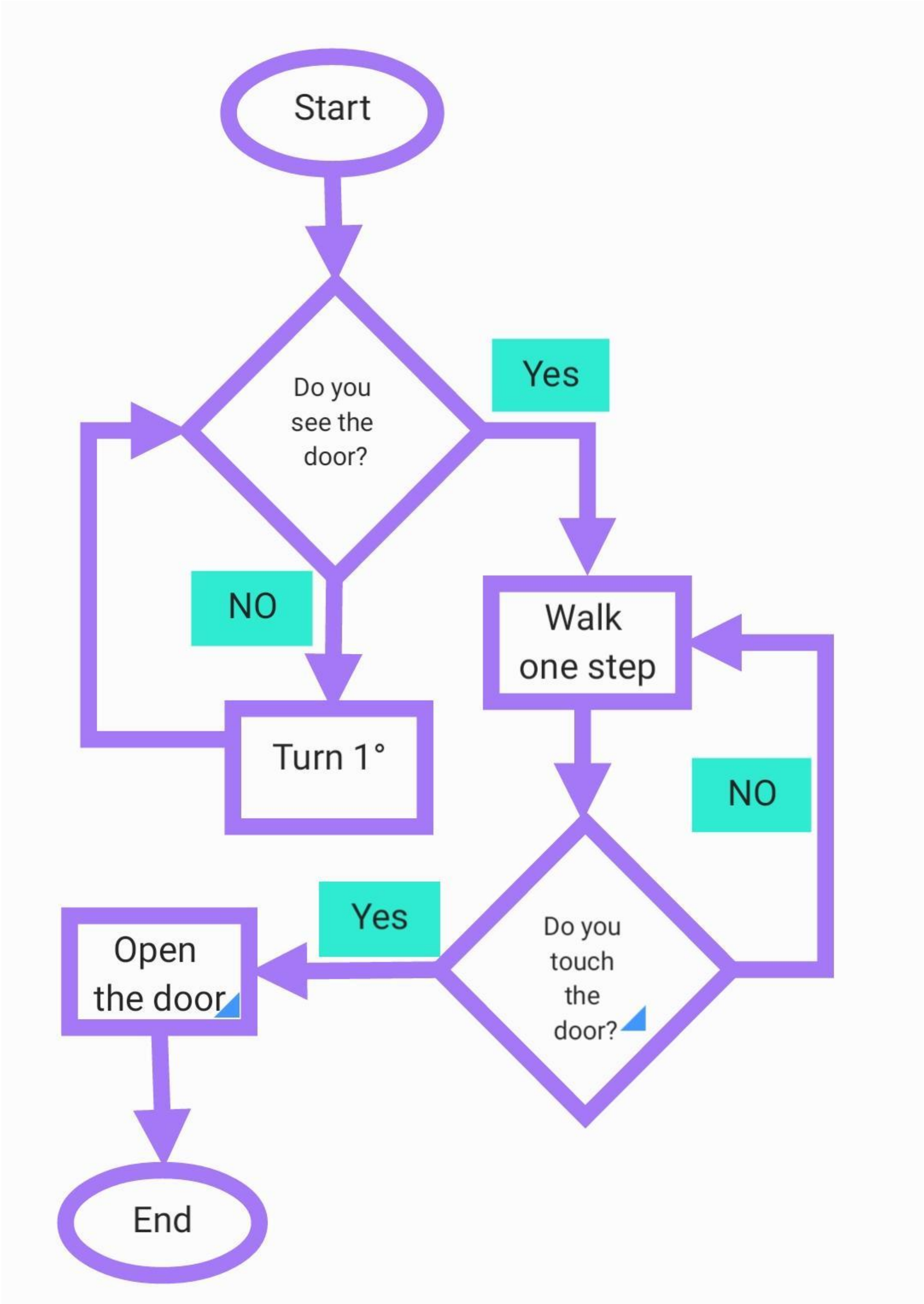
D.1 Adaptation - Differentiation for inclusion of all students	*All students could implement the scenario.*
D.2 Extension	*https://code.org/*
D.3 Resources	*https://www.areatecnologia.com/diagramas-de-flujo.htm* *https://www.youtube.com/watch?v=awhRzotTT0E&list=LLkNaV2CUupBwIE*

	o-n6aT93A
D.4 Experience deriving from the implementation of the scenario	*The students have a first approach to programming languages and begin to understand the different control structures. The teacher can change, if deemed appropriate, the machine for a student from phase 2 onwards.*
D.5 Relations to other scenarios	
D.6 Reviews by teachers	
D.7 Assessment of the scenario	*[1=Very Bad – 5=Very Good]*
D.8 References	
Part E. Annexes	
	Worksheet 1 - Example of solutions to the problems posed PHASE I *Worksheet 2 - Example of solutions to the problems posed PHASE II .*

Worksheet 1 - Example of solutions to the problems posed
PHASE I.



Worksheet 2 - Example of solutions to the problems posed PHASE II.



Exemplar Scenario 09: *"Useless" robots*

Part A. General Data	
A.1 Title:	*"Useless" robots*
A.2 Author(s):	*Feness, Kristine* *Langeland, Monica* *Lauw, Sabine* *Opdahl, Borghild Marie* Sætveit, Trude All the above are science teachers from Fyllingsdalen videregående skole
A.3 Abstract/ Summary:	In short terms this project is about building a "useless robot" to inspire teachers and students to further their knowledge of electronic design and programming. A useless robot solves a problem you didn't know that you had. For example, "do you need someone that can wave to you?" Make a waving robot. One possible solution to this can be done with the ARM- based microcomputer called Microbit. The Microbit is easily programmable with their own block-based programming language (Makecode) so little to none programming experience is required. In addition to programming the microbit, the students must design a robot using cardboard and whatever decorations they want. In this way, the task is twofold and appeals to several students. The students work together in groups to solve the task, both in relation to design and programming.
A.4 Keywords:	*Microbit, Makecode, programming, robotics, design, innovation, electronics, servo*
A.5 Version:	*Final*
A.6 Date:	*18/8/2022*
A.7 Copyright license:	CC BY-SA 3.0 *(https://creativecommons.org/licenses/?lang=en)*
Part B. Learning Data	
B.1 Grade(s):	*Grade 11, Ages: 15 - 16, but can be younger*
B.2 Subject(s):	*Mathematics, Computer Science, Arts*
B.3 Topic(s):	*Use of technology, including block-programming*

B.4 Computational Thinking Dimensions:	*Check or note the dimensions which the scenario involves:*

Algorithmic Thinking (AL)	X
Abstraction (AB)	X
Generalization (GE)	
Logical reasoning (LR)	X
Pattern matching (PM)	
Problem decomposition (PD)	X
Problem translation (PT)	X
Evaluation (EV)	X
Representation (RE)	X
Data collection (DC)	
Data representation (DR)	
Data analysis (DA)	
Modelling (MO)	
Simulation – (SIM)	X
Automation (AUT)	X
Sequencing (SE)	X
Testing (TE)	X
Understanding People – (UP) /Artificial Intelligence (AI)	

B.5 Computational Thinking Approaches:	*Check or note the CT approaches which the scenario employs*

Tinkering experimenting & playing	X
Creating, designing, and making	X
Debugging, finding, and fixing errors	X
Persevering, keeping going	X
Collaborating, working together	X

B.6 Thematic in the context of the CompuT Project:

Educational Robotics or Physical Computing	X	
Computational Science project	Modelling/Simulation	X
	Bifocal modelling	X
	Sensors use or making	X
	Maths and CS	X
	Other: …	
Data science project		
History of science and technology		
Digital game, software, or mobile app		
Digital humanities projects	Digital Storytelling	
	Interactive Fiction	
	Text mining	
	Algorithms in everyday life	
	Other: …	
Artificial Intelligence Projects		
Studio approach – Future Classroom projects		
Unplugged experiential or using manipulatives		
Other:….		

B.7 Purpose/Aim of the learning scenario:	*The aim of the exercise is to give students an introduction to algorithmic thinking. This is done with a low barrier to enter block programming language with Microbit. This will increase their knowledge within computer science and algorithmic thinking, so it won't be as hard to learn a real programming language like python in the future. Another important goal is collaboration between students and inspire creative design and innovation.*
B.8 Learning outcomes/goals[26]:	*Specify observable actions and evaluable performance criteria in terms of students' knowledge, skills, and attitudes-affective domains.*

B.8.1 Knowledge	*Basic knowledge of block programming*
B.8.2 Skills	*Planning, making code*
B.8.3 Attitudes-affective	*Open minded* *Work collaboratively*

[26] For the effective formulation of learning-instructional goals the works of Mager, who claims for the definition of observable actions and Measurable Criteria of performance evaluation under specific conditions, could be useful. Mager, F. (1975). Preparing Instructional Objectives. (2nd ed.). Belmont, CA: Fearon. & Mager, F. (1997). Preparing instructional objectives: A critical tool in the development of effective instruction. Atlanta: The Center for Effective Performance. The verbs could follow the Bloom's knowledge taxonomy, see for example: https://tips.uark.edu/blooms-taxonomy-verb-chart/. It is important to use higher order thinking verbs. Anderson, L. W., & Krathwohl, D. R. (2001). A taxonomy for learning, teaching, and assessing, Abridged Edition. Boston, MA: Allyn and Bacon

B.9 Horizontal competences - 21st century skills:	*Note how the scenario might support the development of general competences and various of the so-called 21st century skills.*	
	B.9.1 Learning and innovation skills:	The core skills in the useless robots exercise is collaboration, communication, and creativity.
	B.9.2 Digital literacy skills:	Information and Communication technologies (ICT) literacy
	B.9.3 Career and life skills:	Flexibility and adaptability, Initiative and self-direction
B.10 Modern teaching methods:	Learning by coding STEM learning Collaborative learning because the students work together in groups and have to agree on the design, what the robot should do, and how to program it.	
B.11 Integration of CT into the curriculum:	The Norwegian curriculum has a section that deals with both basic skills and values that should form the basis for all teaching across subjects. The learning scenario useless robots fit in on several of these points. For example one of the core elements in the Norwegian curriculum is: «*School shall allow the pupils to experience the joy of creating, engagement and the urge to explore, and allow them to experience seeing opportunities and transforming ideas into practical actions.”* Digital skills are one of the 5 basic skills in the curriculum. These must be worked on in all subjects, and with a clear progression. Some subjects have a greater responsibility than others, and when it comes to algorithmic thinking this is emphasized in mathematics and science. From 1st year of upper secondary school the curriculum says: «*formulate and solve problems using algorithmic thinking, various problem-solving strategies, digital tools and programming”* and *” identify variable quantities in different situations, set up formulas and explore these using digital tools”*	
B.12 Relation to curriculum and/or standards:	Norwegian National Curriculum, Grade 11, 1T (theoretical mathematics): *formulate and solve problems using algorithmic thinking, various problem-solving strategies, digital tools and programming* Norwegian National Curriculum, Grade 11, Science: Evaluate and create programs that model science phenomena *The curriculum explains this as: The students will understand, create and use technology, including programming and modelling, in work with science subjects.*	

B.13. Prerequisite knowledge:	It can be an advantage to know a little bit of block programming in advance, but the introductory course the students receive just before the task should also provide enough basic skills to complete the task	
B.14. Difficulty Level of the Scenario:	*Easy*	
B.15. Social setting of the scenario:	*Small group of 3-4 students*	
B.16 Place of implementation:	*Classroom*	
B.17 Teaching time – Duration:	*240 minutes*	
B.18 Educational material, resources, instruments, tools, and media:	**B.18.1 Software:**	*MakeCode editor*
	B.18.2 Hardware:	*Microbit, servo motor, voltage source, connection cables*
	B.18.3 Online resources:	*Microbit.org*
	B.18.4 Conventional educational material:	*Tutorials* on paper, design elements such as cardboard, wheels, scissors, glue

Part C. Learning Experience Design

C.1. Activities-Action-Plot-Storyboard sequence table:

Phase 1.	**Introduction to Microbit and Makecode.org**	
Activity/Task	**Description/Procedure**	**Duration**
A1.1 **Introduction activities**	*The teacher introduces the task orally and shows the power point.* *The teacher explains very fundamentally the various possibilities of a microbit.*	*20 min*
A1.2 ***Practice together with the teacher***	The teachers and students go to **makecode.microbit.org**, and they perform a first task together. The students learn to make their first program and export the program to their microbit.	*20 min*
A1.3 ***Exploration activities***	*Each group of students continues with the tasks in the booklet. The aim is to gather sufficient knowledge about programming the microbit with servos.*	*50 min*

Phase 2.	Design and build robot	
Activity/Task	**Description/Procedure**	**Duration**
A2.1 ***Analysis and design of the robot***	*Each group decide what task their robot should perform.*	*100 min*
A2.2 ***Program the microbit***	*The group makes a programming code, such that the microbit and servo preform the desired task.*	
A2.3 ***Building the robot***	*The groups build the robot using cardboard and attach the microbit and servo.*	
A2.4 ***Testing the robot***	*The group test their robot to make sure it works as intended.*	
Comments to phase 2: The order of activities in this phase differs from group to group. The group have an initial idea from A2.1 but change their plan during construction. After testing in phase A2.4 the group may need to do changes in their program and therefore go back to A2.2. A group that manages their time well, may decide to spend more time to decorate their robot, phase A2.3, after testing their robot.		
Phase 3	**Presentation and evaluation (assessment activities)**	
Activity/Task	**Description/Procedure**	**Duration**
A3.1 ***Presentation***	*Each group present their robot for the rest of the class.*	*20 min*
A3.2 ***Competition***	*The students decide which robot has the best design and which robot is the most useless.* *Each student gets three tokens that he/she can gives as points to his/her desired winner.*	*10 min*
A3.3 ***Evaluation***	*Each groups evaluate their performance, see C2 Assessment.*	*20 min*

C.2 Assessment

Each group will present their product to the rest of the class. They must then answer the following.

1) Explain what the useless robot should do?
2) Show what it does
3) What problems did you encounter along the way?
4) How did you solve the problem?
5) Describe how you managed to work together in the group
6) If you were to solve the problem again, what would you do differently?

	We do not evaluate the assignment with grades, but give oral feedback to each group in relation to the questions above. The reason for not using grades is that we want the assignment to serve as an inspiration to continue working with algorithmic thinking.	
	C.2.1 Students feedback and reflection	*Each group has a conversation with the teacher about how they solved the problem, what problems they encountered along the way, and how they attacked the problems.*
C.3 Homework/ Work with parents-family	*Self-evaluation of questions 1-6 (C.2 Assessment)*	
Part D. Information for the Teachers		
D.1 Adaptation - Differentiation for inclusion of all students	In order for as many students as possible to participate and feel mastered, it is important that all students work their way through some simple introductory tasks in microbit. It is important that each individual student undergoes the basic training on their own PC.	
D.2 Extension	We use this task as a starting point for further programming in python and use of Microbit in science education.	
D.3 Resources	*Microbit.org, training booklet, PowerPoint used by teacher*	
D.4 Experience deriving from the implementation of the scenario	The experience from our implementation is that the task created commitment. It is a plus that there is both an artistic part that does not use CT, and the part where one uses microbit. This meant that more students took an active part in the task. We observed that some students opted out of the microbit part of the assignment.	
D.5 Relations to other scenarios		
D.6 Reviews by teachers		
D.7 Assessment of the scenario	*[1=Very Bad – 5=Very Good]*	
D.8 References	*The idea of useless robots was originally developed by the Norwegian national centre for IT in education, a former organization by the Norwegian Ministry of Education and Research.*	
Part E. Annexes		
	Booklet for students. -[https://tinyurl.com/ycx67863] Power point presentation for teachers. -[https://tinyurl.com/44pcysub]	

Appendix V. Reflection on learning scripts implementation

The appendix contains indicative theoretical evaluations and reflections on the empirical implementation of some of the exemplar scenarios developed in the project.

Theoretical Evaluation of the Exemplar Scenario "Finding needles in the World's Biggest Haystack"

Anastasios Savas, Directory of Education of Dodecanese, Greece

The "Finding Needles in the World's Biggest Haystack" scenario mainly concerns the Web search methodology and algorithms, while also handling subjects such as web pages, html, metadata, and indexing. The scenario is proposed for ages 12-15 years old and cultivates several computational thinking dimensions throughout the implementation process. Given the wide spread of new technologies and the ever-increasing use of the World Wide Web and search engines, the subject of the scenario is considered quite interesting for the students and important for several educational purposes. The scenario introduces students to searching methods in an unplugged way, using the example of a book and several pages and words on it. Students get familiar with the indexing method, in an interesting and innovative way, as they are taught that computers and search engines do not perform some kind of "magic" to come up with the results, but they base their function in unplugged methods previously used by people, even before the advent of computers. Students are then introduced to several critical concepts such as search engines and advanced searching methods, indexing, HTML, page ranking, adaptation through Machine Learning etc.

The subjects that the scenario is proposed for are search engines and algorithms, but it could also be used as a starting point to teach several critical concepts such as the ones mentioned above. Students of several ages could be engaged to it, according to their capabilities and previous knowledge. The duration could also be modified, depending on the number and difficulty of the activities implemented. Various computational thinking dimensions are involved in the scenario, all applied in an interesting context. Overall, searching the web is an every-day, common activity for people of all ages and understanding of it can benefit future citizens and workers. Regarding the teaching methods and social setting of the scenario, students are proposed to work in groups, testing and evaluating the methods proposed by the teacher, using different words and book pages, role playing and exchanging information between groups, thus exploiting all the advantages of modern, current educational approaches to cultivate computational thinking in class. Several 21st century skills can also be developed through this way of working and learning. The scenario introduces basic methods and concepts of Computer Science to teach search methods, that is to solve a real-life problem. This is a basic method used to integrate computational thinking in class, so this scenario can be described as a typical example of computational thinking scenario.

Despite the very interesting content, the variety of concepts involved in the scenario includes the risk of difficulty in understanding. Teachers should adjust the scenario to the classes' needs, based on the age and level of students. On a next version, the scenario could be enriched with more Worksheets, complementary to the descriptions already provided, to better guide students and teachers throughout the process. Overall, it is a very interesting and engaging scenario, confronting a current issue with an engaging and meaningful way. It is suitable for students at Junior high school and will definitely be implemented in our school next year.

Theoretical Evaluation of the Exemplar Scenario "Studying the Skyros Archipelago Lizard"

Anastasios Savas, Directory of Education of Dodecanese, Greece

The pedagogical scenario titled "Studying the Skyros Archipelago Lizard" concerns the data analysis dimension of the computational thinking mindset. More specifically it uses the data storing and analysis capabilities of digital computers to solve real world problems. In the case of this scenario the problem is the answer to scientific question: How the presence of predators (e.g. snakes, eagles) shapes the features of specific local populations of preys (lizards). The scenario is obviously adopting the interdisciplinary approach to integrated Computational Thinking in Biology and Statistics. Using the excellent software environment CODAP and real world authentic scientific data from the Skyros islands the students are able for question posing, and compute simple descriptive statistical measures (mean value, standard deviation) to compare sub-groups of the population and support their answers. Students are so introduced to data analysis and refresh their statistical and scientific methodology capabilities. No need to say that students will also advance their biology knowledge.

What I find really interesting is the natural way that students are separated in groups to solve subproblems using similar resonance. This makes easy the implementation of the scenario in various sizes of classes. The intuitive application of the statistical concepts of mean value and standard deviation will help to reinforce their understanding by the students. It may also be difficult to implement for the students that may have no good understanding of the descriptive statistics measurements. In this case a corresponding preparation of the students, by introduction or refreshment of the statics concepts may be needed.

For me the specific scenario is really an exemplar for the computational thinking concept as the application of Computer Science concepts and methods for the solving of problems to other Scientific disciplines and the building of knowledge. More practically I find this scenario very interesting to implement in vocational education where I teach (ages 16-18) because I believe it helps students to consolidate knowledge of data analytics, statistics and science methodology (question, hypotheses, data collection and analysis, answer to question). This knowledge will advance the ability of my students to apply digital data analysis to solve real world problems and opens the word of data analytics to the view of feature professionals.

Theoretical Evaluation of the Exemplar Scenario "Cryptography"

Vasileios Kasapidis, Directory of Education of Dodecanese, Greece

The purpose of the scenario is to help students become familiar with the concept of cryptography and various methods of encrypting and decrypting messages. Students will then be able to protect their data by using various cryptographic methods to send and receive messages in the ever-evolving age of technology. The scenario consists of a series of worksheets that break down the various aspects of the scenario's walkthrough methodology. The first 4 worksheets are of a scalable difficulty. The first 2 worksheets are basic and well written and introduce the term cryptography with the use of morse code and braille language both of which are easy to take in. Continuing with the worksheets, two real cryptography techniques are explained, the Caesar cipher and the Enigma machine, which both are interesting to the students since both have historical value. The last four worksheets dig in further to the term of cryptography with modern methods of ciphering and applications of cryptography, including asymmetric encryption, RSA (Public Key Encryption) and digital signatures. Those last worksheets include the use of certain computer software applications to demonstrate the above mentioned techniques.

The overall educational scenario is very well designed and includes interesting learning steps to keep the student focused. Despite being a lengthy scenario that a teacher will require extra time to complete the learning process, it is driven by the self explanatory worksheets that students can easily do by them selves and have the teacher acting as a coach. The last worksheets are focused on a more advanced and with a theoretical aspect on how those methods are implemented and can be omitted by the teacher in case the available time is not adequate. According to the teaching needs the scenario can be altered in such a way that worksheets require less time to complete, since each worksheet consists of activities that students have to complete in both ways, ciphering and deciphering certain messages.

As a last note to the authors, it's worth mentioning that the last worksheet includes an extend of mathematical background that students of certain age may find difficult to work with therefore it can also be altered by the teacher in order to be suitable to the class.

Reflection on the implementation of the Exemplar Scenario "Useless Robots"

Monica Langeland, Fyllingsdalen vgs., Norway

Fyllingsdalen vgs have used the scenario "Useless Robots" as an activity the first week of school for new students. The students complete the whole scenario in one day.
Programming have been gradually implemented in the Norwegian curriculum during the last two years. Therefore the topic is quite new for most students. The students come from different lower secondary schools, and how programming is implemented varies from school to school. It's useful that our new students get a quick introduction to the programming hardware that is available at our school (Microbit).
The first week of school is important for building a good learning environment in the classes. "Useless robots" is an activity that focuses on teamwork, creativity, endurance, problem-solving and troubleshooting. These are learning methods that we want the students to use during their next three years at our school.
The students are randomly put together in groups of three students. Most groups function sufficient. In some cases one student have prior knowledge to Microbit and complete the task without involving the other students. The teacher have to make sure that all students participate in their group. In other cases the students divided the work among them, but then they see that they need to collaborate closely in order to make a functioning robot. This enchants the student's ability to communicate.
The level of creativity varies between the groups. Therefore it's important that the teacher asks questions in the brainstorming part of the project, for example "What is the most boring activity you perform during the day?" Then the students go on to solve their own problem, which make them invest more energy in the project.
The subject in upper secondary school in Norway are the same as students know from their precious years at school, which they have completed with a different level of success. Since programming is quite new to all, they meet the topic with a more open mind. They are not so afraid to make mistakes. We think that this gives them endurance during the day. In addition they have a clear goal – they have to complete their useless robot.

The students occasionally find that the useless robot that worked at one point does not work when show it to the class. We think it might be a good idea for the students to take pictures and film their own process. Then they have documented that the robot works, and they don't end the project with a negative feeling of showing something that doesn't works.
By using the scenario we hope that the students get to know each other and learn programming in a fun way. The atmosphere in the classroom is relaxed and playful. The biggest success in the scenario is the learning by design and making approach. The students make a tangible product. If there is a problem with their design or programming, they have to solve it. The result is evidence of their progress in programming. Many students are surprised by their own ability to program and their final result.

Reflection on the implementation of the Exemplar Scenario “Cats and Dogs”

Stavroula Prantsoudi, University of the Aegean/LTEE, Greece

The purpose of the scenario is to introduce students to the concepts of Artificial Intelligence (AI) and Machine Learning (ML) and raise their awareness on issues related to AI ethics and algorithmic bias. The scenario was implemented in a class of 12 students, aged 15, in an urban high school in central Greece. It was implemented while on the Computer Science class (1 hour per week) and lasted 3 hourly sessions (3 weeks). The students enthusiastically welcomed the subject of AI and were thrilled to express their opinions and questions during the scenarios’ implementation.
Concerning the Introduction to AI (Worksheet 1) students gave varying answers to the relevant questions. They did not manage to sufficiently define AI but gave rather controversial and incomplete answers. They also only partially recognized the applications of AI: most of them (11/12) answered that chat bots, robots, and virtual assistants (Siri, Alexa) make use of AI, but fewer selected search engines (7/12), translation systems (6/12), autonomous vehicles (4/12), social media (2/12) and online advertisements (1/12). As risks caused by using AI, most of the students referred to job loss due to automation, socio-economic inequality, and the danger of weapons automation.
The students followed the instructions on Worksheet 2 and built, trained, and tested their ML models. They also cooperated with their classmates and tested each other’s models. The students went back to feed their models with more data and train them again before they answered the assessment worksheet, where their answers were mostly correct. The steps were well described, and students did not meet any difficulties on following them. Regarding the AI ethics/safety (Worksheet 3), after the implementation of the activity students seemed to gain better understanding of the way ML is used and computers are trained. They mostly answered that it is very difficult to create an AI system that would work properly in every case, acknowledging the several restrictions and difficulties of AI. They also understood the importance of the human factor on the proper training of systems, proposing the employment of “people from different nationalities” and feeding the systems with variety of data, to avoid bias and discrimination issues. However, they seemed to precede the loss of jobs as the most important danger of AI, a belief which could be further researched.
Overall, the implementation of the scenario seems to have improved students’ knowledge on issues related to AI and ML, helping them understand the ways in which a computer can be trained to become an “intelligent” machine which can help humans make decisions. It also helped on raising students’ awareness on algorithmic bias and discrimination issues, feeding fruitful discussions in class, which provoked students’ interest and attention. Students had the

chance to wonder and express themselves on current important issues and discuss on matters hardly discussed before. The scenario was very well received and will definitely be implemented again in future classes.

Comparative reflection of "Cats and Dogs" scenario in Norway, Spain, and Greece

The exemplar scenarios "Cats and Dogs", concerning Artificial Intelligence (AI) and Machine Learning (ML), was implemented in three countries of the program, Greece, Spain, and Norway. Teachers from the three partner countries implemented the scenario in different class settings and reflected on the outcome, providing data to feed a cross-cultural investigation of the computational thinking cultivation by students in different countries, using the same educational scenario. The worksheets were collected and compared to provide an overall reflection of the scenario in different cultural settings.

The number of students in the classes varied and the final data collected concerned 21 Norwegian students, 16 Greek students and 9 Spanish students, all aged 15-16 years. Factors such as previous knowledge of Computer Science concepts or the position of computational thinking in the national curricula were not examined since the scenario concerns an introduction to AI with certain prerequisites and goals. The implementation of the scenario met the general purposes of the CompuT project and was not mandatory for teachers and students.

Following the steps described in the scenario, students of all countries answered a group of general questions concerning their previous knowledge on AI and ML. An educational intervention was then implemented, where they were asked to create, test, modify and evaluate a ML model which could discern between a cat or a dog, given a certain picture. The students collected data to create appropriate data sets, classified their data and used test data to test their model. They were also guided to return and train their model again to improve its performance. After completing the intervention, they were asked a group of questions to test their acquisition of AI and ML knowledge resulting from the intervention.

The data collected provided some interesting conclusion on the effect of the scenario. Before the intervention students answered that computers show intelligence, giving unclear and general answers, without being able to sufficiently argument on them. They answered that people can teach computers by programming them ("giving them instructions", "creating codes and patterns", "coding"), or even not at all, while after the intervention they managed to understand that computers "use information or sets of data categorized", or "machine learning algorithms use historical data as input to predict new output values". Concerning the ML applications, students before the interventions mainly referred to automation of labor, giving general answers such as "robots", "phones" and "machines", when asked to provide some examples of ML applications. However, they seem to have gained a better understanding of ML, since they gave varying and wider scope answers such as "social media apps", "medical cases", "self-driving cars" and the "for you page", after the intervention. After completing the scenario, they also managed to detect the non-ML applications, such as the calculator, traffic lights, or old Nokia phones. Before the intervention students also gave general answers when asked about the importance of ML, such as "it can make life easier", or "make certain jobs easier", "improve efficiency and improve safety", limiting heir answers to the loss of job positions and the danger of computers controlling humans when asked about possible moral issues raising from the use of AI. After the intervention they widen their answers and become more aware of algorithmic bias cases and several moral issues such as discrimination, lack of responsibility, access to personal data etc. Finally, they gain knowledge on why and how a system can be biased (“errors in a computer system that create unfair outcomes”, “privileging one category over another”), understanding the human responsibility in properly feeding the system with data.

Overall, the results coming from the data collected were interesting and encouraging. Students from all countries seemed to shift on a better and more precise understanding of the AI and ML technologies and the general purposes of the scenario were accomplished in most cases. The answers did not seem to differ among students with different nationality or class settings. All students gave similar answers, guided from the expected learning outcomes and accomplishing the scenarios’ purposes. According to the teacher’s feedback, most students found the scenario interesting and intriguing, and they enjoyed employing such a current and engaging subject. Students were more than willing to discuss and reflect on issues generating from the AI field, such as algorithmic bias and ethics, feeding fruitful discussions and many issues of concern on the digital age. They also improved their ability to think computationally, in the process of trying to solve problems of real life. The certain scenario is fully recommended for the introduction of AI and ML in secondary education.

UNIVERSITY OF THE AEGEAN

LTEE lab
University of the Aegean
ltee.aegean.gr

CompuT

Computational Thinking at School

Erasmus+ KA201 Project: 2019-1-EL01-KA201-062883