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HOLOMAKERS PROJECT

Motivating secondary school students towards STEM careers through hologram making and innovative virtual image processing practices with direct links to current research and laboratory practices

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O3- THE HOLOMAKERS CURRICULUM

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Declaration

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Abstract

The technology-driven economy and skilled workforce in STEM (Science, Technology, Engineering and Maths) fields are considered the driving forces for innovation and growth in the European economy. However, students' interest and enthusiasm in STEM education are not adequate and actions to motivate towards STEM related disciplines and careers are needed. The Holomakers project aims at inspiring secondary school students (14-17 years old) in making STEM fields a career choice by introducing them in the magic world of hologram making and virtual image processing and design. In addition, the project focuses on teachers' professional development and skill-building through a number of teacher training sessions that span the project implementation period. An innovative aspect of the project is the development of the portable holography kits that can be used for hologram making in the classroom by the students and for outreach purposes, during school events, science festivals and teacher training workshops. This report brings up pedagogical trends and methodologies that can be deployed in the class in order to implement the Holomakers learning intervention. It also summarises how the Holomakers learning intervention can be applied, why and how Arts and STEM should be brought together, the skills that the students can develop and the type of resources that can support teaching practices.

1. The Holomakers pedagogical framework

The theory of constructionism (Papert, 1993) claims that children learn best when they construct artifacts and knowledge by playing with and exploring concrete materials. The social context of these explorations is also crucial, and teachers can provide scaffolding by creating a learning environment that supports students' explorations and experimentation. The Holomakers projects are based on this pedagogical approach and aims at supporting students develop skills through hands-on, collaborative and project-based practices. Main tenets of constructionist education include (Bers et al., 2002):

- A constructionist approach to education: Setting up educational environments to help learners design and build meaningful projects to share with others and encourage learning by doing.
- The importance of objects: Objects and technological tools are important for facilitating the learning of abstract phenomena.
- Powerful ideas empower the learner: Powerful ideas offer new ways of learning and thinking that help learners make meaningful connections with other knowledge domains.
- The value of self-reflection: Meaningful learning experiences occur when learners monitor and evaluate their own thinking and learning process

The constructionist approach to learning is also reflected in the Holomakers pedagogical model which is heavily inspired by the creative thinking spiral introduced by Mitch Resnick (2007):

Figure 1Creative thinking spiral (Resnick, 2007)

In going through this process, "the students develop and refine their abilities as creative thinkers. They learn to develop their own ideas, try them out, test the boundaries, experiment with alternatives, get input from others – and, perhaps most significantly, generate new ideas based on their experiences" (Resnick, 2007). As Mitch Resnick explains "In reality, the steps in the process are not as distinct or sequential as indicated in the diagram. Imagining, creating, playing, sharing, and reflecting are mixed together in many different ways. But the key elements are always there, in one form or another" (Resnick, 2007).

The creative spiral is applied in the Holomakers learning intervention and is in the root of the Holomakers projects. The students are encouraged to go through a brainstorming process, to imagine the objects to be holographed, to reflect upon their characteristics, to use the available tools in order to create holograms, to playfully experiment with several angles, positions and heights, to share their results, to reflect upon them and improve them in case needed. The projects are interdisciplinary in nature and the students are invited to search for information online, to explore different disciplines and subject areas (i.e. Arts, Humanities, History and more) and creatively bring their findings together. In other words, the creative thinking spiral is placed in an interdisciplinary context were team-work is highly encouraged through the implementation of practical projects. In addition, our work is based on the premise that experience of carrying out extended practical projects can provide students with insights into scientific practice and can increase interest in science and motivation to continue their studies and to explore from a more authentic perspective science (Woolnough, 1994).

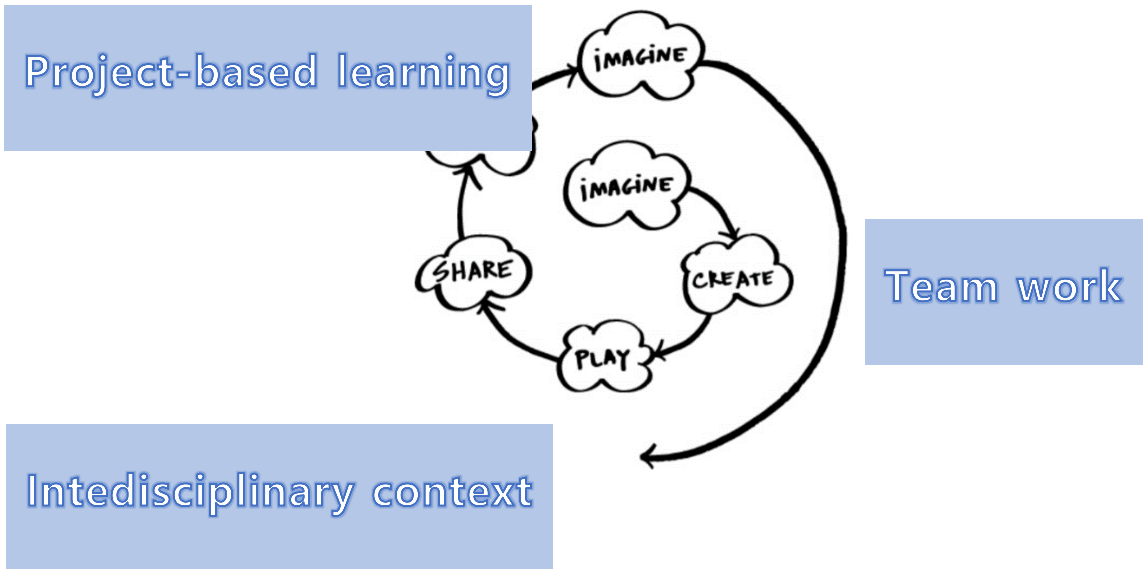

Figure 2 Creative thinking spiral (Resnick, 2007)

1.1 Collaborative learning

Collaborative learning describes situations in which subjects are becoming mutually aware of their shared goal and are working in groups interactively towards this goal, triggering learning mechanisms. Collaborative learning is connected to approaches that present learning as an active, constructive, and social process where an individual actively constructs knowledge facilitated by peer interaction.

Though collaborative learning takes on a range of forms and interpretations, in each form there is a shift away from the typical and traditional roles held by the teachers and the learners. In fact, collaborative learning constitutes a significant push against from the typical teacher-centred or lecture centred milicu' in classrooms (Smith and MacGregor, 1992, p.1). In the context of a collaborative learning approach, teachers can find themselves to act as scafolders, as designers of intellectual experiences for students, as "mid- wives of a more emergent process" (Smith and MacGregor, 1992, p.1), or as Dillenbourg (1999) states as the mediums to make the class work in a productive direction.

Noteworthy, the fact that the students have been structured in groups does not necessarily lead to the development of a collaborative spirit (Bennett,1996). Groups can easily turn out to form a situation in which the members are working individually and not necessarily collaboratively. For group work to be effective, the role of the teacher is to foster a climate of mutual trust, to encourage children, guide them and discretely facilitate the work of each group. Identifying groups (how to divide, how many members in each group) can be done either by the teacher in a playful way, or by chance, or by the personal choice of the students. Following the pedagogical ideas underpinning the Holomakers methodology, the teamwork is highly encouraged. The students early from the beginning are invited to form groups of 3-4. As the sessions are going by, the students can move to support other groups as well, to exchange tips and to allocate roles. In some groups the students may be equally involved in the project tasks but role rotation may also happen. For example, some students may be more involved into information searching and figures/model preparation/selection, others more into preparing the set-up for the hologram recordings, others more into the actual recording.

1.2 Project-based learning

Project-based learning (PBL) is a dynamic model that organizes learning around projects. This dynamic methodology engages learners in sustained, cooperative investigation and includes authentic content, authentic assessment, teacher facilitation, explicit educational goals, collaborative learning, and reflection (Thomas, 2000).

An innovative aspect of PBL is that it pushes against teacher-centred lessons and isolated classroom practices. PBL helps make learning meaningful and useful to students by establishing connections to life outside the classroom, addressing real world problems, and developing real world skills. PBL supports learners to develop a variety of skills including the ability to work well with others, make thoughtful decisions, take initiative, solve problems, develop self-directed learning skills and motivation for learning. Thus, established principles of learning, such as motivation, relevance, practice, active learning, and contextual learning operate significantly in a PBL environment, and to a much lesser extent in conventional curricula.

In addition, PBL is described as a process in which curriculum results can be easily identified, but in which the results of the students' learning process are not predetermined or completely predictable. PBL encourage students to handle many sources of information and disciplines that are necessary to solve problems or answer questions that are really relevant and each group or student may need to deal with different challenges. In the classroom, PBL provides significant opportunities for teachers to communicate and establish relationships with their students. Teachers are required to be ready to shift their role based on modern didactic practices and to become facilitators and scaffolders and co-learners.

In essence, the PBL model consists of these seven characteristics:

- Revolves around an open-ended question, challenge, or problem to research and respond to and/or solve.
- Is based on inquiry and experimentation
- Brings what students should academically know and understand
- Allows students to make their own choices while working on their projects
- Provides opportunities for feedback and revision of the plan and the project
- Fosters and uses 21st-century skills (such as critical thinking, communication, collaboration, and creativity and more)
- Requires students to share their problems, research process, methods, and results

1.3 Making and hands on practices in Education: taking the project-based learning a step forward

Making is fundamental to what it means to be human.

We must make, create, and express ourselves to feel whole.

There is something unique about making physical things.

Things we make are like little pieces of us and seem to embody portions of our soul.

The Maker Movement represents “a growing movement of hobbyists, tinkerers, engineers, hackers, and artists committed to creatively designing and building material objects for both playful and useful ends” (Martin, 2015, p.30). While the Maker Movement has developed in out-of-school spaces and has mostly involved adult participants, there is growing interest in the educational community to bring Maker Movement at school level and offer students opportunities to explore STEAM related concepts through hands-on and engineering practices (Martin 2015; O’Leary, 2012).

The **Makerspace or FabLab** is a place where project-based learning paths are developed, making and hands-on are practiced. Usually are described also as collaborative workspaces inside a school, library or public/private facility for making, learning, exploring and sharing. Students work over a protracted period of time towards developing a project on a given challenge that engages them in a creative process, in solving a real-world problem or reflecting on a complex question. They apply their knowledge and skills developing a solution, in the form of a product, a prototype. As a result, students develop deep content knowledge as well as problem solving and critical thinking, creativity, and communication skills in the context of doing an authentic, meaningful product. Project Based Learning unleashes initiative, collaboration and creativity. STEM (Science, technology, engineering and maths) oriented paths, typical of the **Maker Movement**, are recently opening up to arts – humanities, language arts, dance, drama, music, visual arts, design and new media, combining both scientific and creative process through inquiry and problem-based learning method.

Makertown12[1] builds on this growing interest in the Maker Movement; it is “an event supported by the European Commission happening every year that much resembles a makers’ fair: besides showcasing projects and new technologies, particular attention is given to discussing how to place

[1] https://makerstown.eu/ (accessed in September 2019)

the world of making in the EU agenda; the event has dedicated panels and discussions that bring together makers, entrepreneurs and policy makers" (Rosa et al, 2018, p.23).

An interesting good practice example comes also from Fondazione Mondo Digitale (partner in the project), which launched in 2014 the Phyrtual Innovation Gym based in Rome(Italy) http://www.innovationgym.org/, where innovative methods of 21st century education are being experimented. Including a fully equipped FabLab modelled on MIT's Centre for Bits and Atoms, it became a meeting space for new and old professions related to handcrafting and digital fabrication, where the Maker Culture includes engineering-oriented pursuits such as electronics, robotics, 3-D printing, and the use of Computer Numeric Control tools, as well as more traditional activities such as metalworking, woodworking, arts and crafts, attracting in the maker movement also digital artists and designers.

Another good practice example comes from Edumotiva (partner in the project) which in the context of the eCraft2Learn H2020 project established in 2017 makerspaces in Athens. a place established in the Technopolis City of Athens Technological and Cultural park (Greece) by Edumotiva[2] in the context of the eCraft2Learn H2020 project. The place offer students opportunities to engage in crafting, programming, robotics, electrical circuit making, 3D modeling and printing and exploring the DIY culture. Similar places in a smaller scale were established in schools in Athens (Greece) in disadvantaged areas.

The Holomakers project team envisions that holographic practices can be part of the making practices in Maker Spaces in formal and non formal educational places. The development of portable kits for hologram recordings and the simplification of the process (without limiting the scientific part) in order to meet school needs are promising factors. While going through this document, imagine how holography can be applied in your school, fablab or the makerspace of your neighborhood.

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[2] http://edumotiva.eu

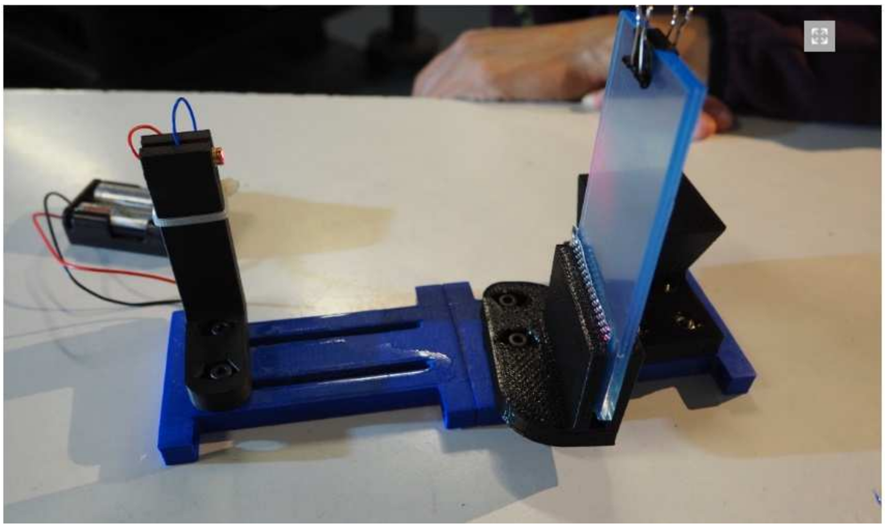


Figure 3 Portable Holokit developed in the context of the Holomakers Project

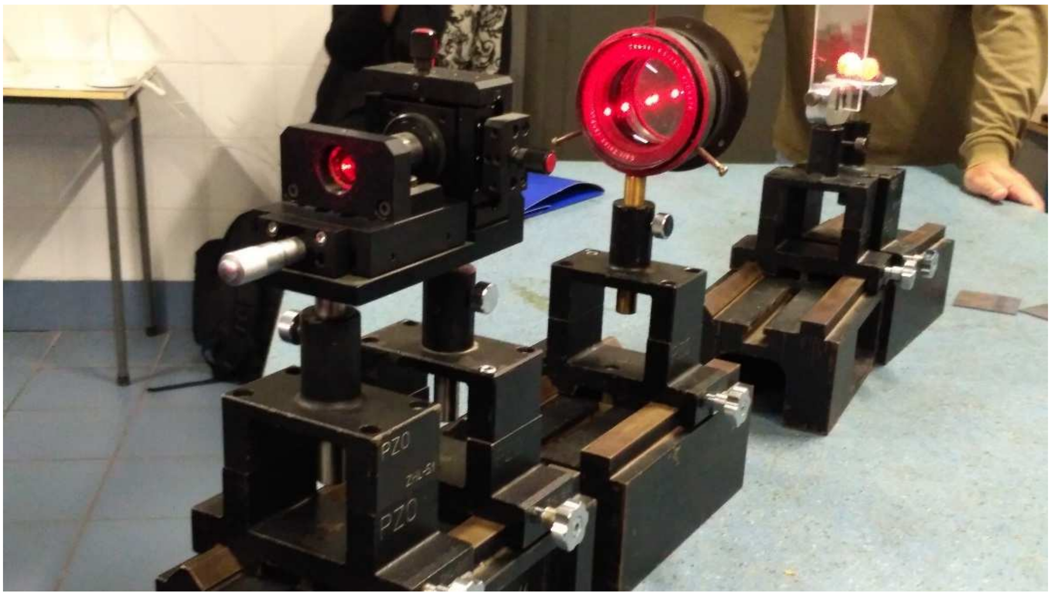


Figure 4 Scientific eqquipment for hologram making.

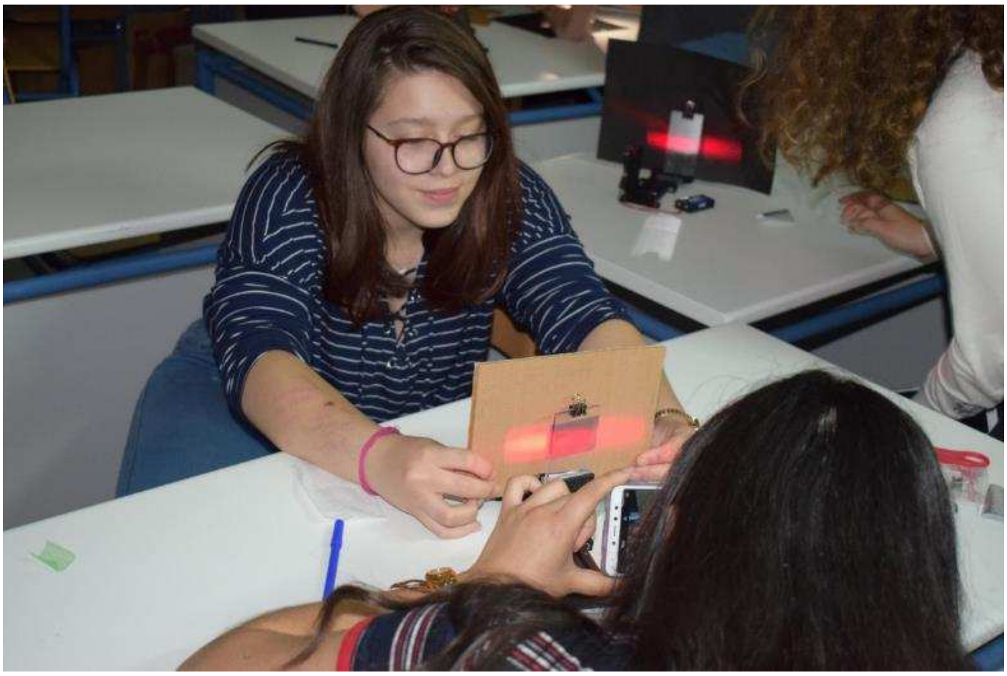


Figure 5 Holography enters the school class

2. The aspect of Arts in STEM

"The love of complexity without reductionism makes art;

the love of complexity with reductionism makes science."

Edward O. Wilson, Consilience: The Unity of Knowledge,

Knopf, New York, 1989, p. 54.

The acronym STEM stands for Science, Technology, Engineering and Mathematics. STEAM integrates Art and design into STEM, enabling a further focus on innovation in new technologies, discoveries and advancements. The STEAM "movement" is attributed to John Maeda, a designer and former professor at the MIT Media Lab and President of the Rhode Island School of Design's from 2008-2013. Mr. Maeda states that arts (including liberal arts, fine arts, music, design-thinking, and language arts) are critical components to innovation, and as such, the concept isn't about giving equal or more time to STEM or to arts, but instead to incorporate artistic and design-related skills and thinking processes to student-learning in STEM.

Looking at the teaching perspective, visual representation of complex subjects is an opportunity for students to conceptualize new projects and ideas. In that sense, having an artist involved in the process can become essential and an opportunity. In many areas and categories, from medical, botanical and zoological illustrations to the rise of "Edutainment", creative approaches have been developing new ways for students to absorb and be excited about STEM subjects. As an example, the American Association for the Advancement of Science (AAAS) organises every year an "International Science & Engineering Visualization Challenge". In this occasion, artists are involved to support scientists to explain, visualize and communicate phenomena, processes, shapes, complexities etc. More than any words, equations etc. These artistic representations become of great support for fall.

Figure 6 Artist Jason Hackenwerth's Balloon Sculpture at Edinburgh International Science Festival.

In order for youngsters to explore STEAM, it is important to highlight the underlying scientific process skills; observing and questioning, investigating, analysing and reporting and reflecting on the "big idea." These skills enable them to formulate thoughts into questions, solve problems and allow for the learning of new concepts and "big ideas" to become apparent and meaningful. It also helps make the connection between scientific ("Let's find out.") and innovative ("What if?") thinking. In that sense arts can be used to inspire learning and teach STEM concepts.

As a consequence, for STEAM subjects to succeed, hands-on project and design-based learning approaches are recommended as they are more consistent with the learning styles we attribute to the millennial and younger generations (*see part 1.2 Project-based Learning*). These approaches spark creativity, inquiry, critical and innovative thinking, dialogue and collaboration. This may enable youngsters to take thoughtful risks, engage in experiential learning, persist in problem-solving, embrace collaboration, and work through the creative process.

2.1 Arts & Holography

Holography has the advantage of allowing a deep study of a wide range of fundamental STEM concepts and principles[3]. It brings many fields together, such as optics, chemistry, computer science, electrical engineering, visualization, three-dimensional display, and human perception in a unique and comprehensive way.

[3] https://holomakers.eu/the-project/why-holography/

Looking back, in 70 years, holography has moved from an optical concept, through analogue technologies, which promised a new way of viewing and manipulating our visual and conceptual world, to digital production which now sits alongside data-driven virtual worlds constructed by digital natives. Through an interdisciplinary context, different areas of knowledge like physics, chemistry and visual arts can be meaningfully brought together.

As such, implementing educational programmes and activities with students on holography offers a great opportunity to combine artistic production and elaboration to scientific issues and curriculum. Students explore the underlying physical phenomena that make holograms work, mathematical techniques that allow the behaviour of holography to be understood, predicted, and exploited. In the meantime, as in any artistic creation, they also process the aim, the messages, the representation and the inspirations behind the art opera.

Holography can potentially be seen as a marginalized artistic movement, especially nowadays when you consider recent digital innovations that offer great visual presentation, like with 3D technology. Still, as the technique and material needed are not so inaccessible nor depending on major industrial investments and innovation, many international artists still perform and experiment the production and use of holograms. International symposiums and conferences were artists and Scientifics are conveyed, publications and international exhibition still demonstrate how much vivid the movement is.

It is important though to encourage students understand the difference between real holographic techniques and the stereoscopic or digital projections made through 3D pyramids and other practices (virtual reality, augmented reality) that inaccurately are called holograms. According to the Holomakers methodology these "applications" can be used to challenge students' thinking of what is a hologram and what is NOT.

Figure 7 Center for Holographic Arts – New York

Unexplored by many and underestimated by others, holography technique is a rich multidisciplinary discipline that enables potential artistic and educational dimension to involve students in STEAM programmes and activities, were more than ever the “A” for Art and design have profound meanings.

2.2 Inspirational examples of when Arts meets STEM

In the last decade, STEAM educational experiences and projects have significantly expended worldwide, involving students of all ages. This enabled to offer and share a variety of pedagogical material and research papers on the issue as well as concrete toolkit to implement and take inspiration. Here below are presented different experiences that combined the involvement of artists inside traditional STEM educational programmes, some involved and empowered students to take the lead in innovative projects.

“Enlight” european project & School Labs

The project ENLIGHT (European Light Expression Network) started in May 2016 for a duration of 32 months and was implemented under the Creative Europe Programme. Its key objectives were to develop new audiences for multidisciplinary visual arts, light art in particular, also raising awareness among the arts community as well as general public and schools. The project involved the following

European partner: The Manchester Metropolitan University (UK), I/O/Lab Rogalands Senter For Framtidskunst (Norway), Fondazione Mondo Digitale (Italy) and Curated Place (UK).

Artists had the chance to take part in artist residencies (Manchester, Rome and Stavanger) during which they developed their own project, to implement a range of workshops and master-classes, to participate in debates alongside professional development meetings and to present their work outcomes during four international festivals (BNL Media Art Festival - Rome; En-Light_En Festival - Manchester, i/o/lab Center – Stavanger and Aberdeen's Festival of Light - Aberdeen).

In 2017, during the Media Art Festival in Rome, four workshops involving students from several schools of Rome were each implemented with the lead of an artist per workshop. One of them, for example, involved a classroom from the school "Istituto comprensivo Settembrini" and together with the artist Silvia De Gennaro they created the project called "3°I 41.9183532 N – 12.5065285 E". The project, inspired by the reading of "The History of the World in 12 maps" by Jerry Brotton, took the title from the name of the class and the coordinates of the school Settembrini. Each student created his own galaxy formed by the school world and 7 other worlds, the number of planets recently discovered by NASA, which are the planet Internet, Spirituality, Happiness, Culture, Nature, Adults and Restlessness. For each planet they branch off several satellites. Elaborating the data of the students, photos and thoughts on their planets was then presented inside a video that resumed the movement of this great, varied and original galaxy throughout the Media Art Festival. Through an artistic project, the students embraced scientific issues tackling with astronomy and physics, in a ludic and involving process.

Lego Education

The worldwide known brand Lego has for long developed many educational programmes, and within the years it eventually fully integrated traditional schools programmes and STEAM curriculums. Lego Education, a distinct brand, has been an innovator in the education field nowadays offering products, resources and curriculum material to involve students from preschool, elementary, middle school and after school and to support educators and teachers. The playful learning experiences and teaching solutions based on the Lego system of bricks offers an opportunity to "think outside the

blocks" using a versatile medium", to promote creative thinking and it enables every student to succeed by encouraging them to become active, collaborative learners, build skills for future challenges, and establish a positive mindset toward learning.

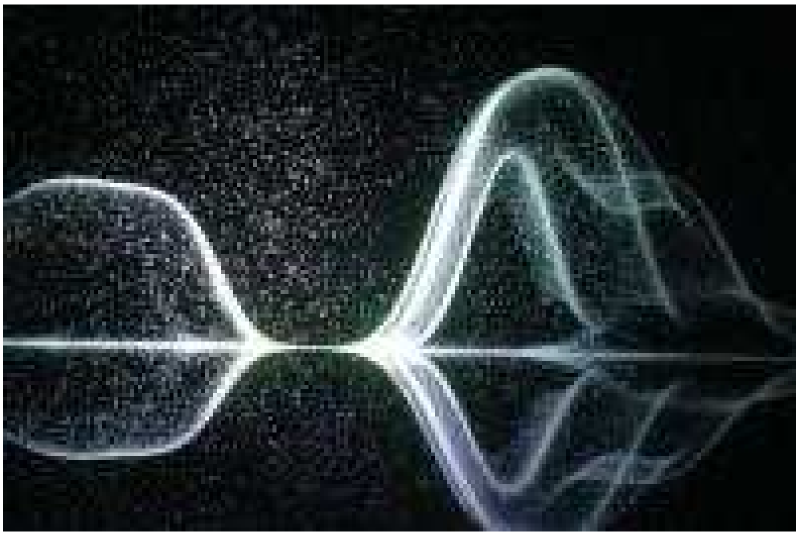
For example, the Lego Mindstorms equipment with an EV3 receiver, a type of technology aimed at students in secondary education (aged 10 years and above) allows pupils to build and programme robots while having fun in the meantime. The WeDo 2.0 offers youngsters from 7 years old and above to programme with Scratch and to experiment on computational thinking.

In the last few years, Lego has been touring with the international exhibition "The art of the Brick". The artist Nathan Sawaya, responsible of the exhibition, says "*using Lego as an art medium for me has had many personal benefits (...) one the most rewarding benefits has been seeing kids exposed to fine art through a medium they are familiar with*".

Finally, as to further illustrate the involvement of Lego Education into training and educational area, it started to propose since late 90's the Lego Serious Play facilitation methodology. Focused on companies' members and adult groups in general, it is claimed that participants come away with skills to communicate more effectively, to engage their imaginations more readily and to approach their work with increased confidence, commitment and insight.

In the last decade, Fondazione Mondo Digitale in Italy had used all these Lego Education opportunities to further involve students from all age into STEAM educational programmes and activities.

Artistic Exhibition “La Scienza illumina” / “Science illuminates”



Within the European Researchers' Night in 2015, the exhibition "Science illuminates " was installed inside the university crypt of Sapienza University of Rome. The exhibition, organized for the International Year of Light, was promoted by Sapienza and Maker Faire Rome - The European Edition in collaboration with the Fondazione Mondo Digitale, the National Institute of Nuclear Physics (INFN) and Frascati Scienza. The protagonists of the evening are the university professors of the Sapienza university, the artists and many makers: the showcases, which contain the exhibited "works" and some of the interactive installations, were in fact made with numerical control machines. Many young makers of the Innovation Gym of Fondazione Mondo Digitale took part in a thematic path on light and its uses in nature, science and art.

The exhibition "Science illuminates" aimed to be a link between the great issue of environmental sustainability and of new technologies based on light and their applications in everyday life: from geometric optics, to quantum mechanics. In this sense, the visitors were guided on an interesting STEAM journey that involved all disciplines, including art.

Moreover, the inaugural event, in fact, was accompanied by a performance of sound art on light, performed by Otolab, a group of multimedia artists from Milan that deals with experimentation in the field of digital art and electronic music.

3. Skills for the 21st century labour market

The labour market of the 21st century is in a continuously expansional state, mainly due to the rapid technological advancements that have risen during the last decades. Imposed legislation towards a more environmentally friendly ecosystem or the natural need for human evolution has been the two main roots for this breakthrough. The labour market is directly related and affected by this evolutionary state, in terms of the skilfulness of the labour force and its ability to follow up and become or remain involved. Skills are a pull factor for investment and a catalyst in the virtuous circle of job creation and growth, in every sector of today’s market.

Although the technological growth and innovation have become an obvious element in the 21st century, the situation in Europe still calls for action. Approximately, more than fifty percent of all 12 million long-term unemployed are considered as low-skilled. Furthermore, almost 70 million Europeans lack adequate reading and writing skills, and even more have poor digital and numeracy skills (ECweb2017, ECskills2017). These facts impose serious potential risks to both employed and unemployment, such as job dismissal, poverty and even social exclusion. For this, higher education institutions and companies must provide their graduates and employees with adequate and relevant tools and support, to aid them to acquire up-to-date and valuable skills.

All the above have a direct impact on employers since the lack of appropriate, and skilful, potential employees enforces them to compromise with lower quality work force, than they need in order to innovate and grow; almost 40% of European employers are a subject to this statement. Consequently, many people work in jobs that do not match their skills and talents. The preparation levels and quality of potential employees and graduates are perceived differently by teachers and employers. Only few people have the entrepreneurial mindsets and skills needed to set up their own business.

Beyond looking for the right occupation-specific skills, employers are increasingly demanding transferable skills, such as the ability to work in a team, creative thinking and problem solving. This skills mix is also essential for people considering starting their own business. Yet too little emphasis is usually placed on such skills in curricula and they are rarely formally assessed in many Member States. Interdisciplinary profiles – people with the ability to combine work across different fields - are increasingly valued by employers, but are in short supply on the labour market.

2.1 Holomakers learning intervention and skill development

Through its practical examples and activities, the various aspects of skill acquisition are explored, from preliminary levels until the achievement of the main target; that is the advancement of both the individual, the labour market and subsequently, the society. Below, the various digital skills are presented as well as how the project aims to expose and engage each one of them, through practical and hands-on techniques.

STEM related skills	The projects have been designed in a way that allow the exploration of different STEM related concepts (i.e. physics: coherence, diffraction, study of wave properties, technology: programming in Octave, assembling the Holokit and more, engineering: reflecting upon the materiality and the texture of different objects, finding the optimal set up maths: Fourier, calculations and operations)
Artistic skills	The projects have been structured in such a way in order to allow exploration of artworks, engagement in artistic techniques (i.e. stop motion), reflection upon philosophical issues (i.e. about the conception of identity) and how these are reflected in art (i.e street art, famous artwork etc).
Team-work	In the Holomakers curriculum all the projects are done in groups engaging students in team work and collaborative skill building.
Digital competences	In computer-generated hologram making the students extensively use Octave software that allows programming primarily intended for numerical computations. In addition, the students prepare presentations of their work using also digital technology (i.e. power point).
Creative thinking	The pedagogical model of the Holomakers curriculum encourages students to come up with ideas for selecting and preparing the figurew/models to be holographed. In some of the tasks, students are asked to design and envision their figures/models.

Critical thinking	Students' work in the Holomakers projects call for exploration and critical reflection. The projects promote self-guided, self-disciplined thinking and encourage students to reason.
Problem solving	During hologram making, the students encounter several problems. Most of the projects in the Holomakers curriculum have been selected in way to make students face with challenges and work towards overcoming it.
Entrepreneurship skills	The challenge of the Holomakers curriculum is students to move beyond the already given projects and to work on their own ideas realizing the capacity of the available tools. However, the ideas they will develop for the project will be presented to the class and they will defend their project idea. Some of the other projects are also requiring students to initiate an idea, test it, and present it. These processes can be linked to entrepreneurship skills to some extent.
Learning to learn and learning through failures	The pedagogical model of the Holomakers curriculum promotes students to work on their own pace in groups and learn from their mistakes. Teachers are encouraged to enable students to do reflective thinking in every project. Such reflective thinking is strongly related to the self-regulated learning skills.

2.2 Inspiring places for skill building

Recognising the need for building and updating skills at secondary school level (and beyond), the school and research community establishes places where several 21st century skills can be practiced and cultivated. Some examples appear below:

- **Fondazione Mondo Digitale Phyrtual Innovation Gym**[4] is a center dedicated to experiential learning and the practice of innovation to stimulate professional growth, self-

[4] https://www.innovationgym.org/

enterprise and 21st century skills. Different equipped laboratories host project- based practices oriented to students development of both hard and soft skills.

- **Fablab:** this area is dedicated to both digital and traditional manufacturing and is animated by makers, the new craftsmen. It is open to all citizens, organisations and schools. The first Roman FabLab has been modelled on MIT's Centre for Bits and Atoms. Tools include: 3D Sharebot printer, 3D PowerWASP printer, laser cutter, plotter, cutter, pantograph, lapper, lathe, vertical drill and soldering iron.
- **Robotics Centre:** the centre is dedicated to developing new didactic methodologies to teach young students about scientific and technological subjects and professions. Tools include: Bee Robots Didactic Kits, We Do Lego, NXT Mindstorm, EV3
- **Ideation Room:** a didactic area to improve creativity, 360-degree innovation and enterprise through the practice of self-awareness, problem-solving, decision-making, business modelling, drawing and coding.Tools include: Lego Serious Play, Interactive Multimedia Board with WII Remote, Root Cause Analysis Tools, Business Model Canvas, didactic micro-modules, software and apps design challenges.
- **Activity Space:** this edutainment space is dedicated to leadership, team building and motivation through physical and mental exercises and games to learn and practice 21st century skills. Tools include: ZoomeTool, Toobeez, balls, ropes, etc.
- **eCraft2Learn makerspace:** a place established in the Technopolis City of Athens Technological and Cultural park (Greece) by Edumotiva[5] in the context of the eCraft2Learn H2020 project. The place offer students opportunities to engage in crafting, programming, robotics, electrical circuit making, 3D modeling and printing and exploring the DIY culture. Similar places in a smaller scale were established in schools in Athens (Greece) in disadvantaged areas.

[5] http://edumotiva.eu

4 The Holomakers learning intervention

The Holomakers project aims at engaging students in research and scientific practices through simple science-related activities/project that can be implemented with items/tools that do not require a professional and well-equipped laboratory. **Low cost tools and technologies** have been brought together in order to create a portable kit for making simple holograms.

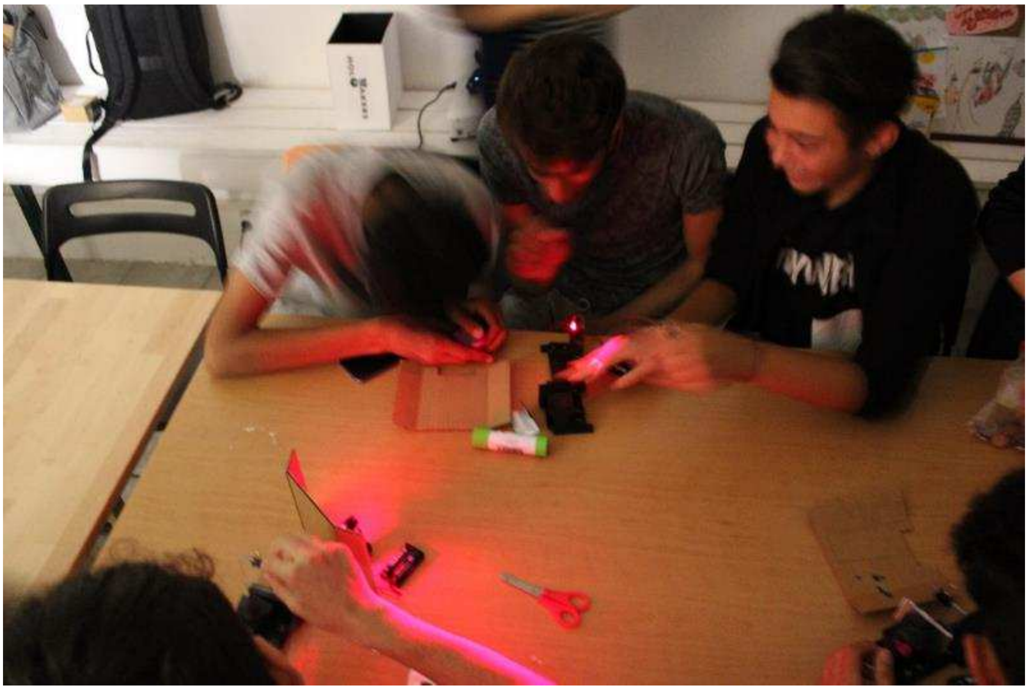


Figure 8 A group of students working with the Holokit

Below you can find information on how the teachers and the students are supposed to work together, the key processes of the Holomakers learning intervention, the projects that can be deployed, the available educational resources and possible implementation workplans.

4.1 Roles of students and teachers

The roles of the teacher and the students are briefly described below:

Role of teacher: the teachers are not the sages on the stage and they are not supposed to have all the answers to the questions that may emerge during the holographic practices. They rather help and encourage the students to explore and construct their own knowledge, to organise their thoughts and ideas, to work effectively in teams. They encourage teamwork, experimentation, hands-on activity, challenge seeking and the sharing of knowledge. A**s Seymour Papert (1993) advocated, 'the role of the teacher is to create conditions for invention rather than to provide ready-made knowledge'.** Through questions and observations, the teacher engages students in articulating and

extending their own observations, through processes, and explorations. The teacher may not directly answer students' questions but rather show them how to find it themselves. **This kind of exploration fosters an environment in which what we often see as "failure" is actually a natural step of the learning process, a signal to ask questions and explore further**. The Holomakers curriculum encourages teachers to take several roles (the roles of the mentor, trainer, facilitator of the learning process, self-esteem booster, co-maker, co-learner, evaluator and more) and adapt their support and guidance based on the needs along the way. In other words, the teachers in the Holomakers projects should be ready to step out of their comfort zone. Regardless their backgrounds and level of experience, they are invited to apply new practices, to explore new tools and materials.

Role of students: The project aims at supporting students in working collaboratively, developing and refining their abilities as creative thinkers. While they are engaged in Holomakers activities learn to develop their own ideas, try them out, test the boundaries, experiment with alternatives, get input from others – and, perhaps most significantly, generate new ideas based on their experiences that can lead to improved outcomes and results.

Holomakers team and experts: The holomakers implementation team ensures that the available equipment is available to the schools, provides all possible supportive resources and facilitates the learning process online in case needed by offering support to the teachers through the Holomakers online class and forums.

4.2 The key processes

Students' engagement in practical and hands-on project is likely to be most effective when:

- the learning objectives are clear, and relatively few in number for any given task
- the task design highlights the main objectives
- an explicit strategy is used to stimulate the students' thinking beforehand
- the practical project is answering a question the student is already thinking about
- the task design 'scaffolds' students' efforts to make links between the different domains of knowledge

The abovementioned points have been taken into account while designing the Holomakers resources. In order to better facilitate the learning practice the following key processes have been also identified. These are considered integral parts of the Holomakers learning intervention.

- **Introductory sessions:** These include sessions that aim at smoothly introducing students in the basics concepts of Holography as well as the ideas underpinning the Holokit development.

- **Physical experiments:** These include 1 or 2 sessions that aim at engaging students in the execution of physical experiments in order to obtain a more concrete idea of abstract definitions.

- **Physical Hologram making:** This stage can be completed into several sessions depending the project that is deployed each time. It includes the step of setting up the Holokit, preparing the film, selecting or making the figures/models to be holographed, trying out several positions and alternatives, recording the hologram using the Holokit and reflecting upon the result. The Holomakers curriculum includes 4 activities/projects for physical Hologram making that can be easily extended by the students or the teachers.

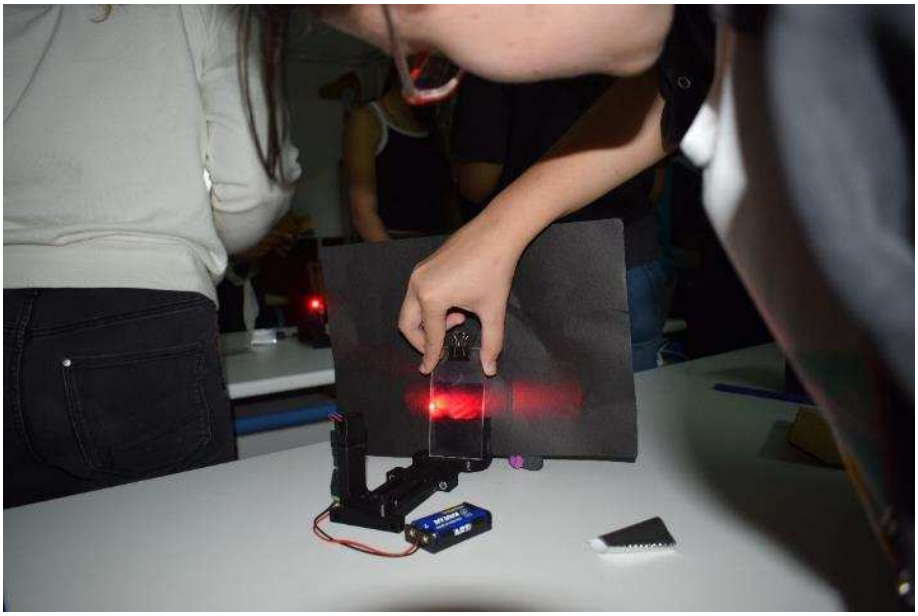
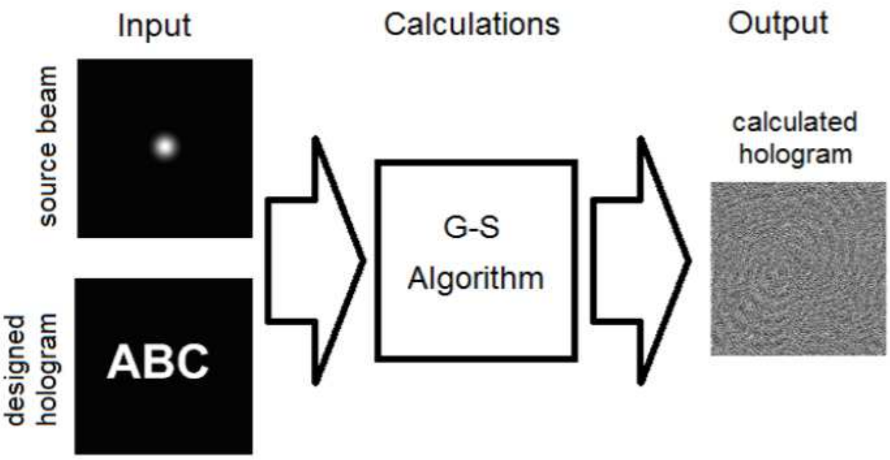


Figure 9 Physical hologram making with the Holokit

- **Computer-generated Hologram making:** This stage includes several sessions as well. **The students are encouraged to apply** the method of digitally generating holographic interference patterns[6]. The Holomakers curriculum includes 2 activities/projects for physical Hologram making that can be easily extended by the students or the teachers. To digitally generate a hologram, the Gerchberg-Saxton algorithm is applied. This algorithm needs the input distribution of the designed intensity and the intensity distribution of the light beam in which the hologram is to be reproduced. As a result of the algorithm's operation, one can obtain a graphic file with a phase distribution being a designed hologram. The general idea and the steps to be followed is presented below:

[6] https://en.wikipedia.org/wiki/Wave_interference



For more information please see Output 1[7]

- **Discussion with experts/ with peers & Reflection:** This stage brings experts voice on the learning stage. The interaction among teachers, experts, artists and students is highly encouraged. A debriefing session in the end may also help students realize the steps that were carried out, the needs that emerged and how their work can be further improved.

- **Sharing:** The sharing of the projects with others is considered of great significance. The teachers encourage all the groups to share the current status of their work in the end of each session, to talk about the processes that they went through and their future plans. In addition, the groups are encouraged to showcase their work in the school community and the wider public. In this light, the students may presented their projects in Festivals and interact with people of all ages and from varying scientific backgrounds as well as with other groups of students that participate in the festival either as exhibitors or visitors. The students and the teachers are also encouraged to record their work using their smartphones or cameras. At a later stage, some of this material may be uploaded by them in their social media accounts.

[7] https://holomakers.eu/wp-content/uploads/2019/10/HOLOMAKERS-Technical-Reference-Guide-.pdf

Figure 10 Sharing in the Media Art Festival- Demonstration of the 3D model that will be 3D printed and holographed (Italy)

Figure 11 Sharing in Athens Science Festival- Demonstration of recorded holograms with the Holokit in a black box (Greece)

Figure 12 Demonstration of the Holomakers black box

4.3 The Holomakers workplans

Taking into account that the school curriculum poses frequently obstacles in the deployment of longitude projects, the Holomakers intervention can be divided into sessions. The number of activities to be done can be freely decided by the teachers. The key processes in each stage (see section 4.2) can be also reduced in time or adjusted to your classroom needs. Three workplans are presented below. Workplan 3 is the short one whereas workplan 1 and 2 include all the key process presented above in different order (to accommodate needs emerged during the piloting phase).

Work Plan 1 (full version)

Introductory session(s)

- 1-3 hours depending on students' background

  Ready made presentations are available in Polish, Greek, Italian and Spanish

  Involvement in discussion in the class/ Discussion with experts

Physical experiments

- 1-2 hours (depending on the number of physical experiments that will be made)

  Guidelines for teachers and worksheet for students in available

  Debriefing discussion in the end

Computer-generated Holograms

- 3- 16 hours (a familiarization stage is required)

  2 examplar acivities*, guidelines for teachers and worksheet for students, tutorial in Octave and videos are available

  Debriefing discussion in the end & sharing

Physical Hologram making

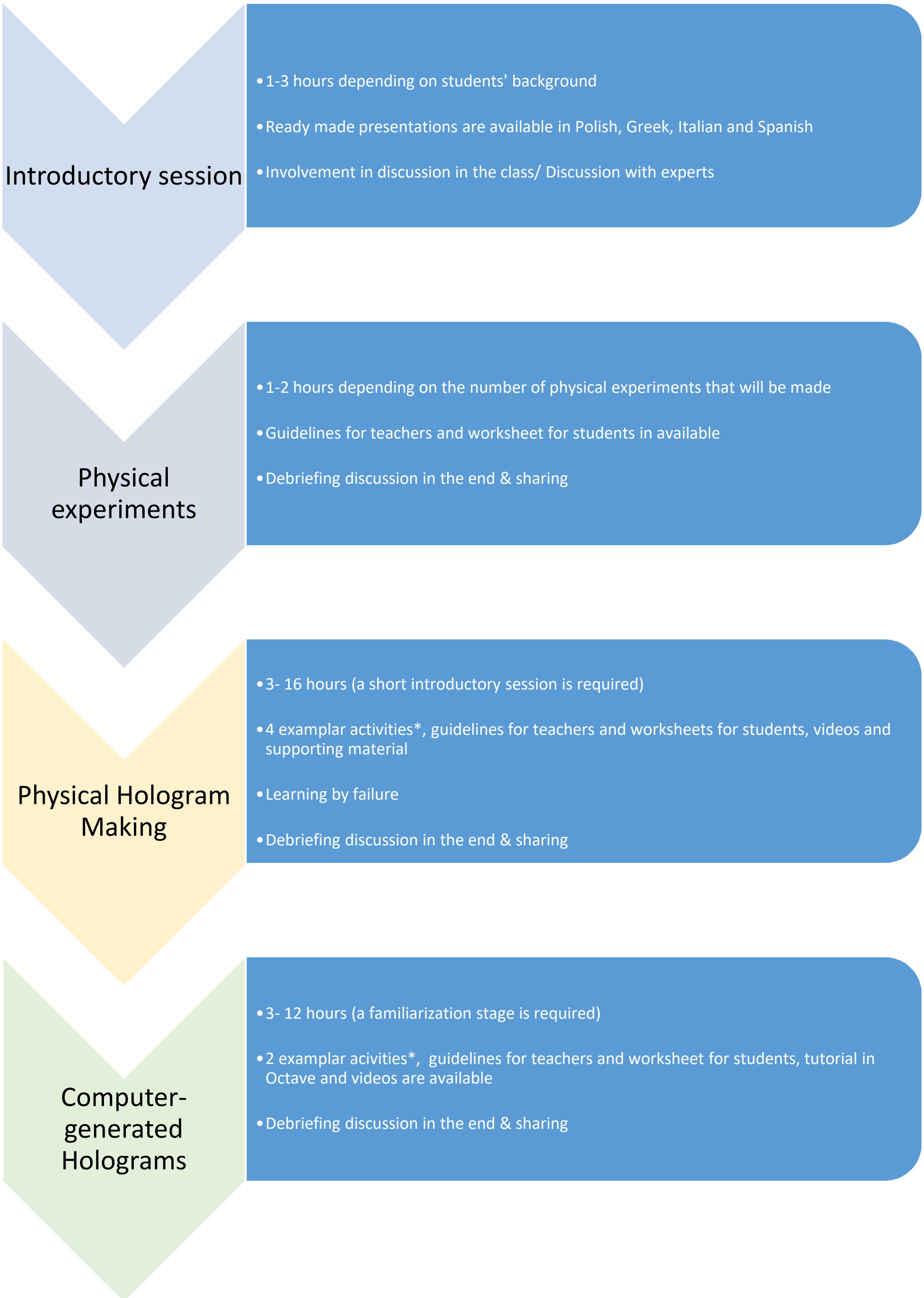
- 3- 15 hours (a short introductory session is required)

  4 examplar activities*, guidelines for teachers and worksheets for students, videos and supporting material

  Debriefing discussion in the end & sharing

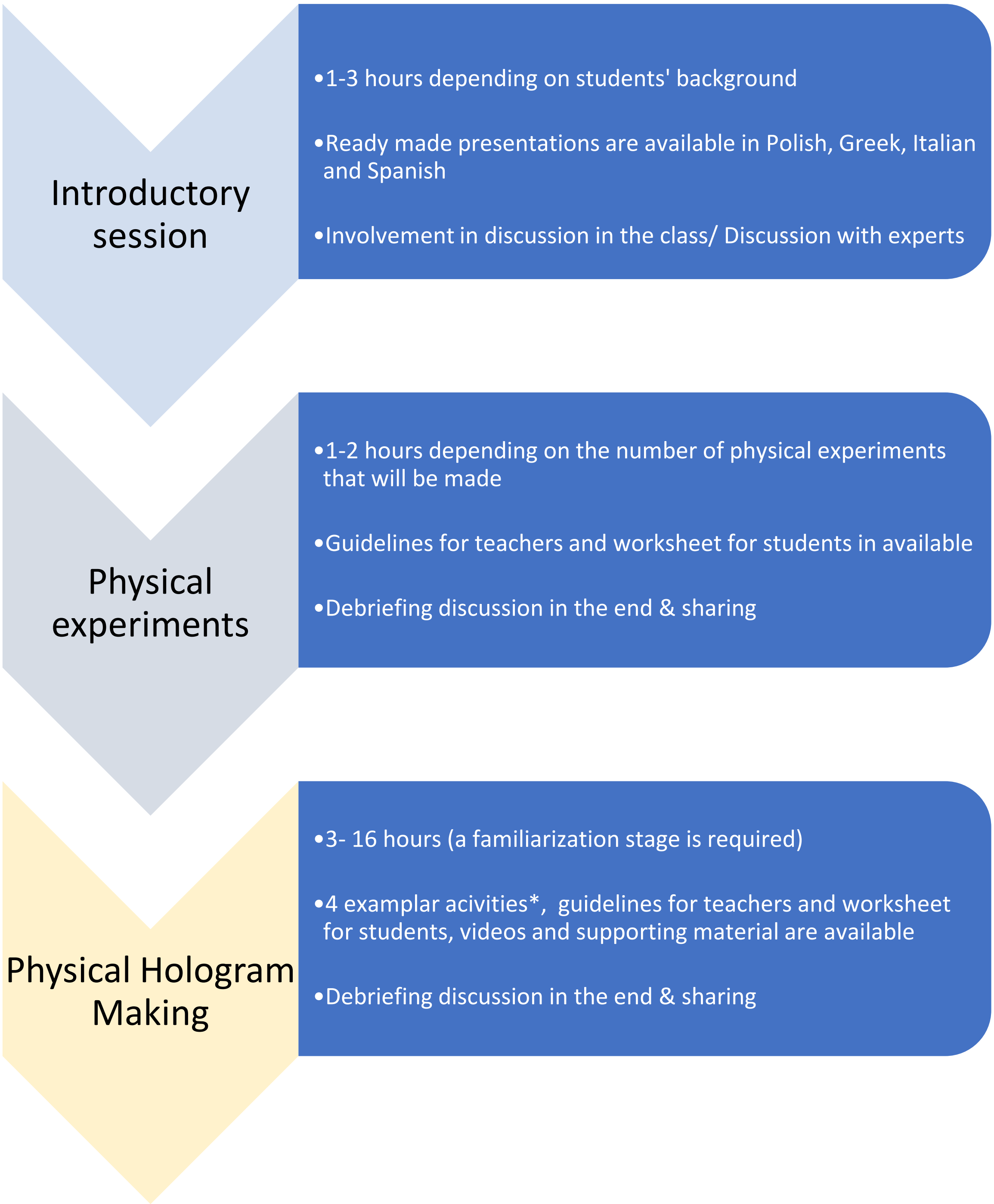
(*) the number of activities to be done can be freely selected by the teachers

Workplan 2 (full version)



(*) the number of activities to be done can be freely selected by the teachers

Work plan 3 (short version)



(*) the number of activities to be done can be freely selected by the teachers

4.4 Activities for the class

The 1st pilot round starts with simple physical experiments around the basic concepts of holography. Then through playful projects that are linked to arts students are invited to re-construct patterns and/or construct their own in Octave (computer-generated holograms). During the 2nd pilot the students are invited to make their own physical holograms working with the Holokit (the portable device developed in the context of Output 2[8]).

Because of the nature of the projects, there is potential for the students to become more curious about physics, math, science in their normal STEM classes because they can use this knowledge to complete their projects. With the infusion of Arts in STEM we aim at offering students opportunities to explore interdisciplinarity in learning subjects, express their artistic skills and replenish their creativity.

Below you can find key information about each project as well as review the available supporting material for students and teachers.

4.4.1 Simple physical experiments

The purpose of this physical experiment is to determine the distance between the recording tracks on a CD/DVD. This is possible due to the fact that the CD/DVD can be treated as a reflective diffraction grating. The period of this grid corresponds to the distance between the tracks with the saved information.

Est. Duration	**2-3 hours**
Equipment needed	• laser pointer emitting a wave of a known length (λ) (usually this value is given on a sticker on the pointer), • a recorded CD/DVD • measure tape • holder for the laser • screen for observing diffraction orders

[8] Find more about the Holokit: https://www.youtube.com/watch?v=wFbqvzraYds&feature=youtu.be

Learning objectives	We expect students to: • get familiar with the concept of diffraction • get familiar with the changes in the diffraction image in relation to the distance of the laser pointer from the disk • get familiar with the changes in the diffraction image in relation to the distance of the screen from the disc?
Preparation needed	The teachers should recall the knowledge gained during C1. They just need to become familiar with the process using images &calculated patterns as well as the scripts available in the 'Examples' and in the 'Scripts' folders in the Dropbox (O3>Projects>Cultural Artefact>…)
Worksheet	https://holomakers.eu/wp-content/uploads/2019/11/CD-DVD-experiment-worksheet.pdf
Description for teachers	https://holomakers.eu/wp-content/uploads/2019/11/CD-DVD-experiment.pdf

After lighting the CD/DVD with a laser beam, the students can observe the appearance of additional diffraction orders (see **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**). Reflected light is diffracted, thanks to which new directions of beam propagation appear. The students are encouraged to observe them as light spots on the screen.

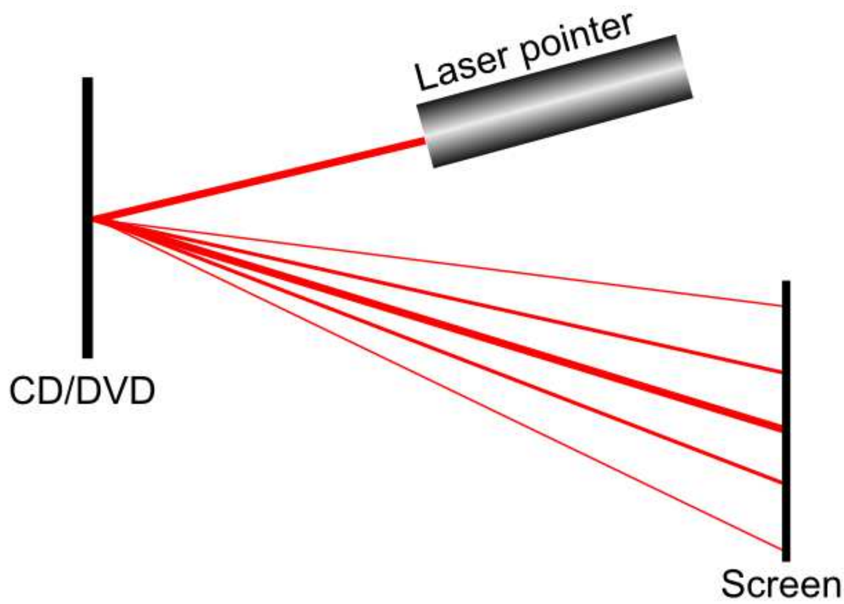


Figure 13 Reflection of light from a CD / DVD

4.4.2 Reconstructing and constructing patterns: the case of the 4 cultural artefacts

This activity is one of the interdisciplinary projects in STEAM for computer generated holograms that is proposed within the context of the Holomakers project. In this project, we expect from the students to become familiar with the basic principles of optics and computer-generated holograms, by getting motivated through a game of exchanging cultural information via encrypted messages. The encrypted messages will be holographic patterns derived from based on Fourier transform Gerchberg–Saxton (GS) algorithm on images of physical cultural artefacts. This project will be executed/ performed in two phases and the *GNU Octave* software will be the basic operating tool. This project is a playful approach to computer generated holograms and includes a set of preparatory tasks for future analog hologram making.

Est. Duration	**2-3 hours** (for one cultural artefact)
Equipment needed	Octave, simple camera
Links to supporting files	https://holomakers.eu/wp-content/uploads/2019/11/Cultural-Artefact.zip
Learning objectives	We expect students to: • get familiar with the procedures of producing a computer generated hologram • understand what a holographic interference pattern is • get familiar with the basic operations of GNU Octave software for computing a holographic interference pattern • understand how to re-construct a holographic interference pattern • problematize upon the interference concept • practice their collaborative skills towards producing a text that will come along the holographic pattern
Preparation needed	They just need to become familiar with the process using images &calculated patterns
Worksheets	https://holomakers.eu/wp-content/uploads/2019/06/CulturalArtefacts_worksheet.pdf
Description for teachers	https://holomakers.eu/wp-content/uploads/2018/11/Cultural-artefacts_final.pdf

The students are informed that this is an encrypted image/picture (see picture below), sent from another country, and is currently appeared as a holographic pattern. Therefore, if they want to reveal/discover its content they need to get familiar with some basic principles of optics and particularly with Fourier transform, as well as with procedures related to computer- generated holography (GS algorithm).

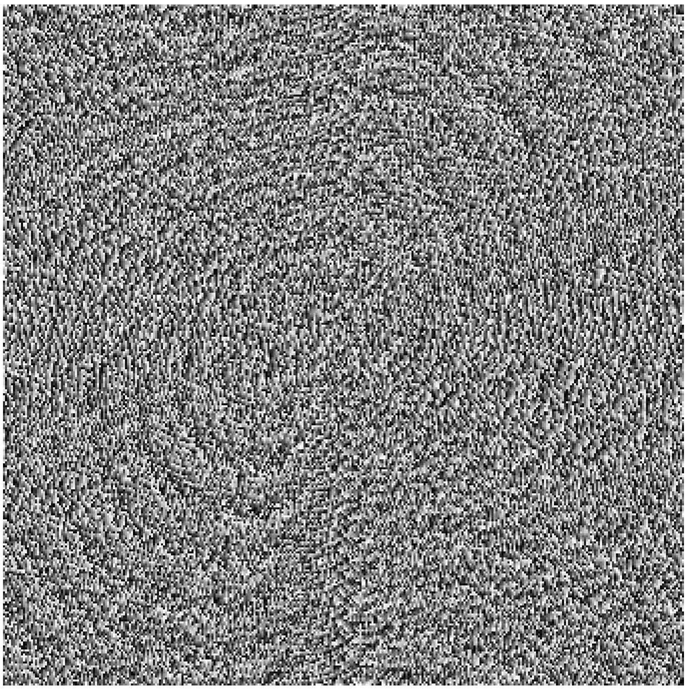


Figure 14 Calculated pattern

The students are then requested to respond to the received message by creating and sending their own encrypted message. Each school/department will choose a representative cultural artefact that would like to send to another school/partner of the community in order to reply to the received message as well as to share/exchange (some significant) cultural information. Students should be encouraged to do a short research in order to become more engaged to the entire procedure, but keeping in mind that the artefact should be a physical object that is easily accessible and that can be easily captured on camera. An example of such artefact is presented in the picture below.

Figure 15 Cycladic statue- example of a cultural artefact

4.4.3 The oxymoronic sentences

This activity focuses on the artistic research according to STEAM educational approach to learning Science, Technology, Engineering, and Mathematics (STEM) using Art as access points to guide student creativity rethinking science based principles. This approach encourages inquiry, dialogue, and critical thinking. The activity aims to teach students to think critically and use engineering or technology in imaginative designs, approaching creatively to real-world problems while building on students' mathematics and science knowledge. STEAM programs infuse ART to STEM curriculum by exploring science through creativity. The end results are students who take thoughtful risks, engage in experiential learning, persist in problem-solving, embrace collaboration, and work through the creative process while learning science and mathematics. The activity starts involving students thinking about the meaning of Holographic picture, promoting their reflection on the fact that it does not exist itself. The idea is to think about what we cannot see about the micro cosmos, what we can not see exists or not?

From this point of view the intention is to explore the opportunities offered by the Octave software to create our own reality, understanding how science, engineering and mathematics can support us in representing what a hologram is in an oxymoronic way. Using Octave and Fourier transform, we can create a diffraction pattern that is a computer-generated hologram, enhancing the reflection on the possibility to create imagines that do not exist in the real world. A possible way to see this process

is using letters and words, creating oxymoronic sentences (Ex: "I'm always in the place where I don't have to be") in an artistic way to make students reflect about what is there and what is not there.

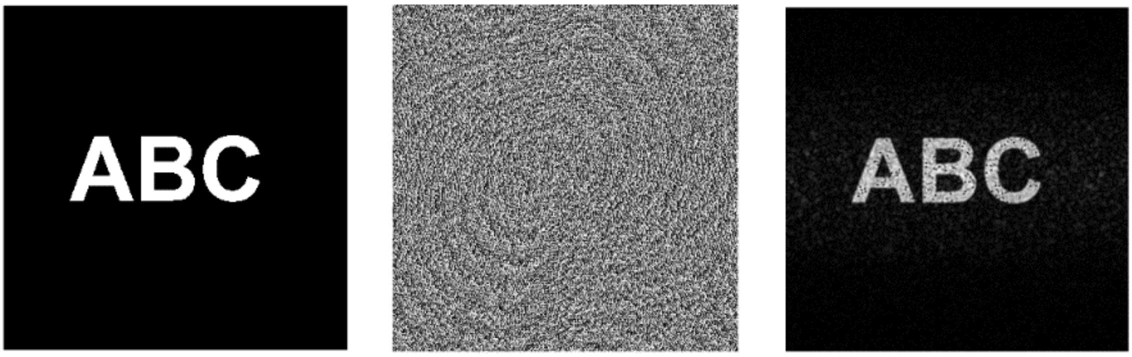


Figure 16. Designed image (left), Diffraction pattern (CGH) (middle), Reconstructed image (right)

Students will use the generated patterned letters to develop an artwork installation (i.e a sentence), creatively representing the process and the difference between physical and imaginary, coded and visualized. The final artwork aims at explaining the nature of holograms by bringing together knowledge of Arts and Science.

Est. Duration	**Minimum 10 hours**
Equipment/materials needed	PC, Octave Software
Links to external files	Additional OERs that might be useful for introductory purposes: https://holomakers.eu/oers/
Learning objectives	**We expect students to:** • Get familiar with the procedures of producing computer generated holograms • Understand how to re-construct holographic interface patterns • Enhance creativity and problem-solving skills • Practice collaborative and team working skills • Reflect upon what identity is (links to Arts and Humanities)

Preparation needed	Understanding of Computer-generated hologram approach Basic principles of optics
Worksheet for students	https://holomakers.eu/wp-content/uploads/2019/05/Oxymoronic-sentences_worksheet.pdf
Description for students	https://holomakers.eu/wp-content/uploads/2018/11/Oxymoronic-Sentences.pdf

4.4.4 The coin project

This activity is one of the interdisciplinary projects in STEAM for physical hologram making.

In this project, we expect from the students to become familiar with the basic principles of optics through the use of physical holography and specifically through the use of the portable HoloKit, which represents a basic holographic set up. This activity revolves around the 'coins' topic, with coins being the main holographic objects. The students will be encouraged to do a short research on this topic, choose a coin and use the HoloKit in order to successfully record the object.

Est. Duration	**2-4 hours** (dependant on the implementation of the extended activity scenarios)
Equipment/materials needed	The portable HoloKit, batteries, holographic film, coins
Links to external files	Additional OERs that might be useful for introductory purposes: https://holomakers.eu/oers/ External resources: https://holomakers.eu/wp-content/uploads/2019/01/ExternalResources-coins.pdf
Learning objectives	**We expect students to:** • get familiar with the procedures of making a physical hologram using the HoloKit • understand how basic setups for hologram recording function • problematize upon the materiality and texture of the object to be holographed • practice their collaborative skills towards producing a more complex and meaningful – from an artistic perspective – hologram • go deeper in the context of the project and to explore the topic of coins from many different perspectives (i.e. History, Monetary Heritage, Maths)

Preparation needed	The teachers need to become familiar with the process by testing different angles and positions of the object to be holographed as well as different kind of coins with different sizes and various materials/textures.
Worksheet for students	https://holomakers.eu/wp-content/uploads/2019/01/TheCoin_Project-worksheet.pdf
Description/Guidelines for teachers	https://holomakers.eu/wp-content/uploads/2019/02/TheCoin_project.pdf

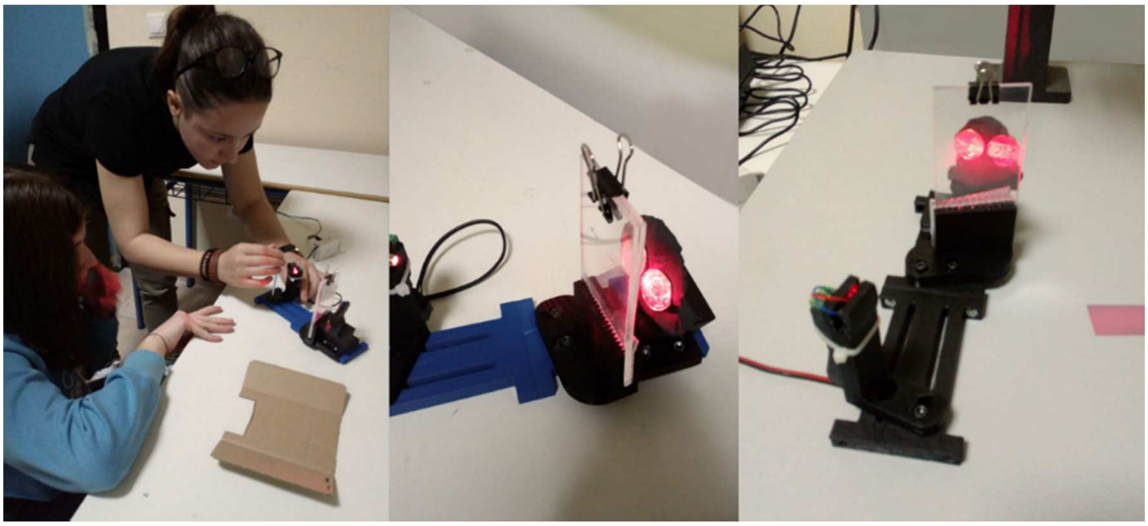


Figure 17 Working in the Coins project

4.4.5 The sea-shell project

This activity is one of the interdisciplinary projects in STEAM for physical hologram making and practice.

Figure 18 Seashells of different shapes and geometries, retrieved from: http://www.stickpng.com/es/img/comida/conchas-marinas/concha-marina, https://www.freeiconspng.com/img/24620, http://png.clipart-library.com/tag/seashell-2.html

In this project, we expect from the students to become familiar with the basic principles of optics through the use of physical holography and specifically through the use of the portable HoloKit, which represents a basic holographic set up. This activity revolves around the '**seashells**' topic, with seashells being the main holographic objects. Students will be encouraged to do a short research on this topic, choose or find (if it is possible) their own seashell and use the HoloKit in order to successfully record the object.

Est. Duration	**3-6 hours** (more time is required for the extended activity scenarios)
Equipment needed	The portable HoloKit, batteries, holographic film, seashells
Links to external files	Additional OERs that might be useful for introductory purposes: https://holomakers.eu/oers/ https://holomakers.eu/wp-content/uploads/2019/01/ExternalResources-Seashells.pdf
Learning objectives	**We expect students to:** • get familiar with the procedures of making a physical hologram using the HoloKit • understand how basic setups for hologram recording function • problematize upon the materiality and texture of the object to be holographed • practice their collaborative skills towards producing a more complex and meaningful – from an artistic perspective – hologram

	• go deeper in the context of the project and to explore 'seashells' from many different perspectives (i.e. Arts, Environmental Education)
Preparation needed	The teachers need to become familiar with the process by testing different angles and positions of the object to be holographed as well as different seashells with different geometries and various textures.
Worksheet for students	https://holomakers.eu/wp-content/uploads/2019/03/Seashell_Project-worksheet.pdf
Guidelines/Description for teachers	https://holomakers.eu/wp-content/uploads/2019/02/Seashells_project.pdf

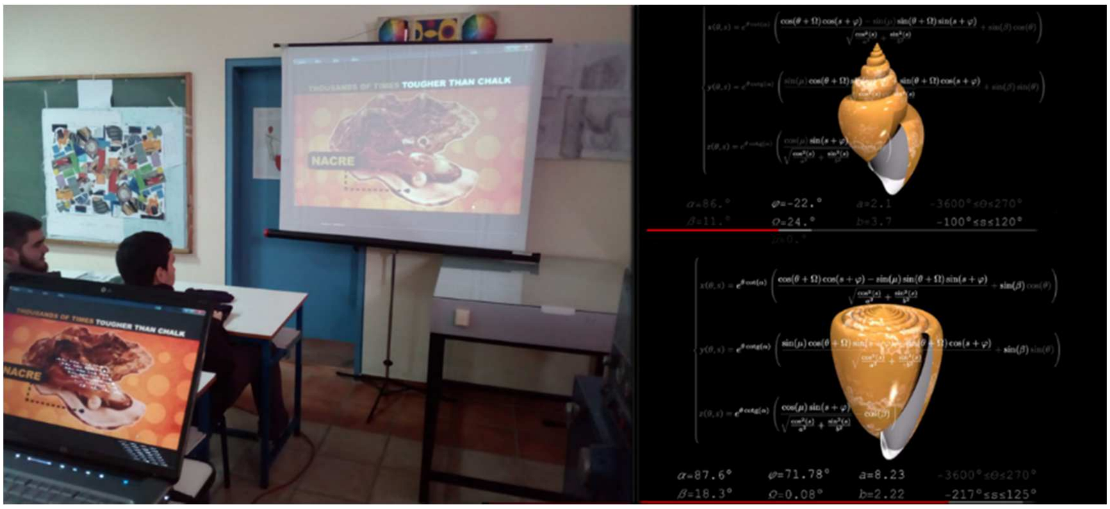


Figure 19 Introduction to the Seashells project- connection with Maths, Biology and Arts.

4.4.6 The plasticine figure project

This activity is one of the interdisciplinary projects in STEAM for physical hologram making and practice.

Figure 20 Figures made of plasticine or clay

In this project, we expect from the students to become familiar with the basic principles of optics through the use of physical holography and specifically through the use of the portable HoloKit, which represents a basic holographic set up. This activity revolves around the 'plasticine figures' with them being the main holographic objects. The students will be encouraged to experiment with plasticine of different colours and types and to their very own plasticine figure. Then they will be invited to use the HoloKit in order to successfully record the figure.

Est. Duration	**2-5 hours** (dependant on the implementation of the extended activity scenarios)
Equipment/materials needed	The portable HoloKit, batteries, holographic film, plasticine of different colours
Links to external files	Additional OERs that might be useful for introductory purposes: https://holomakers.eu/oers/ External resources: https://holomakers.eu/wp-content/uploads/2019/01/ExternalResources-PlasticineFigures.pdf
Learning objectives	**We expect students to:** • get familiar with the procedures of making a physical hologram using the HoloKit • understand how basic setups for hologram recording function • problematize upon the materiality and the colour of the object to be recorded

	• practice their collaborative skills towards producing a more complex and meaningful – from an artistic perspective – hologram
Preparation needed	The teachers need to become familiar with the process by testing different angles and positions of the object to be holographed as well as different colours of plasticine.
Worksheet for students	https://holomakers.eu/wp-content/uploads/2019/03/Plasticine_Project-worksheet.pdf
Guidelines/Description for teachers	https://holomakers.eu/wp-content/uploads/2019/03/PlastecineFigures_project.pdf

Figure 21 Plasticine figures made by the students ready to be holographed.

4.4.7 The identity project

This activity is one of the interdisciplinary projects in STEAM for physical hologram making.

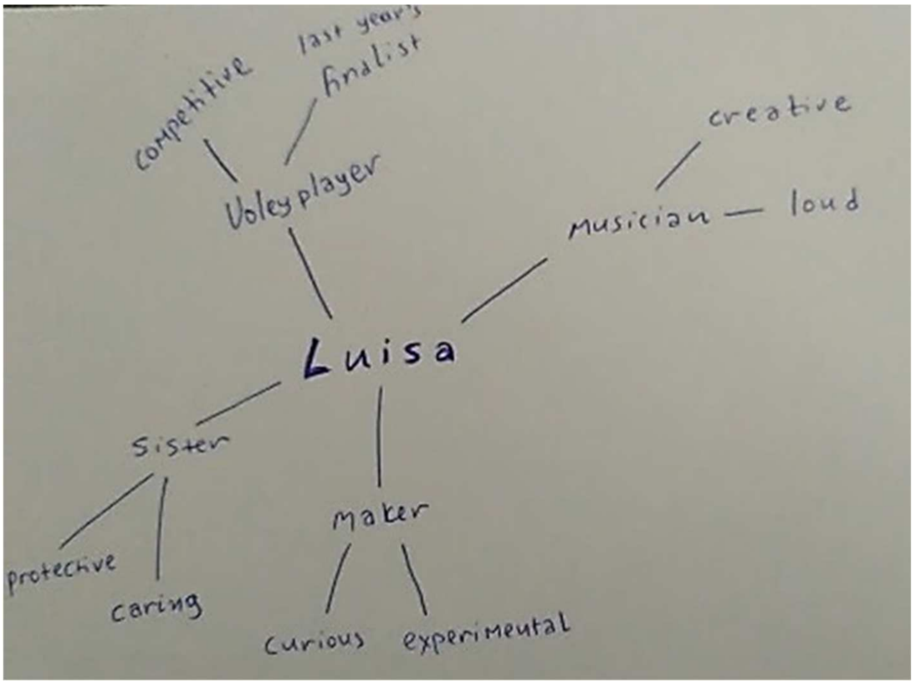


Figure 22 Example of an identity map

In this project, we expect from the students to become familiar with the basic principles of optics through the use of physical holography and specifically through the use of the portable HoloKit, which represents a basic holographic set up. This activity revolves around the concept of identity and anything depictable that denotes this concept. The students will be encouraged to create identity map, find out or create objects that can reflect parts of their identity and then they will be invited to use the HoloKit in order to successfully record them.

Est. Duration	**4-6 hours** (dependant on the implementation of the extended activity scenarios and discussion topics)
Equipment/materials needed	The portable HoloKit, batteries, holographic film, plasticine of different colours, materials that can be used to create shapes and figures
Useful Links	Additional OERs that might be useful for introductory purposes: https://holomakers.eu/oers/ External resources: https://holomakers.eu/wp-content/uploads/2019/03/ExternalResources-identity.pdf

Learning objectives	**We expect students to:** • get familiar with the procedures of making a physical hologram using the HoloKit • understand how basic setups for hologram recording function • problematize upon the materiality and the colour of the object/figure to be recorded • practice their collaborative skills towards producing a more complex and meaningful – from an artistic perspective – hologram • review and deepen their understanding of identity • reflect upon the concept of identity and create figures/emblems/objects that convey relevant thoughts • explore different historical, political, cultural role figures
Preparation needed	The teachers need to become familiar with the process by testing different angles and positions of the object to be holographed as well as different colours of plasticine or other material.
Worksheet for students	https://holomakers.eu/wp-content/uploads/2019/03/Identity_Project-worksheet.pdf
Guidelines and description for teachers	https://holomakers.eu/wp-content/uploads/2019/03/Identity_project.pdf

Figure 23 Students working on the identity project (ideation and planning stage)

4.5 Available OERs for the Holomakers learning intervention

4.5.1 Project descriptions and worksheets per category

Physical experiments & calculations	**The physical experiment project**
Activity description for teachers	https://holomakers.eu/wp-content/uploads/2019/11/CD-DVD-experiment.pdf
Worksheet for students	https://holomakers.eu/wp-content/uploads/2019/11/CD-DVD-experiment-worksheet.pdf
Multilingual material	https://holomakers.eu/intellectual-outputs/multilingual-material/

Activities for computer-generated holograms	**The cultural artefacts activity**	**The oxymoronic sentences**
Activity description for teachers	https://holomakers.eu/wp-content/uploads/2018/11/Cultural-artefacts_final.pdf	https://holomakers.eu/wp-content/uploads/2018/11/Oxymoronic-Sentences.pdf
Worksheet for students	https://holomakers.eu/wp-content/uploads/2019/06/CulturalArtefacts_worksheet.pdf	https://holomakers.eu/wp-content/uploads/2019/05/Oxymoronic-sentences_worksheet.pdf
Multilingual material	https://holomakers.eu/intellectual-outputs/multilingual-material/	

Activities for physical hologram making	The coins project	The seashell project	The plasticine figures project	The identity project
Activity description for teachers	https://holomakers.eu/wp-content/uploads/2019/02/TheCoin_project.pdf	https://holomakers.eu/wp-content/uploads/2019/02/Seashells_project.pdf	https://holomakers.eu/wp-content/uploads/2019/03/PlastecineFigures_project.pdf	https://holomakers.eu/wp-content/uploads/2019/03/Identity_project.pdf
Worksheet for students	https://holomakers.eu/wp-content/uploads/2019/01/TheCoin_Project-worksheet.pdf	https://holomakers.eu/wp-content/uploads/2019/03/Seashell_Project-worksheet.pdf	https://holomakers.eu/wp-content/uploads/2019/03/PlastecineFigures_project.pdf	https://holomakers.eu/wp-content/uploads/2019/03/Identity_Project-worksheet.pdf
Supporting material	https://holomakers.eu/wp-content/uploads/2019/01/ExternalResources-coins.pdf	https://holomakers.eu/wp-content/uploads/2019/01/ExternalResources-Seashells.pdf	https://holomakers.eu/wp-content/uploads/2019/01/ExternalResources-PlasticineFigures.pdf	https://holomakers.eu/wp-content/uploads/2019/03/ExternalResources-identity.pdf
Multilingual material	https://holomakers.eu/intellectual-outputs/multilingual-material/			

Working with the students	
The pilot protocol and the evaluation tools	https://holomakers.eu/intellectual-outputs/multilingual-material/

4.5.2 Videos

A number of videos are available for teachers in order to familiarize themselves with the process and get inspiration from the interviewees (teachers, experts, artists, students). Examples of videos and full playlist are presented below:

Figure 24 Example of technical video- how to assembly the Holokit

Figure 25 Talking about educational benefits

Figure 26 Talking with artists (Alex Fanelli)

Figure 27 Talking with the participating students

Full list	**https://www.youtube.com/watch?v=wFbqvzraYds&list=PLOwbn7Ap_g_AJyXFC8Dxq4DO37PL4uWWb**
Videos on pedagogical aspects and interviews with experts and artists	https://www.youtube.com/playlist?list=PLOwbn7Ap_g_DD3gyOTynEiYBTa1p87c1H
Feedback retrieved by students	https://www.youtube.com/playlist?list=PLOwbn7Ap_g_AHitmIoeSMQeX4cyD1PnMh
Videos on technical aspects	https://www.youtube.com/playlist?list=PLOwbn7Ap_g_BBl-Dhn0-T2WK_dmllkOra

4.5.3 Interactive animations

In order to help students develop understanding around the basic concepts of holography (coherence and interference) three interactive animations have been created. The teachers and the students can play with different paraments (quality of coherence, phase, number of sources etc) and see how their choices affect the coherence or the interference patterns. In this way an abstract phenomenon gets a more visual form helping students better understand the concepts.

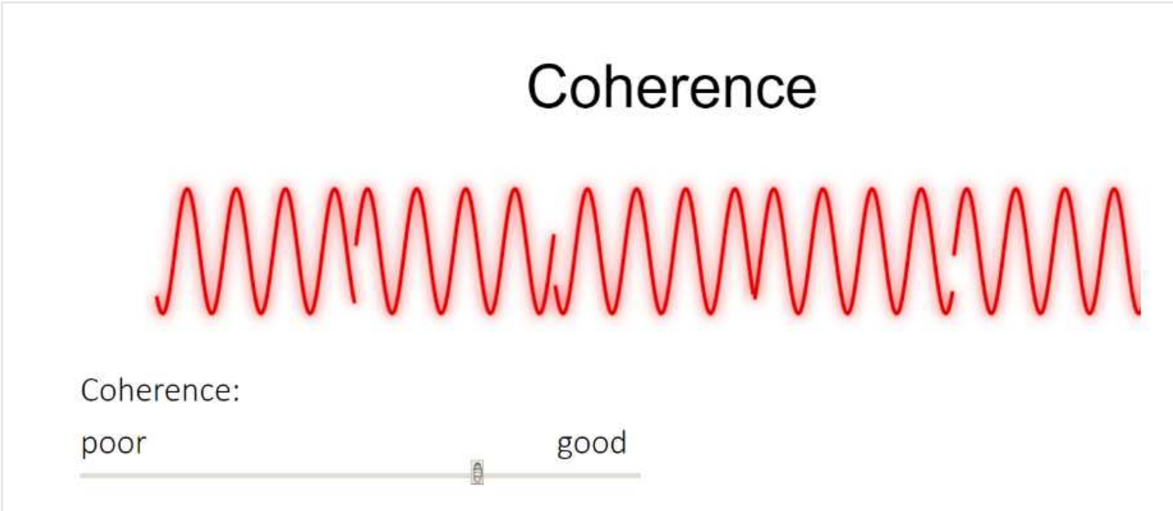


Figure 28 Interactive animation for the concept of coherence

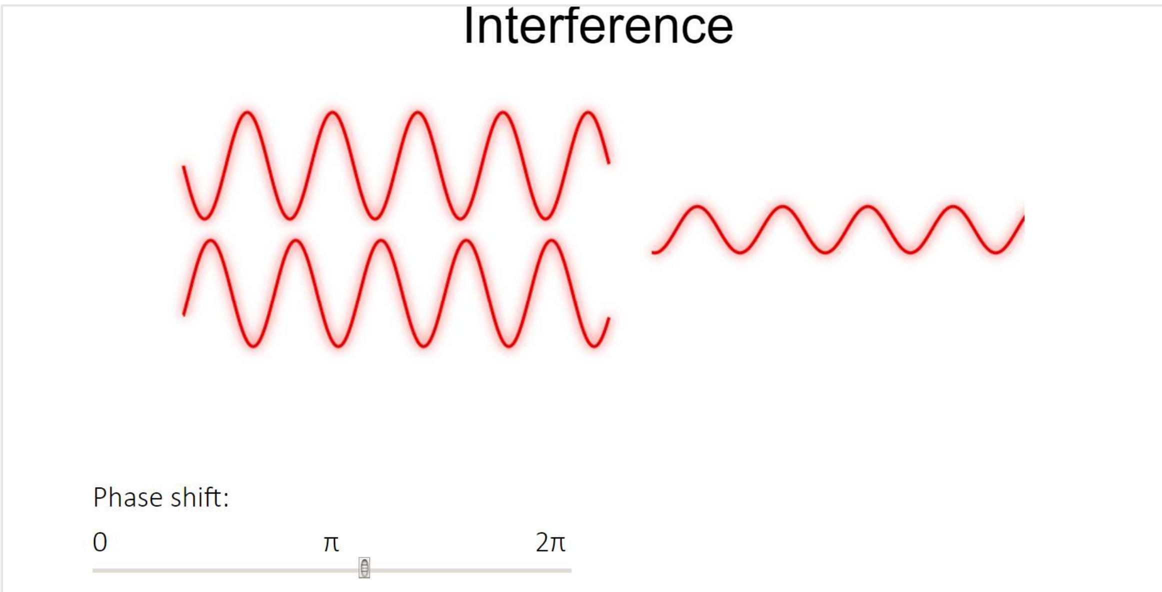


Figure 29 Interactive animation for the concept of interference

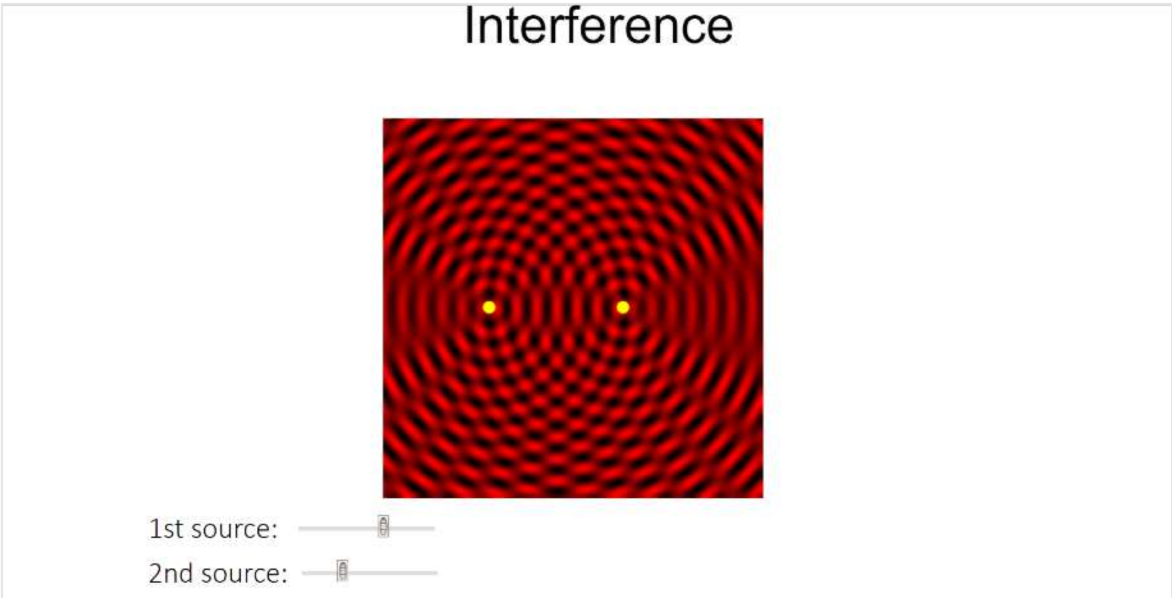


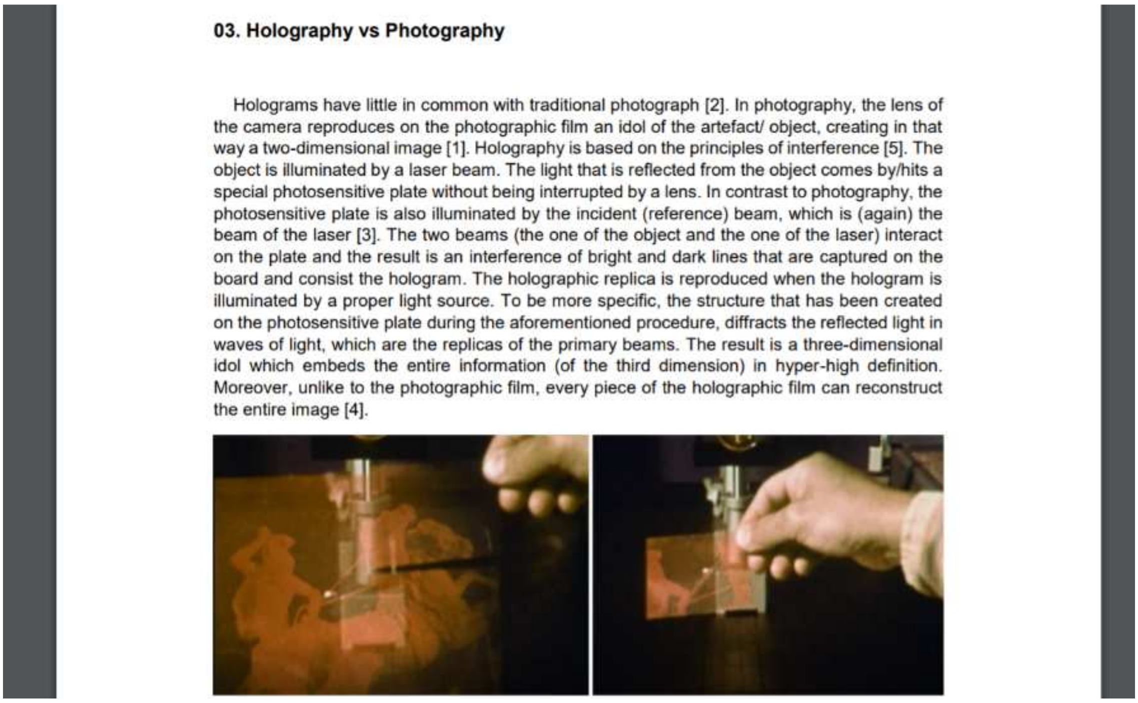
Figure 30Interactive animation for the concept of Interference (2 sources).

The interactive animations can be found online at: https://holomakers.eu/interactive-animations/

4.5.4 Additional supporting material for teachers

In the context of the project a number of open educational resources have been also developed in order to better support teachers in introducing the Holomakers initiative in the class and carrying out the Holomakers learning intervention. The resources revolve around several aspects of holography including: defining holography and holograms, the history of holographyt, Holography and the 3rd dimension, types of holograms, holography vs photography, examples of holograms, introduction to hologram making with the Holokit and more.

The resources can be accessed from here: https://holomakers.eu/oers/



03. Holography vs Photography

Holograms have little in common with traditional photograph [2]. In photography, the lens of the camera reproduces on the photographic film an idol of the artefact/ object, creating in that way a two-dimensional image [1]. Holography is based on the principles of interference [5]. The object is illuminated by a laser beam. The light that is reflected from the object comes by/hits a special photosensitive plate without being interrupted by a lens. In contrast to photography, the photosensitive plate is also illuminated by the incident (reference) beam, which is (again) the beam of the laser [3]. The two beams (the one of the object and the one of the laser) interact on the plate and the result is an interference of bright and dark lines that are captured on the board and consist the hologram. The holographic replica is reproduced when the hologram is illuminated by a proper light source. To be more specific, the structure that has been created on the photosensitive plate during the aforementioned procedure, diffracts the reflected light in waves of light, which are the replicas of the primary beams. The result is a three-dimensional idol which embeds the entire information (of the third dimension) in hyper-high definition. Moreover, unlike to the photographic film, every piece of the holographic film can reconstruct the entire image [4].

Figure 31 Example of the stucture of the resources

The Holomakers initiative embraces failures and use them from a pedagogical point of view to re-enforce learning. Failures are seen as significant opportunities for learning, for improvement, for critical reflection upon the final result. This conception is in line with research and scientific practices and it is important students to start realizing that repetition of holographic recordings is part of the scientific and research process. For this reason, a document with successful and less successful holographic attempts have been prepared. Teachers can use this document to help students see failures as integral part of the process that they go through and as an opportunity for remedial actions and improvements.

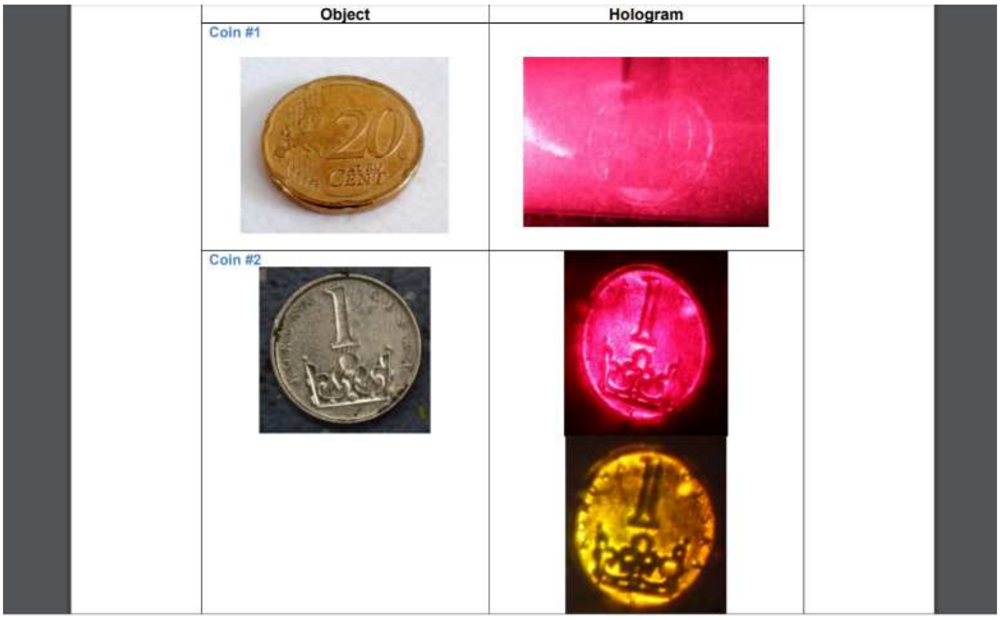


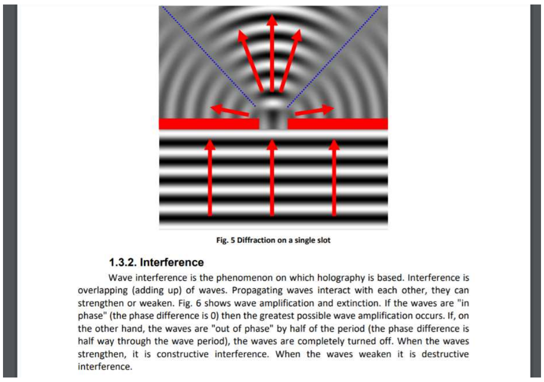
Figure 32 Examples of succesful and less succesful attempts

You can access the file from here: https://holomakers.eu/wp-content/uploads/2019/03/HologramList.pdf

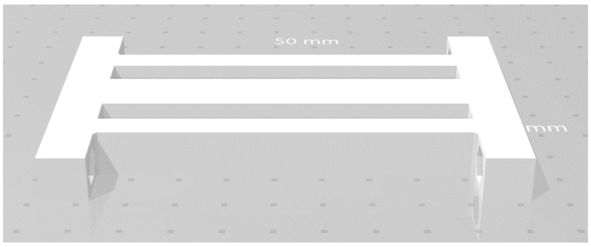
Figure 33 Optoclone created by the Hellenic Institute of Holography.

It is worth showing students examples of holograms recorded in professional settings from the research community (i.e. Warsaw University, Hellenic Institute of Technology[9] and more) and raise the dialogue around the practical applications of holograms.

Among the resources that have been developed are the Technical Reference Guide for teachers, the reference guide for setting up the Holokit, the models needed for the reproduction of the Holokit and the pilot protocol. The technical tutorial aims at guiding teachers through the basic concepts of physics underpinning the holographic process as well as describing in an easy to grasp way how Octave software can be used for computer-generated holograms making. The Holokit reference guide presents in an easy way how one can assembly the Holokit (it should be seen together with the related video). In addition, the Holokit is “demistified” and access to all the components that comprise it is given; in this way the reproduction by the teachers and interested individuals is possible. Last, the pilot protocol is also available for teachers where information on how to work with the students in the context of the pilots are provided together with the evaluation procedures that should be followed.

Technical OERs	 Fig. 5 Diffraction on a single slot **1.3.2. Interference** Wave interference is the phenomenon on which holography is based. Interference is overlapping (adding up) of waves. Propagating waves interact with each other, they can strengthen or weaken. Fig. 6 shows wave amplification and extinction. If the waves are "in phase" (the phase difference is 0) then the greatest possible wave amplification occurs. If, on the other hand, the waves are "out of phase" by half of the period (the phase difference is half way through the wave period), the waves are completely turned off. When the waves strengthen, it is constructive interference. When the waves weaken it is destructive interference. Technical Reference guide: https://holomakers.eu/wp-content/uploads/2019/11/HOLOMAKERS-Technical-Reference-Guide.pdf

[9] http://www.hih.org.gr/en.html

	 Holokit reference guide: https://holomakers.eu/wp-content/uploads/2019/01/Holomakers_holokit_ReferenceGuide.pdf  Models for reproducing the Holoki: https://holomakers.eu/uncategorized/the-3d-models-of-the-holokit/
Pilot deployment guidelines	The pilot protocol: https://holomakers.eu/wp-content/uploads/2019/11/O4-PilotProtocol-_final.pdf

4.6 The online class

An online class (https://holomakers.eu/online-class/) in available where interested teachers can register and get free access to the educational resources developed in the context of the Holomakers project (for registration guidelines see Appendix). The online class is open to everyone interested in the Holomakers learning initiative (teachers, educators, makers, educational practitioners, trainers, perspective students). It acts as a repository of educational content (thematically organised) but in addition offers services that support the e-learning practice (communication tools (i.e. chatroom), announcement area, external links area, direct contact with experts through email, multimedia section and more). The class and the Holomakers course will be freely open for 5 years (post project implementation period) and all the resources are available under the Creative Commons License "Share Alike" to further boost the exploitation of the project outcomes.

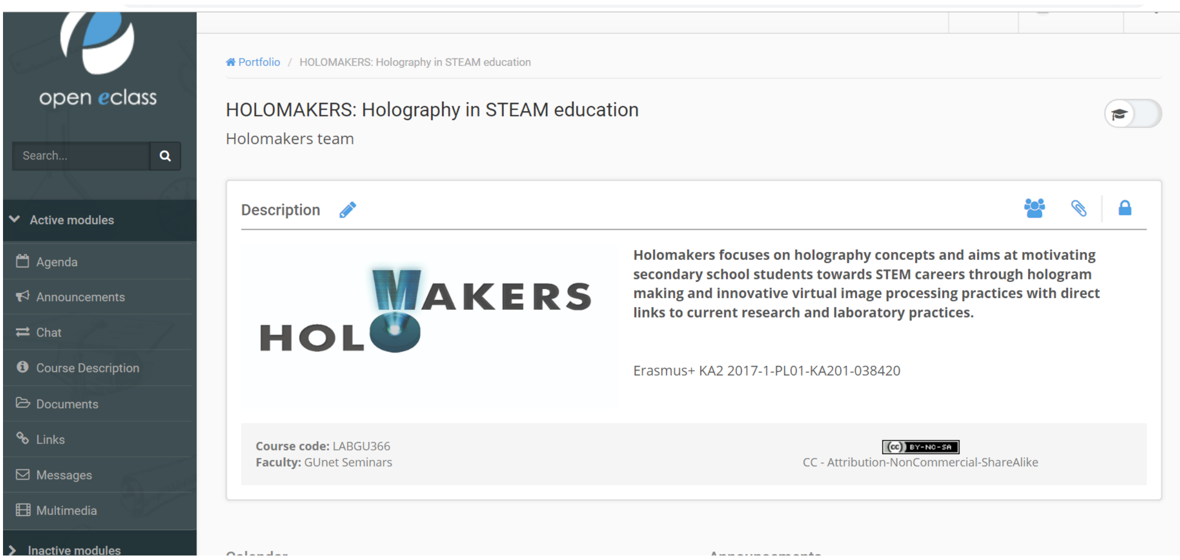


Figure 34 The Holomakers online class

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5 Appendix

5.1 The Holomakers class- Registration guidelines for teachers

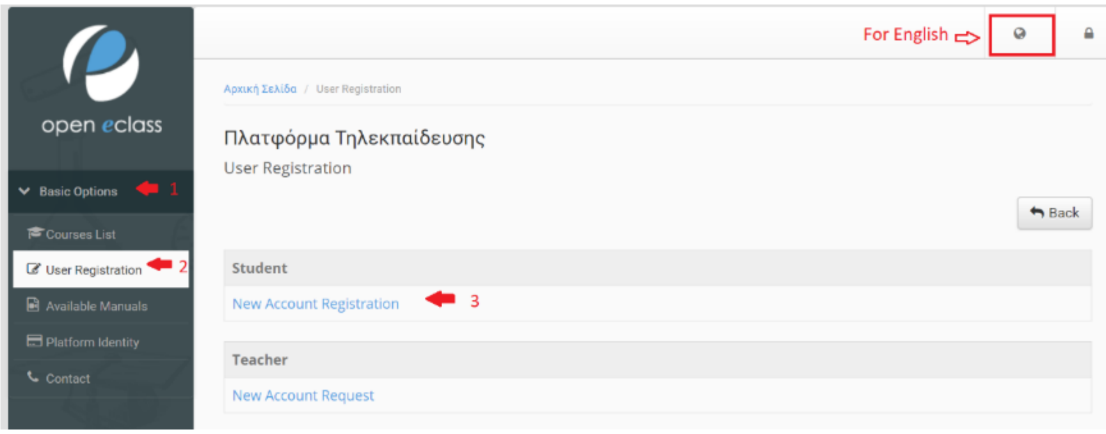
How can I register myself?

How can I register myself?

1) Click the link below to start the registration process

   https://eclass.gunet.gr/index.php?localize=en

   Click Register and then go to "student registration box" and select "New Account registration" (see picture below)



2) **Please provide all the information needed**. Fill in your name, surname, username, password, email and select Faculty.

Please, take care of the following points:

Email

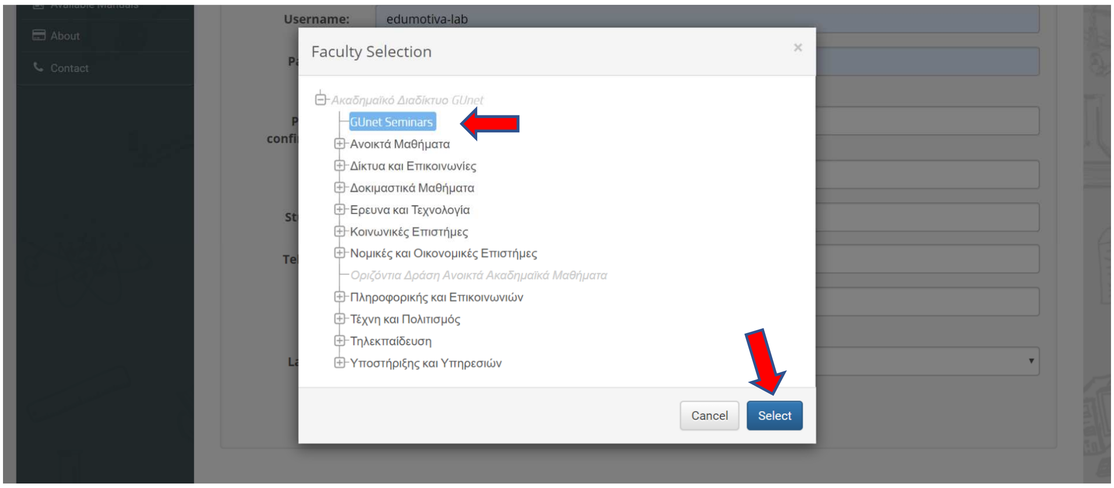
Email may appear as optional, but you are advised to put it here because it will ease the registration process and will help our communication (i.e. you can receive recent announcements etc).

StudentID

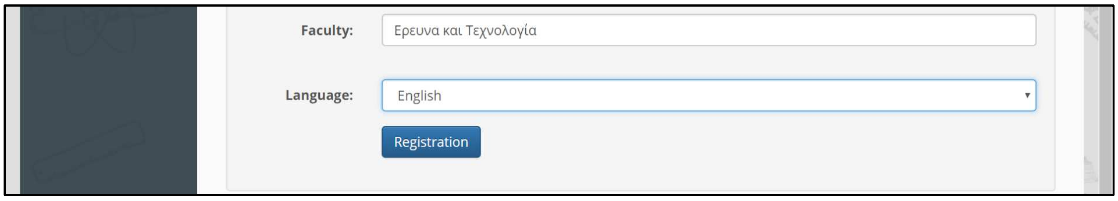
StudentID is: you can leave it empty or *optionally type down:* ***holomakers***

Faculty

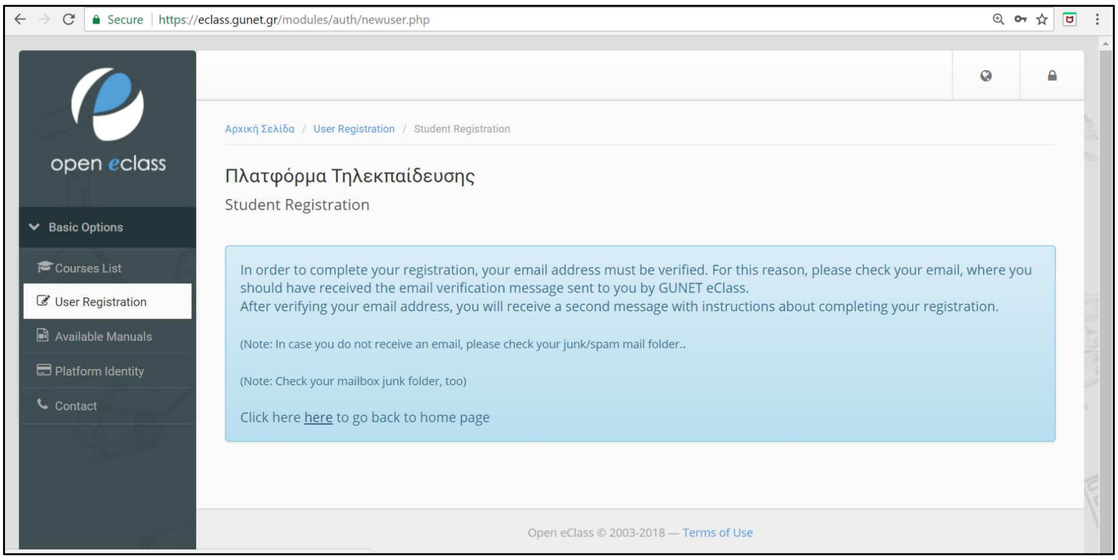
You should select the **option GUnet Seminars)** (see picture below) and then click on the "select" button.



You can select also the language and then click 'Registration'



3) Great! Now your email address must be verified. So please check your mailbox. A confirmation email has been sent to you by GUNET eClass.

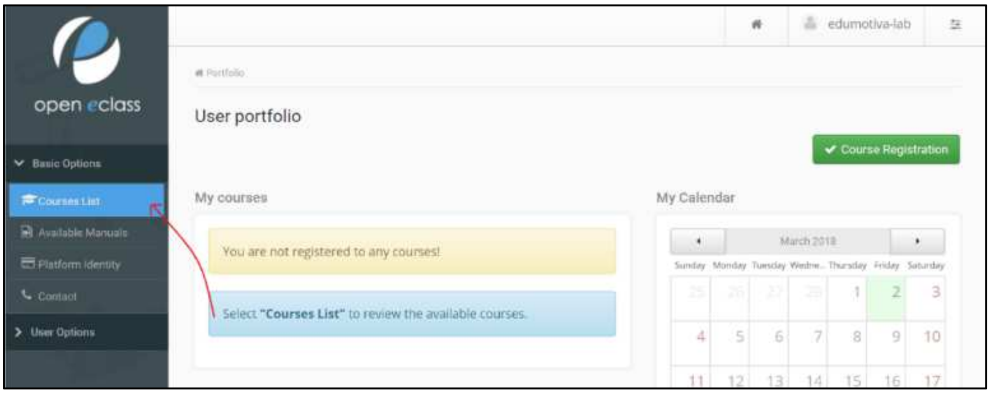


4) Log in using your username and password.

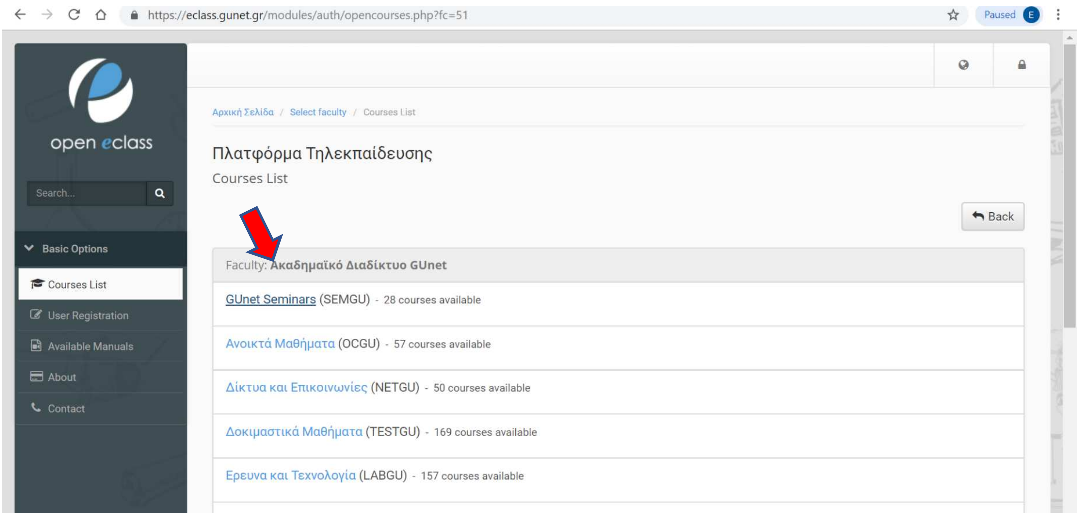
https://eclass.gunet.gr/main/login_form.php?next=%2Fcourses%2FLABGU366%2F

5) **Great!** The final step now is to express your interest in registering to the Holomakers course. Read the steps and see the pictures below.

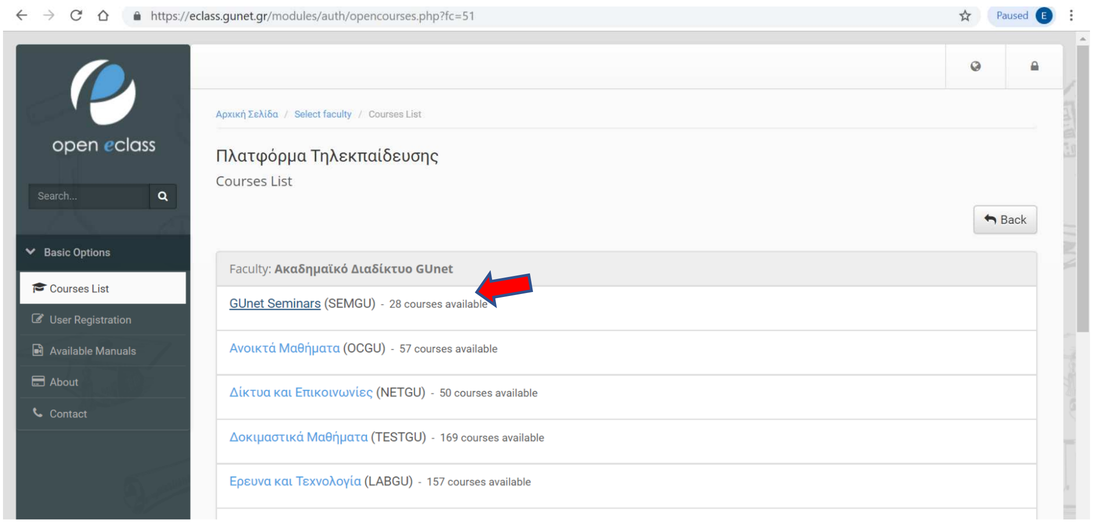
Click on the **course list** **(1)**, then on the **Faculty** **(2)** and then scroll down and select **'GUnet Seminars'** **(3)** and from the list select **HOLOMAKERS (LABGU366)** **(4)**



(1)


https://eclass.gunet.gr/modules/auth/opencourses.php?fc=51
open eclass
Αρχική Σελίδα / Select faculty / Courses List
Πλατφόρμα Τηλεκπαίδευσης
Courses List
Back
Basic Options
Courses List
User Registration
Available Manuals
About
Contact
Faculty: Ακαδημαϊκό Διαδίκτυο GUnet
GUnet Seminars (SEMGU) - 28 courses available
Ανοικτά Μαθήματα (OCGU) - 57 courses available
Δίκτυα και Επικοινωνίες (NETGU) - 50 courses available
Δοκιμαστικά Μαθήματα (TESTGU) - 169 courses available
Ερευνα και Τεχνολογία (LABGU) - 157 courses available

(1)


https://eclass.gunet.gr/modules/auth/opencourses.php?fc=51
open eclass
Αρχική Σελίδα / Select faculty / Courses List
Πλατφόρμα Τηλεκπαίδευσης
Courses List
Back
Basic Options
Courses List
User Registration
Available Manuals
About
Contact
Faculty: Ακαδημαϊκό Διαδίκτυο GUnet
GUnet Seminars (SEMGU) - 28 courses available
Ανοικτά Μαθήματα (OCGU) - 57 courses available
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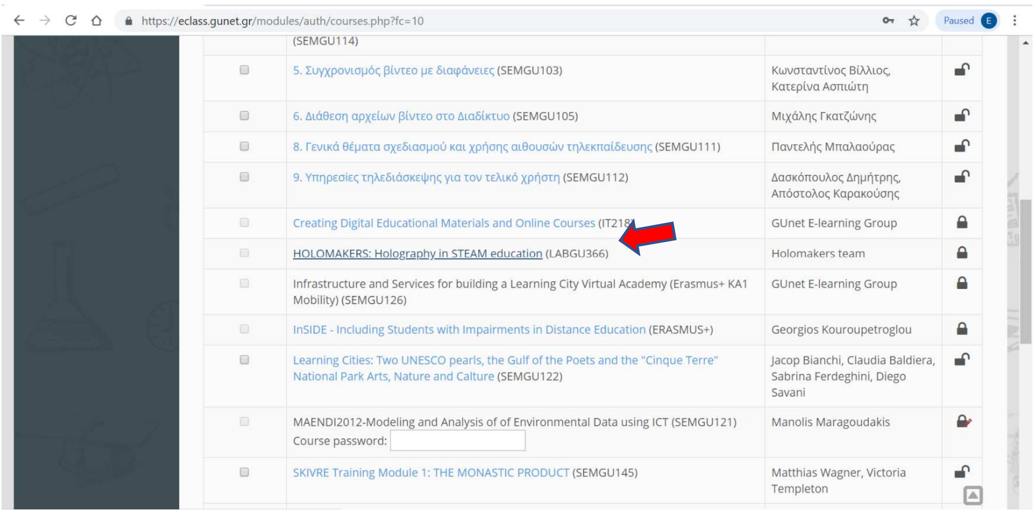
Δοκιμαστικά Μαθήματα (TESTGU) - 169 courses available
Ερευνα και Τεχνολογία (LABGU) - 157 courses available

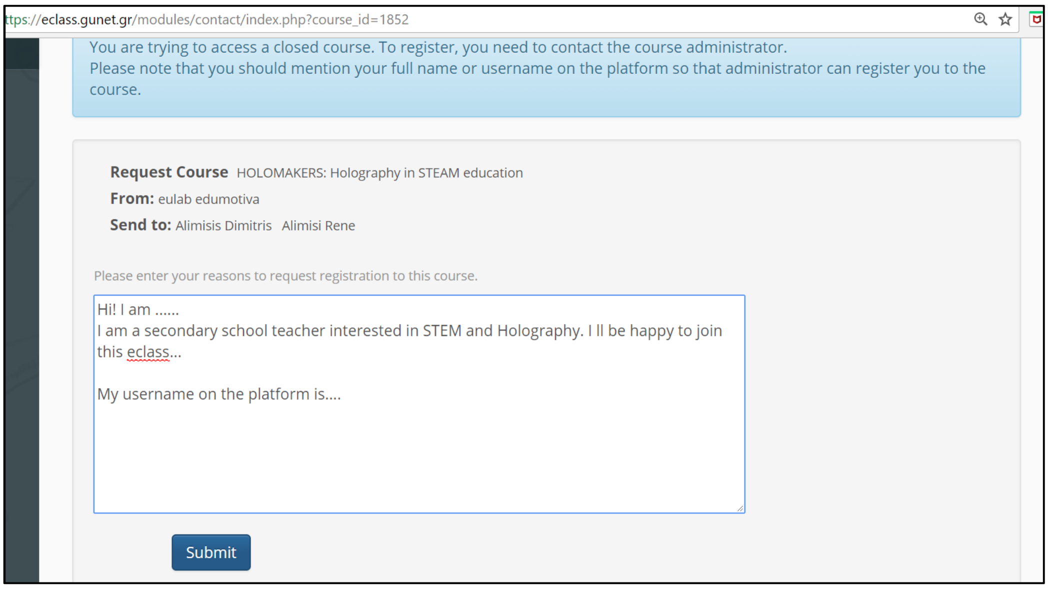
(3)


https://eclass.gunet.gr/modules/auth/courses.php?fc=10
5. Συγχρονισμός βίντεο με διαφάνειες (SEMGU103)
Κωνσταντίνος Βίλλιος, Κατερίνα Ασπιώτη
6. Διάθεση αρχείων βίντεο στο Διαδίκτυο (SEMGU105)
Μιχάλης Γκατζώνης
8. Γενικά θέματα σχεδιασμού και χρήσης αιθουσών τηλεκπαίδευσης (SEMGU111)
Παντελής Μπαλαούρας
9. Υπηρεσίες τηλεδιάσκεψης για τον τελικό χρήστη (SEMGU112)
Δασκόπουλος Δημήτρης, Απόστολος Καρακούσης
Creating Digital Educational Materials and Online Courses (IT218)
GUnet E-learning Group
HOLOMAKERS: Holography in STEAM education (LABGU366)
Holomakers team
Infrastructure and Services for building a Learning City Virtual Academy (Erasmus+ KA1 Mobility) (SEMGU126)
GUnet E-learning Group
InSIDE - Including Students with Impairments in Distance Education (ERASMUS+)
Georgios Kouroupetroglou
Learning Cities: Two UNESCO pearls, the Gulf of the Poets and the "Cinque Terre" National Park Arts, Nature and Calture (SEMGU122)
Jacop Bianchi, Claudia Baldiera, Sabrina Ferdeghini, Diego Savani
MAENDI2012-Modeling and Analysis of of Environmental Data using ICT (SEMGU121)
Course password:
Manolis Maragoudakis
SKIVRE Training Module 1: THE MONASTIC PRODUCT (SEMGU145)
Matthias Wagner, Victoria Templeton

(4)

Great! Almost there…just complete the request form (simply do not leave it empty) and click **Submit**

For example:



In case you have any problem, do not hesitate to contact us at info@holomakers.eu

Website: http://holomakers.eu

Twitter: @holomakers_eu

Facebook: @holomakers