June 2023

STEAMTeach

Science | Technology | Engineering | Arts | Mathematics

O3: TEACHERS IMPLEMENTING STEAMTEACH IN THEIR CLASSROOMS WITH THEIR STUDENTS

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

PROJECT

PROJECT ACRONYM	STEAMTeach
PROJECT TITLE	STEAM Education for Teaching Professionalism
PROJECT REFERENCE	2020-1-ES01-KA201-082102
START DATE	1st October 2020
KEY ACTION	Cooperation for innovation and the exchange of good practices
ACTION TYPE	Strategic Partnerships for school education

INTELLECTUAL OUTPUT DETAILS

INTELLECTUAL OUTPUT (IO) NUMBER AND TITLE	O3: Teachers implementing STEAMTeach in their classrooms with their students
RESPONSIBLE ORGANISER OF THE IO	Jyvaskylan Yliopisto
START DATE	1st October 2020
END DATE	30nd June 2023
MEDIA	Text File
DISSEMINATION LEVEL	Public

REPORT DETAILS

VERSION	1.0
DATE	30th June 2023
MAIN AUTHORS' NAME AND EMAIL ADDRESS	Kristof Fenyvesi[1] (fenyvesi.kristof@gmail.com), Zaira Ortiz-Laso[2] (ortizz@unican.es), José Manuel Diego-Mantecón[2] (diegojm@unican.es), Tony Houghton[3] (ajh249@gmail.com), Dimitris Diamantidis[4] (dimitrd@eds.uoa.gr), and Vilmos Vass[5] (vvass@metropolitan.hu)
CONTRIBUTING INSTITUTIONS	[1]Jyvaskylan Yliopisto, [2]Universidad de Cantabria, [3]Universitat Linz, [4]Ethniko Kai Kapodistriako Panepistimio Athinon, and [5]Budapesti Metropolitan Egyetem

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

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

REVIEWED BY	Zaira Ortiz-Laso[2] (ortizz@unican.es) and José Manuel Diego-Mantecón[2] (diegojm@unican.es)
STATUS	Submitted

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

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

TABLE OF CONTENTS

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

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

1 INTRODUCTION

Each consortium partner worked with at least 5 teachers who were already trained in IO2. The purpose of the collaboration was to support the teachers to implement STEAM activities in their classrooms with their students. A number of pre-service teachers participating in the IO2 were also selected to be observed during their school practice. Pre-service teachers often undertook a period of practice at schools as part of the university programmes in which they were involved. All the selected teachers were evaluated while implementing the STEAM approach in their classrooms.

Observations and interviews were carried out to assess the impact of the programmes (IO2) in the classrooms. An observation guide was developed for evaluating the different aspects of the practices; for example, the STEAM methodologies and approaches that were implemented by the teachers during the instruction (e.g. inclusive pedagogy models, inquiry-based learning or engineering design process), the innovative tools that were employed (e.g. original technology and software used) and the interdisciplinary learning that took place (e.g. interdisciplinary curricular content introduced; teacher-student co-creation of knowledge). We also evaluated whether the instruction had a real impact on students' motivation and learning, as well as teacher satisfaction with their practice.

The STEAM Teach implementation was undertaken in Phase 1 and Phase 2, according to the design and development of Programme 1 and Programme 2, being the latter a refinement of the former. The implemented activities covered different education trends, including computational thinking tools, apps (e.g. GeoGebra), models, and digital fabrication solutions (e.g. 3D printing). The implementation phases also introduced community- and practice-based, co-created pedagogical models, including: (1) culture and gender-inclusive problem-solving through learning activities, (2) different kinds and levels of participation, and (3) competencies needed in various types of participation in culturally diverse societies existing in technologically rich environments.

IO3 generated an open access repository in the project website from the materials used by the teachers during the implementation phases: activities description, resolution of activities, materials, and teacher's recommendations about how to use the material and about how to assess the STEAM activities within each particular curriculum.

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

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

The evaluation of the implementation followed these steps in each phase:

During the realization of IO3, each partner selected the teachers working on the implementation phases according to their implication in the training programmes. Each partner encouraged their teachers to select materials relevant to their activities, adjust them to their own uses, and suggest developments in follow-up co-creation sessions.

1. **Country- and Topic-specific assessments of the STEAMteach implemented.** Each partner contributed to the comparative assessment to explore the differences and similarities between the implementation carried out in each context, and the teacher satisfaction and expectations related to this question.
2. **The process and outcomes of Phases 1 and 2 were documented and communicated** by each partner. Overall coordination and information were provided by JYU.
3. **The report is written** with the outcomes obtained from the implementation phases.

2 INTERNATIONAL COMMUNITY

In the project's original submission, we presented IO4 under the title 'Fostering International Teacher Collaboration: Co-creating Ideas and Advancing Knowledge Together.' Regrettably, the evaluators did not deem it a priority, leading to its non-approval and subsequent lack of funding. The core objective of this output was to establish a dynamic international community where our STEAMTeach educators could collaborate virtually, thus enriching the implementation stages within their unique contexts. This platform was designed to facilitate the exchange of innovative ideas and constructive feedback from teachers across the participant contexts. Although this particular intellectual output did not receive the financial support, we were unwavering in our commitment to nurturing this community. Our belief in its potential to enrich implementation across our partners remained steadfast, and thus we establish such community.

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

Strategy

The main strategy of the STEAMTeach project to establish a European teachers' community was to have an impact at school and national levels to strengthen connections between teachers from different countries then (Figure 1). In this sense, the five partners acted individually to enhance collaborations between the teachers attending the professional development and non-participant teachers in her/his school. This interaction aimed to identify collaborators in the immediate context to design and implement a STEAM project. When those connections were established, the interactions were beyond and the STEAMTeach project attempted to establish a national network for supporting teachers technically and emotionally. These national connections contributed, for example, to overcome difficulties in each particular context related to the curriculum and the lack of resources. They also helped teachers who did not find any colleague in her/his school to feel sustained by others who are also willing to abandon the traditional learning approach for training competent students. In May 2022, the University of Cantabria partner required the remaining participants to recruit at least two teachers from their national communities to take part in a larger-level community. The profile of participants should be teachers with fluent English who were active in the national connections for both sharing their own materials and being flexible when receiving recommendations from colleagues and trainers.

Figure 1: STEAMTeach approach to promote collaborations among teachers

The European-level community was launched during the transnational project meeting in Greece (June 2022). This date was strategically chosen for secondary education teachers to be able to start to work in an international context at the beginning of the next academic year. In that event, the selected secondary education teachers from Austria, Hungary, Spain, and Greece explained their backgrounds, teacher experience, and their goals (https://www.steamteach.unican.es/collaborations/). Some teachers attended the event

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

face-to-face (Spain and Greece), and others online. After that event, teachers were split into groups according to their interests. For example, two Austrian teachers, two Spanish, one Hungarian, and one Greek were distributed in a group because they were interested in computational thinking and/or sustainability- related topics. The following link contains information on one of the meetings carried out in October 2022 and coordinated by a STEAMTeach trainer can be found https://www.steamteach.unican.es/october-2022-online/). Interactions between this group resulted, for instance, in an adaptation of the project implemented by the Spanish teachers in Greek regular lessons (Vertical Garden), and one activity proposed by Hungarian trainers for training teachers. A collective meeting (online and face-to-face) in which most teachers participating in the international community summarized their experience was scheduled (https://www.steamteach.unican.es/december-2022-online-linz/). After this meeting, and considering previous observations in each country, a collection of recommendations was provided for establishing effective communities:

- Establishing initially a national community for knowing teachers' interest and expertise
- Involving teachers with fluent English level
- Organizing an international kick-off session in which the teachers explain their interests
- Planning periodically encounters organized by community creators
- Motivating the community at international (e.g., email) and national (e.g., mail and phone) levels
- Transmitting the support of the community trainers

We believe that this international community provided a platform for educators to acquire insights, consequently leading to improvements in the individual partner implementations discussed in the subsequent sections.

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

3 IMPLEMENTATION IN SPAIN

In Spain two implementation phases took place. Most teachers shared the projects that have designed as part of the STEAMTeach professional development preprogramme (e.g. teaching guides, videos). These activities have been shared in the project website https://www.steamteach.unican.es/spanish-implementation/ together with information of the context in which the activity was executed. In addition, high quality projects have been compiled in the Open STEAM Group repository of STEAM projects https://www.opensteamgroup.unican.es/repository/

3.1 Phase 1

The first implementation phase in Spain was conducted between March 2022 and April 2022 and involved nineteen in-service and pre-service teachers from nine educational centres. A total of 19 in-service teachers in Cantabria undertook STEAM activities after attending the STEAMTeach professional development programme. We did involve not only secondary education teachers (10), which are the main target group of the STEAMTeach project but also primary (8) and early childhood education (1) teachers. In addition, a secondary education pre-service teacher (1) implemented a project, with the support of an in-service teacher, as part of his master's thesis for the Teacher Training Master's Degree at the Universidad de Cantabria. These teachers completed eleven projects. The following table collects the project title, educational stage, number of teachers implementing the project, and school name.

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

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

Project title	Educational stage	Teacher number	School name
The Room: A Mathematics Museum	Secondary	1	IES Ricardo Bernardo
At the head of the evolution	Secondary	2	Colegio San José - Reinosa
A bridge	Secondary	2	Colegio San José - Santander
Using the butts	Secondary	1	IES Augusto González de Linares
Pong Reloaded	Secondary	1	IES Marqués de Santillana
Robotics in viticulture	Secondary	1	Colegio El Salvador
Sustainable architecture	Secondary	2	Colegio El Salvador
How noisy is it at school?	Primary	4	CEIP Gerardo Diego
Volcanos	Primary	2	Colegio San José - Santander
Solar cars	Primary	2	CEIP Miguel Hernández
Pirate's food	Early Childhood	1	CEIP Jose Ramón Sánchez

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

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

Three hundred thirty-seven (377) students executed the implementation of the above projects. In particular, 138 were secondary education students, 169 were in primary education, and 20 were in early childhood education. Most secondary education students belonged to compulsory schooling, representing the four grades, whereas the primary education pupils were in the last two years. The following table collects the grade and the number of students that executed each project.

Project title	**Grade**	**Student number**
The Room: a Mathematics Museum	1st CSE	10
At the head of the evolution	2nd CSE	6
A bridge	4th CSE	12
Using the butts	2nd CSE	60
Pong Reloaded	1st B	27
Robotics in viticulture	3rd CSE	6
Sustainable architecture	4th CSE	17
How noisy is it at school?	6th PE	96
Volcanos	5th PE	31
Solar cars	5th PE	42
Pirate's food	3rd ECS	20

Explanation of the acronyms: CSE (Compulsory Secondary Education), B (Baccalaureate), PE (Primary Education), and Early Childhood Education (ECS)

3.2 Phase 2

The second implementation phase in Spain was carried out from March 2023 to May 2023. Twenty-four in-service teachers from seven educational centres in Cantabria completed STEAM activities after participating in the second phase of the STEAMTeach professional development programme. They were secondary education (21) and primary education (4) teachers. It is worth mentioning that five secondary education teachers undertook projects in the two STEAMTeach implementation phases. The following table

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

shows the educational stage in which the project was implemented, the number of teachers involved in its implementation, and the school in which was executed.

Project title	**Educational stage**	**Teacher number**	**School name**
Space junk	Secondary	2	IES Manuel Gutiérrez Aragón
1, 2, 3… Ignition!	Secondary	2	Colegio San José - Reinosa
Music and mathematics: a perfect combination	Secondary	2	Colegio Menéndez Pelayo – Castro Urdiales
Sailing in clean seas	Secondary	2	Colegio San José - Reinosa
To infinity and beyond	Secondary	2	Colegio San José - Reinosa
Tracker and San Mateo festival	Secondary	2	Colegio San José - Reinosa
The other side of the screen	Secondary	2	Colegio Bellavista Julio Blanco
LareMate	Secondary	1	IES Fuente Fresnedo
Fashion Footprint	Secondary	3	Colegio El Salvador
Climate change and the melting of the poles	Secondary	3	IES Ricardo Bernardo
Sustainable city	Primary	2	Colegio San José - Reinosa
Solar car Racing	Primary	2	CEIP María Sanz de Sautuola

As shown in the table below, 329 students completed the above project, with 221 of them taking compulsory secondary education. The projects were implemented in the four grades of compulsory secondary education, and the last three grades of primary education.

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

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

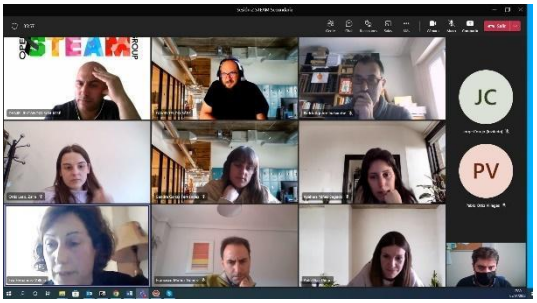
Project title	Grade	Student number
Space junk	4th CSE	20
1, 2, 3… Ignition!	2nd CSE	26
Music and mathematics: a perfect combination	1st CSE	54
Sailing in clean seas	3rd CSE	8
To infinity and beyond	1st CSE	32
Tracker and San Mateo festival	4th CSE	19
The other side of the screen	4th CSE	7
LareMate	3rd CSE	15
Fashion Footprint	3rd CSE	10
Climate change and the melting of the poles	1st CSE	30
Sustainable city	5th PE	21
Solar car racing	4th and 6th PE	87

CSE (Compulsory Secondary Education) and PE (Primary Education)

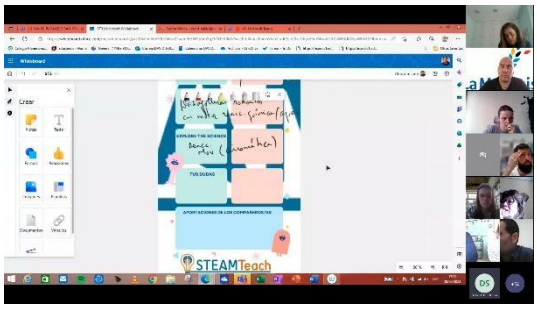
3.3 Evaluation

During the implementation of projects, teachers attended at least two online group meetings. The first meeting aimed to reflect on the initial project design (target group, content to be addressed, the context in which the project was framed and doubts). The second one sought to reflect on the project implementation (difficulties, feelings, and possible extension). These group discussions, in addition to forms that they filled out before each online meeting and finalising the implementation, allowed having in-depth information about each implementation phase.

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.



Second online meeting with high school teachers in April 2022



Second online meeting with teachers in May 2023

After teachers' testimonies in phase 1, we introduced small changes in the second implementation phase related to (1) time execution, and (2) teachers' knowledge.

(1) Most projects in phase 1 were executed between March and April 2022, culminating with the exhibition of projects at the University of Cantabria Science Fair Festival (KIKS format; Diego-Mantecón et al., 2021). However, teachers during the joint meetings and individual interviews expressed that they felt pressure to complete the activities during that period. One teacher verbalised: "It was difficult to allocate time in my schedule so that my students could present the project at the Science Fair Festival". Consequently, in the second implementation phase, we decided to extend the time execution and organising and own event for showing teacher and student products.

(2) In implementation 1, most teachers designing and implementing the projects alone recognised to have more difficulties than the ones working jointly with at least another educator. For the second training phase, we prioritised the enrolment of teachers who applied for the programme with a colleague. This strategy, recommended by Diego-Mantecón et al. (2022), explains why in the second implementation phase at least two teachers intervened in the project execution (see table 3). This modification facilitated project design, however teachers reported that it was difficult to find hours to meet within their workday.

Teachers found the implementation of STEAM projects useful for their students, and they recognised that their students were motivated because of the KIKS format features. It is noteworthy that teachers participating in the second phase of the implementation were

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

especially unconfident with the project evaluation. This is because in Spain a new educational law has begun to be implemented in 2023, and teachers have been asked to adapt their practice and evaluation to a competency-based learning approach, generating a general dissatisfaction among teachers.

4 IMPLEMENTATION IN AUSTRIA

In Austria, two implementation phases occurred. The majority of teachers shared the projects they had designed as part of the STEAMTeach professional development preprogramme, which included teaching guides and photos. These activities were shared on the project website at https://www.steamteach.unican.es/austrian-implementation/, along with contextual information about the execution of each activity.

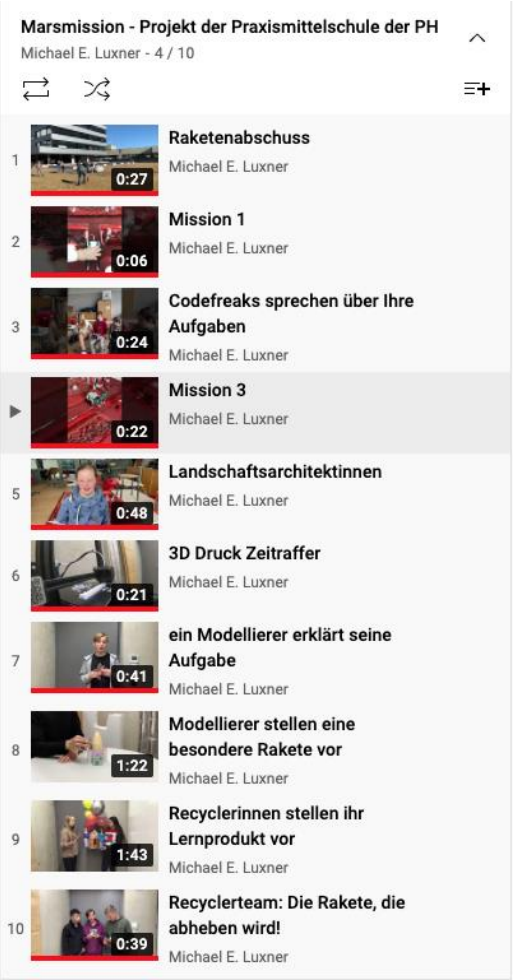
4.1 Phase 1

The first implementation phase in Austria was conducted in March 2022 and involved 5 in-service and 5 pre-service teachers from two educational centres. A total of 10 in-service teachers in Innsbruck and Feldkirch undertook STEAM activities after attending the STEAMTeach professional development programme. These teachers worked together on two integrated STEAM projects displaying both teacher collaboration and student creativity resulting in eleven completed projects. The following table collects the project title, educational stage, number of teachers implementing the project, and school name.

Project title	**Educational stage**	**Teacher number**	**School name**
STEAM to Mars*	Secondary & associated middle school	1-5	Pedagogische Tirol Innsbruck
Let it STEAM, let it STEAM, let it STEAM!*	Secondary	6-10	Pädagogische Hochschule Vorarlberg

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

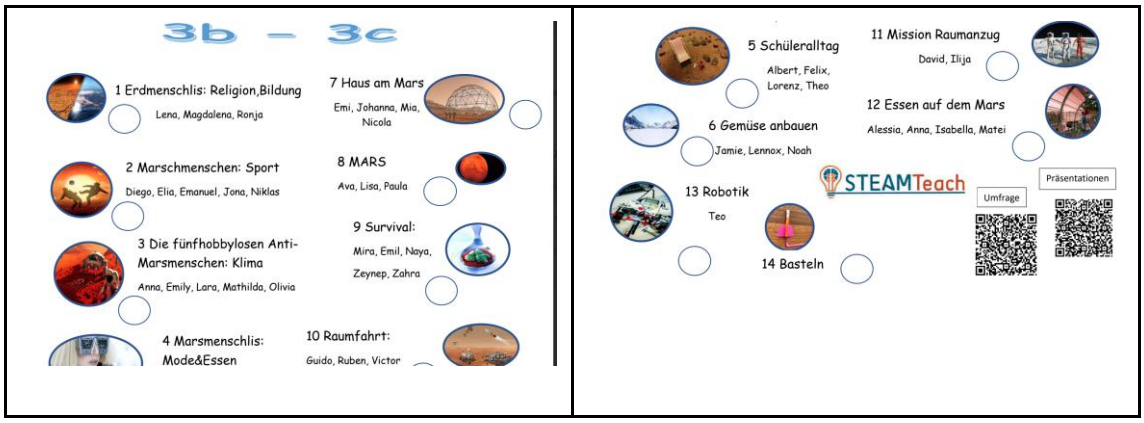
Due to the integrated nature of the projects, it was not possible to separate out the individual projects except from a student perspective - they produced 10 projects. From a teacher perspective, the summary description of the STEAM to Mars gives a flavour:



Modern STEAM education increasingly involves and includes new aspects of technology. This project intends to pick space travel as a highly engaging topic and design a concept, that includes all STEAM components. The concept is organised in stations, so students can choose from multiple small projects like 3D modelling and printing a mars-rocket, programming a mars-rover with scratch, planning and launching a water rocket and analysing its flight parabola via mobile devices or developing and printing 3D models of the planets within the solar system. We want to explore how such a project can be developed, and which subject-specific and interdisciplinary learning processes can be observed during the implementation in a fourth secondary school class.

Likewise, in Feldkirch, the Let it STEAM initiative led to a variety of stimulating activities, ranging from Origami to iPad exploration, constructing a house using 3D printing, and visiting a local 3D company involved in house construction (details provided in the subsequent sections). This effort culminated in the presentation of 14 projects to the school, parents, and the community (refer also to the final section):

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.



An average of 60 students participated in the projects (with some dipping in and out).

4.2 Phase 2

The second implementation phase in Austria was carried out from March 2023 until the end of the project. Again, ten core teachers engaged in developing the current and new projects in collaboration between the two organisations in Feldkirch and Innsbruck. However, it will be noted that with the collaborative nature of the project, more educators were involved, for example, 11 extra Tyrol schools (numbers not known), community partners educational and commercial. The following table shows the educational stage in which the project was implemented, together with a summary description:

STEAM to Mars project - award winning to be extended in Innsbruck and with Feldkirch.

BREAD project - excellent wide ranging STEAM project, demonstrable involvement of various teacher disciplines, responding to child-centred developments, reflection/assessment slides.

Digital air quality - real problem, community of experts from health/ construction, 11 Tyrol schools.

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

Project title	Educational stage	Teacher number	School name
Let it STEAM!	Secondary	5	Pädagogische Hochschule Vorarlberg
STEAM to Mars	Secondary	5	Pedagogische Tirol Innsbruck
BREAD project	Secondary	5	Pedagogische Tirol Innsbruck
Digital air quality	Secondary	5	Pedagogische Tirol Innsbruck

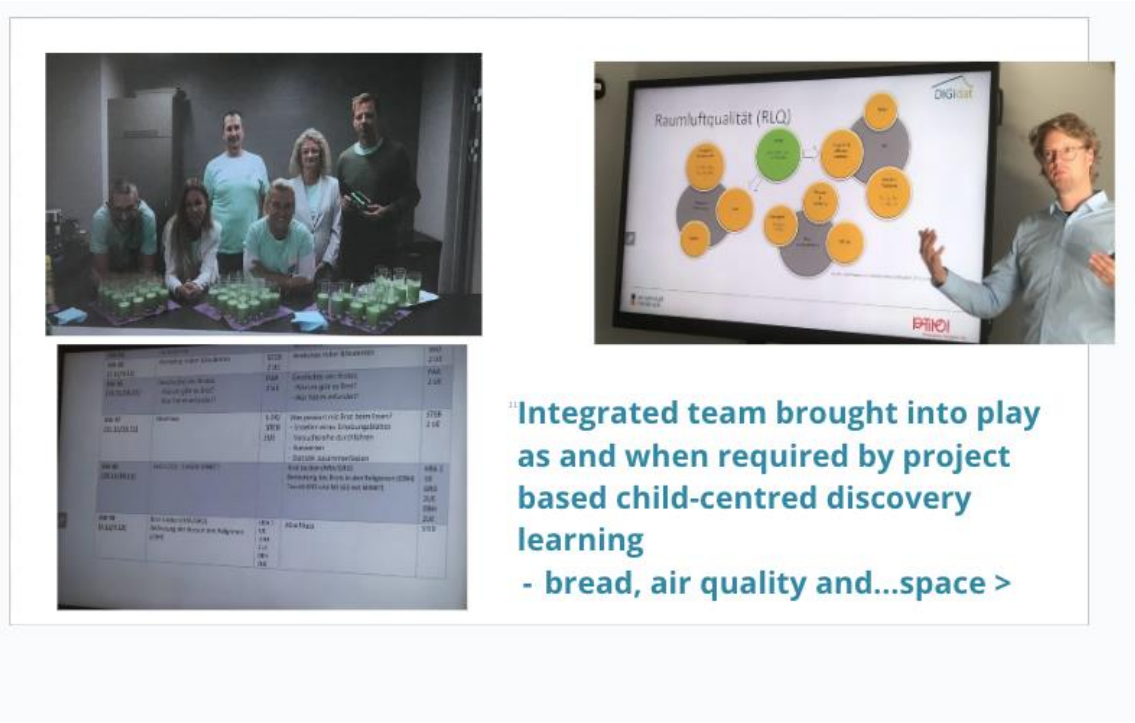
4.3 Evaluation

From the first workshop through implementation, the projects were periodically evaluated for evidence of the impact of STEAM project-based learning. By phase two, the teachers had developed impressive integrated STEAM projects.

The projects successfully advanced the cultivation of a collaborative team by implementing a project-based, child-centered, and discovery-oriented learning approach whenever deemed necessary, as outlined in their own assessment. This success extended to encompass students and families, becoming an essential component of the projects. In

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

addition to the evaluation data, genuinely inspiring integrated STEAM activities were developed. Given the remarkable success of these activities, teachers gained the confidence to recommend this approach to their colleagues. They recognized the importance of gradually forming an integrated school team to address both transdisciplinary challenges and the numerous practical complexities associated with moving beyond individual teachers and classrooms. Important, we also found that students' interest in the project declined after its completion, as they needed to transition to the next one. Additionally, careful attention must be given to practical considerations, encompassing the availability of support, outdoor attire, and potential disruptions when activities move beyond the classroom setting.



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

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

5 IMPLEMENTATION IN HUNGARY

In Hungary, two implementation phases took place. The process of Phase 1 was between 06/11/2021 (1st Teacher Training Day) and 26/03/2022 (2nd Teacher Training Day). The process of Phase 2 was between 26/03/2022 (2nd Teacher Training Day) and 24/02/2023 (3rd Teacher Training Day). The total number of participants was 73 teachers (29/21/23).

5.1 Phase 1

The implementation of the Phase 1 has focused on dissemination. At the end of the 1st Teacher Training Day the teachers made their dissemination plan:

- Best practice (innovative methods)
- Impact of the training (what did I learn?)
- How can I transfer it? (transformation)
- How can I cooperate? (team, networking, interdisciplinarity)

Therefore, Phase 1 of implementation emphasizes the importance of cooperation among the teachers at the school level, especially focusing on inter- and transdisciplinary approach of STEAMTeach and the transfer of relevant competencies (knowledge, skills and attitudes) that come from the training in order to strengthen and apply the innovative teaching and learning methods in and out the classroom.

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

Project title	School and Teacher	Student/ teacher number
The hot air goes off	ELTE Trefort Ágoston Practical Secondary School, Budapest Physics and Informatics Dr. Károly Piláth	25/3
Math in the European painting	Vocational Center and Engineering School and College, Mátészalka History, Geography. Teacher Gábor Fejér	30/3
The aesthetics of the human body	Vocational Center and Engineering School and College, Mátészalka Biology, Informatics. Teacher Ilona Jágri	25/2
From Beethoven to the Paper Piano Kvarkcube in 3D	EGYMI for Move Development, Budapest Math, Physics. Teacher Anna Barsy	40/3
Gastro Practicle Physics	Private Secondary School, Dunajska Streda, Slovakia Physics, Math. Teacher Hajnalka Ollé	25/2

5.2 Phase 2

The implementation of Phase 2 has focused on initiation, implementation and institutionalisation (it depends on the teachers' competencies, the depth of practice on STEAM Pedagogy and the level of adaptivity and innovation of the different schools.

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

Project title	School and Teacher	Student number
Gastro Practicle Physics	Baár Madas Reformed Secondary School, Budapest Physics, Math. Teacher Norbert Horváth	25/2
Playful Practicle Physics with Kvark Cubes	English-Hungarian Bilingual Primary School, Biatorbágy Teacher Ottília Fülöp	20/2
Music in Physics	Márton Bálint Primary and Secondary School, Törökbálint Music, Physics. Teacher Erzsébet Stefán	30/3
The Tragedy of Science – the 200 Year Anniversary of Imre Madách' Birthday	Imre Madách Secondary School, Budapest Literature, Math, The Arts, Music, Physiscs, Geography Dorottya Szabó, Csilla Fülöp, Dr. Katalin Végh, Dr. Tamás Freund the President of the Hungarian Academy of Science	600/5
School Garden		
Emergency Door		
The Beauty of Math		
The Mess and Order		
Playful Practical Physics and Gastronomy	School of Children, Budapest Physics, The Arts. Teacher Bettina Bagyura	25/2

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

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

5.3 Evaluation

The main achievements of the two-phase implementation are at four levels:

- Individual (competencies: K+S+A and mindset)
- Team (inter- and transdisciplinarity, collaboration, mutual understanding and sharing)
- Organizational (projects, programs, strategy, 3rd I)
- Networking (cross-collaboration, innovative networks and projects, best practises)

On the base of three trainings on the STEAMTeach education approach, the teachers (73) from different regions and schools in Hungary (precise data later) learnt and understood the common standards (see IO1). In order to reach institutionalization, after mapping their prior knowledge using Mentimeter, brainstorming and mind mapping on learning, we collected best practices at individual and team levels making poster presentations. Turning directly to the first and the second phase, they need to make at the second training an implementation plan individually based on local innovation on learning and teaching in their lessons precisely, potential opportunity working in teams and organizational innovation as well. It was a diagnosis of local best practices and a map starting the initial situation. The teachers need to indicate the next step in their implementation, based on what they learnt from the workshop and their vision and ideas. The Hungarian expert group inspired and motivated their collaboration and networking at two levels. Firstly, at the school level, they needed to find colleagues from other subject areas. Secondly, they started to organize a network with other teachers and schools on the workshop.

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

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

6 IMPLEMENTATION IN FINLAND

The Finnish Institute for Educational Research (JYU FIER) at the University of Jyväskylä successfully implemented the STEAMTeach project in Finland, positively contributing to the educational landscape in the participating schools and beyond. This innovative initiative strategically integrated Science, Technology, Engineering, Arts, and Mathematics (STEAM) into both preservice and in-service teacher training, as well as local school curricula. Throughout the project, more than 100 pre-service and in-service teachers participated in a series of development workshops, gaining practical strategies and resources to incorporate STEAM education effectively into their classrooms. These workshops, which focused on key areas such as sustainable development, art integration, robotics, and cognitive development, were brought forward in five partnering schools across Jyväskylä and Laukka. Most teachers shared the projects which have been uploaded at our website: https://www.steamteach.unican.es/finnish-implementation/

6.1 Phases 1 and 2

JYU FIER facilitated the Finnish execution of the STEAMTeach project through a sequence of teacher development workshops. These sessions, hosted in various project-partnering schools, concentrated on pivotal areas such as sustainable development, art integration, robotics, and cognitive development. The workshops were designed to be interactive and experiential, equipping teachers with practical strategies and resources for effective STEAM education integration into their classrooms. This experiential approach is endorsed by Bell (2010), who posited that project-based learning cultivates 21st-century skills like critical thinking, problem-solving, and collaboration, and Li et al. (2022), who proposed an innovative STEAM education model underpinned by cooperative teaching, project-based learning, and collaborative learning theories.

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

STEAM-pedagogiikassa voi oppia tiedettä ja insinööritaitoja vaikka tikuista tehden

Norssin alakoulun opettajat Irmeli Pietilä, Elina Törmä ja Sari Keinonen pääsivät tutustumaan STEAM-pedagogiikkaan Koulutuksen tutkimuslaitoksen yliopistonopettaja Kristóf Fenyvesin ja tämän tutkijakollegoiden (kuvassa taustalla Hisashi Fusegi) ohjauksessa.

STEAM on lyhenne sanojen tiede, teknologia, insinööritaidot, taide ja matematiikka englanninkielisistä vastineista.

KUVA: MARKO KAUKO

Sivu 3

The workshops adopted a project-based STEAM learning methodology, prompting teachers to involve their students in real-world problems and solutions. This approach not only rendered learning more engaging and relevant for students but also fostered a deeper comprehension of the interconnectedness of the different STEAM disciplines. This is in line with the findings of Kolodner et al. (2003), who discovered that problem-based learning amplified students' understanding of science concepts and honed their problem-solving skills, and Rodríguez-Nieto and Alsina (2022), who examined the networking strategies between ethnomathematics, STEAM education, and the globalized approach to analyse mathematical connections in daily practices.

During the first phase and second, the project catered to a diverse cohort of over 100 pre-service and in-service teachers, selected based on their involvement and interest in the STEAMTeach project. Five teachers from five distinct Finnish schools were invited for further collaboration and evaluation of their STEAM instructions in real classrooms with students, providing a practical context for assessing the effectiveness of the STEAMTeach approach. Beyond the direct collaboration with teachers, STEAMTeach Finland extended its reach to more than 250 lower-secondary and approximately 60 elementary school students through the STEAMTeach teachers. The following Table provides the project number developed per school and teacher, as well as the number of students included in each project. The schools were instrumental in providing the necessary platform for the implementation and evaluation of the STEAMTeach project.

Project title	School and Teacher	Student number
3D Printing for Enhancing Collective Creativities and Key Competence Development	Jyväskylä Christian School, Jyväskylä Jukka Sinnemäki	25
Cognitive Games to Develop Problem-solving		
4Dframe hands-on robotics		
Activating learning through embodied methods in the STEAM classroom		
Water Wonders	Norssi, University of Jyväskylä's Teacher Training School, Jyväskylä Minna Suikkari	20
RoboMakers		
Micro:Bit Mastery project		
Sustainability STEAM Day with the participation of the whole school	Sydän Laukka School, Laukka Mirka Havinga	300 + 25 students. More than 10 teachers.
Castle of Five Liters		
Microworld in a Shoebox		
Pentomino Puzzles		
Japan Meets Design		
The Northern Lights: Art Meets Science	Kortepohja School, Jyväskylä Gwyneth Koljonen	20
The "Finland in Focus"		
The "Grow Your Own: Green Box"		
LEGO Spike Challenge:		
4DFrame Soccer Bots		
Warka Water Wonders	Viitaniemi School, Jyväskylä Leena Kuorikoski	25 students + 10 guest students and 6 guest teachers.

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

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

The STEAMTeach project marked significant milestones. During the second implementation phase, over 30 teachers engaged in hands-on learning activities, such as constructing their own Warka tower models to address water scarcity in hot areas, using the 4DFrame STEAM education toolkit. A video documenting the event highlighted the transformative power of STEAM education for both teachers and students.

6.2 Evaluation

The project-based STEAM learning approach was successfully aligned with Finland's National Core Curriculum for Basic Education, focusing on sustainability, multidisciplinary learning, and phenomenon-based learning. The incorporation of materials from previous projects, such as KIKS, further bolstered teachers' STEAM-related knowledge and skills. The project's objective of fostering a holistic educational approach resulted in the enhancement of critical thinking, creativity, and problem-solving skills among both educators and students. These findings concur with Becker and Park's (2011) research, which demonstrated positive student outcomes from integrative STEM education, and Wu, Liu, and Huang's (2022) exploration of the correlation between learning domains and intention in STEAM education. The project also leveraged digital tools and technologies in the classroom, as discussed by Salmi, Thuneberg, and Vainikainen (2018) in their study on the use of augmented reality in science education and Lavicza et al. (2022) about evaluating digital tools for STEAM education.

The STEAMTeach project profoundly impacted on both teacher and student engagement and pedagogical outcomes. Teachers reported increased confidence in integrating STEAM into their teaching practices, and students demonstrated improved competencies across various subjects. The project-based learning approach fostered a more engaging and interactive learning environment, promoting active participation from students. This not only enhanced their understanding of the subject matter but also developed their problem-solving and critical-thinking skills. Furthermore, the project facilitated interdisciplinary learning, enabling students to see the connections between different subjects and understand their relevance to real-world issues. This holistic approach to education prepared students for the future job market, equipping them with the necessary skills to thrive in a technologically advanced and interconnected world.

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

7 IMPLEMENTATION IN GREECE

In Greece, two implementation phases occurred. The majority of teachers shared the projects they had designed as part of the STEAMTeach professional development preprogramme; some of the activities are shared on the project web site: https://www.steamteach.unican.es/greek-implementation/. It is noteworthy that the Greek partner have monitored more than 400 student activities.

7.1 Phase 1

The first implementation phase in Greece was held in October and November 2022. It was the beginning of the school year in Greece, and 7 out of the 30 teacher-trainers that had taken part to the first teacher training programme (IO2), took part in the 1st classroom implementation phase, too. They designed their own activities of choose among the activities that we – as trainers – used in the training for hands-on activities during the workshops.

In the table, below a distribution of the teachers is presented, with regards of their school, the grade that their teach, the project that they choose to implement, and whether it was their own design or was already development by us (NKUA). A total of 7 teachers were involved, not 10, as 3 of them implemented various projects.

Activity-Project title	**Educational stage**	**Teacher number**	**School name**
Making Tessellations (NKUA)	Secondary	4	2nd Model JHS of Athens, Varvakeio Model HS, 1st JHS of Ilion
Dancing Animations (NKUA)	Secondary	3	2nd Model JHS of Athens, Varvakeio Model HS, 1st JHS of Ilion

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

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

The Supermarket (NKUA)	Primary	1	Primary School of Megara
Auto-parking (Teachers' design)	Secondary	1	2nd Model JHS of Athens
The playground (Teachers' design)	Secondary	1	2nd Model JHS of Athens

The profile of students who participated in Phase 1 is presented in the table below. In summary, a total of 236 students took part, with 218 from secondary schools and 18 from primary schools. Additionally, the majority of the involved teachers were mathematics instructors.

Project title	**School**	**Teacher's field**	**Grade**	**Student number**
Making Tessellations	2nd Model JHS of Athens	Mathematics	8 – (class B3)	26
	2nd Model JHS of Athens	Mathematics	9 – (class C1)	26
	Varvakeio Model HS	Mathematics	10 – (class A1)	23
	1st JHS of Ilion	Informatics	8 – (class B1)	21
Dancing Animations	2nd Model JHS of Athens	Mathematics	9 – (class C2)	26
	Varvakeio Model HS	Mathematics	10 – (class A2)	24
	1st JHS of Ilion	Informatics	9 – (class C1)	20

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

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

The supermarket	Primary School of Megara	Primary	6	18
Auto-parking	2nd Model JHS of Athens	Mathematics	8 – (class B2)	26
The playground	2nd Model JHS of Athens	Mathematics	8 – (class B3)	26
			TOTAL	236

7.2 Phase 2

The second implementation phase in Greece was held in March & April of 2023; our rationale was to implement student activities right after the teacher training workshops, and since the second phase of IO2 – the teacher training – was conducted in February of 2023, the implementation was a follow up. In this phase all the teachers of the first phase made new implementations using the feedback and their reflections on the first phase. Additionally, 5 more teachers were recruited in this second phase of the classroom implementation. It worth saying that the results of implementation phase 1, and the NKUA team reflection on them led to a modification of the training program; the second program was more focused on PBL (project-based learning) since it was the only teaching approach that teachers of implementation phase 1 used, according to their point of view.

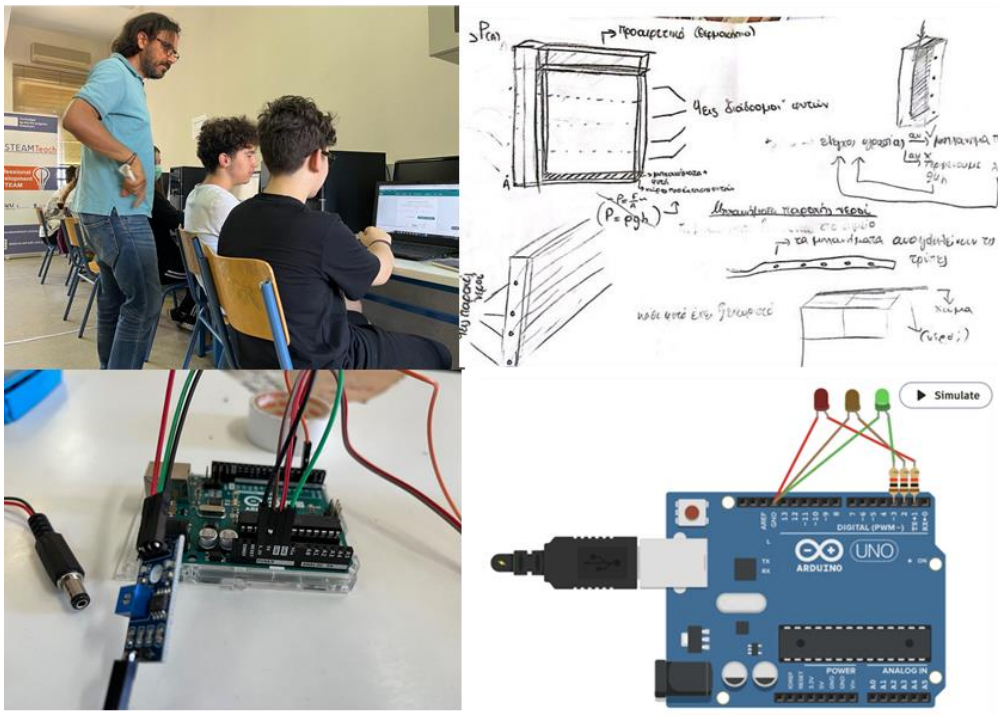
In the table, below a distribution of the teachers is presented, like the table of the first phase. Moreover, they grey cell are indicative of the teachers that had already participated in the first phase. So, the teachers in the white cell are the new ones.

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

Activity-Project title	Educational stage	Teacher number	School name
Making Tessellations (NKUA)	Secondary	3	2nd Model JHS of Athens, Varvakeio Model HS
Making Tessellations (NKUA)	Secondary	1	1st JHS of Ilion
Dancing Animations (NKUA)	Secondary	2	2nd Model JHS of Athens, Varvakeio Model HS
Dancing Animations (NKUA)	Secondary	1	1st JHS of Ilion
The Supermarket (NKUA)	Primary	1	Primary School of Megara
Auto-parking (Teachers' design)	Secondary	2	2nd Model JHS of Athens
The playground (Teachers' design)	Secondary	1	2nd Model JHS of Athens
The Vertical Gardens (Teachers' design based on a Spanish team idea)	Secondary	2	2nd Model JHS of Athens
Traffic lights	Secondary	1	2nd Model JHS of Athens
Data handling	Secondary	2	2nd Model JHS of Athens, Varvakeio Model HS
Spirals	Secondary	1	2nd Model JHS of Athens
Design tasks for peers	Secondary	2	2nd Model JHS of Athens, Varvakeio Model HS

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

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.



During the second phase, 15 teachers were involved, since 3 of them implemented more than one project. The profile of students that took part to the implementation phase 2 is shown in the Table below. In total 327 students participated in phase 2; 223 of them (highlighted in light grey) were already involved in Phase 1. Several of the 327 students participated in more than one activity, so we have monitored 431 student activities, during Phase 2.

Project title	**School**	**Teacher's field**	**Grade**	**Student number**
Making Tessellations	2nd Model JHS of Athens	Maths	8 – (class B4)	26
	2nd Model JHS of Athens	Maths	9 – (class C6)	26
	Varvakeio Model HS	Maths	10 – (class A2)	22

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

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

	1st JHS of Ilion	Informatics	9 – (class C2)	20
Dancing Animations	2nd Model JHS of Athens	Maths	9 – (class C5)	26
	Varvakeio Model HS	Maths	10 – (class A3)	23
	1st JHS of Ilion	Informatics	9 – (class C3)	21
The supermarket	Primary School of Megara	Primary	5	17
Auto-parking	2nd Model JHS of Athens	Maths	8 – (class B3)	26
The playground	2nd Model JHS of Athens	Maths	8 – (class B2)	26
The Vertical Gardens	2nd Model JHS of Athens	Maths	9 – (class C1)	26
	2nd Model JHS of Athens	Maths	9 – (class C2)	26
Traffic lights	2nd Model JHS of Athens	Maths	9 – (class C1)	26
Data handling	2nd Model JHS of Athens	Maths	9 – (class C2)	26
	Varvakeio Model HS	Maths	11 – (class B2)	21
Spirals	2nd Model JHS of Athens	Maths	8 – (class B3)	26
Design tasks for peers	2nd Model JHS of Athens	Maths	8 – (class B2)	26
	Varvakeio Model HS	Maths	11 – (class B1)	21

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

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

7.3 Evaluation

During the workshop phase (IO2), building upon IO1 – the analysis of the current state of STEAMTeach teacher training, NKUA formulated a targeted teacher training program that emphasized:

- On supporting teachers realize the basic elements of learning approaches that are in line with STEAM education approach, in the framework of STEAMTeach.
- On engaging teachers to hands-on activities with ready-made, exemplary lesson plans for students, based on IO1, to make them familiar with design for STEAM.

Therefore, it is evident that the NKUA team operated from a 'teacher as designer' perspective, a framework that supports Teacher Professional Development (TPD) as outlined by Laurillard (2012). Consequently, design activities received support through the utilization of digital media for educational purposes. Additionally, the NKUA team's access to and expertise in designing teacher training programs focused on ICT use for in-service Mathematics Teachers in Greece (https://e-pimorfosi.cti.gr/en/) provided an extra advantage. To capitalize on this advantage, the NKUA team predominantly recruited Mathematics teachers for the implementation phases 1 and 2, as they were likely to be more dedicated to the objectives of the implementation. The outcomes suggest that these strategic choices collectively contributed to a set of distinctive characteristics:

- The project-based learning approach was the one that the teachers adopted.
- From phase 1 to phase 2, most teachers tried to make their own designs.
- Most of the teachers were teachers of Mathematics, however they managed design their own lessons that were based on Mathematics, but not Mathematics-centered, as it comes out of the content.
- The teacher used the exemplary lessons that NKUA design, for the training, as guides for their own lessons.
- Teachers needed a tool to help them observe their lessons and reflect on them.

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

- A community between teachers could be established, as a learning community (Wenger, 2008). This could be an online, international community, based on the case of Vertical Gardens, where the Greek teachers adapted an idea of the Spanish teachers, or in terms of lesson study (Takahashi & McDougal, 2016), as a type of in-school TPD (teacher professional development) activity.

8 CONCLUSION

For this intellectual output, a number of the in-service and pre-service teachers that took part in the training programmes were selected to implement STEAM education in their classrooms. The implementations were evaluated through observations and interviews. Please see the implementation per country on our webpage:

- https://www.steamteach.unican.es/spanish-implementation/
- https://www.steamteach.unican.es/austrian-implementation/
- https://www.steamteach.unican.es/finnish-implementation/
- https://www.steamteach.unican.es/greek-implementation/
- https://www.steamteach.unican.es/hungarian-implementation/

We evaluated the extent to what the STEAM methodologies and approaches were implemented by the teachers during the instruction (e.g., inclusive pedagogy models, inquiry-based learning or engineering design process), whether innovative tools were employed (e.g. original technology and software used), and whether interdisciplinary learning happened (e.g. interdisciplinary curricular content introduced; teacher-student co-creation of knowledge). As suggested in earlier sections, we found a positive impact on students' motivation and learning, as well as teacher satisfaction with their practice for many of the activities implemented.

The implementation occurred in two phases (Implementation Phase 1 and Implementation Phase 2), aligned with the design and development of Course Programme 1 and the refinement of Course Programme 2 (based on the outcomes from the implementation of Phase 1). The executed activities encompassed various educational approaches,

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

incorporating computational thinking tools, applications (such as GeoGebra), models, and digital fabrication solutions (like 3D printing). These implementation phases introduced community- and practice-based elements, integrating considerations of culture and gender inclusivity, and involving students of varying ages and diverse personal and social characteristics.

The evaluations of these implementations help us to validate the activities and thus the teacher guides that we generated as part of the STEAMTeach project and that we have located in an open-access repository on the project website: https://www.steamteach.unican.es/activities/. These guides describe the activities and recommendations for implementing them in the classroom. Teachers' recommendations about the needed material and also about how to assess the STEAM activities within each particular curriculum are provided.

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

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

REFERENCES

Becker, K. H., & Park, K. (2011). Integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students' learning: A meta-analysis. *Journal of STEM education: Innovations and research, 12*(5).

Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House, 83*(2), 39-43.

Couros, G. (2015). *The Innovator's Mindset*. Dave Burges Consulting.

Diego-Mantecón, J., Blanco, T., Ortiz-Laso, Z., & Lavicza, Z. (2021). STEAM projects with KIKS format for developing key competences. [Proyectos STEAM con formato KIKS para el desarrollo de competencias clave]. *Comunicar, 66*, 33-43. https://doi.org/10.3916/C66-2021-03

Diego-Mantecón, J. M., Ortiz-Laso, Z., & Blanco, T. F. (2022). Reflexiones del Open STEAM Group sobre el impacto del enfoque integrado del contenido en el aprendizaje de las matemáticas. In T. F. Blanco, C. Núñez-García, M. C. Cañadas, & J. A. González-Calero (Eds.), *Investigación en Educación Matemática XXV* (pp. 81-94). SEIEM.

Fenyvesi, K., Brownell, C. S., Sinnemäki, J., & Lavicza, Z. (2022). Activating creativities by emphasising health and wellbeing: a holistic pedagogical practice from Finland. In P. Burnard, & M. Loughrey (Eds.), Sculpting New Creativities in Primary Education (pp. 123-145). Routledge. https://doi.org/10.4324/9781003129714-10

Fullan, M. (2007). *The new meaning of educational change* (4th ed.). Teachers College Press.

Hargreaves, A., & O'Connor, M.T. (2018). *Collaborative Professionalism*. Sage.

Kolodner, J. L., Camp, P. J., Crismond, D., Fasse, B., Gray, J., Holbrook, J., ... & Ryan, M. (2003). Problem-based learning meets case-based reasoning in the middle-school science classroom: Putting learning by design (tm) into practice. *The Journal of the Learning Sciences, 12*(4), 495-547.

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

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.

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

Lavicza, Z., Weinhandl, R., Prodromou, T., Anđić, B., Lieban, D., Hohenwarter, M., Fenyvesi, K., Brownell, C., & Diego-Mantecón, J. M. (2022). Developing and Evaluating Educational Innovations for STEAM Education in Rapidly Changing Digital Technology Environments. *Sustainability, 14*(12), 7237. https://doi.org/10.3390/su14127237

Li, X., Luo, Y., Zhao, Y., Zhu, M., Ma, Y., & Liao, S. (2022). Promoting STEAM Education in Primary School through Cooperative Teaching: A Design-Based Research Study. *Sustainability, 14*(16).

Rodríguez-Nieto, G., & Alsina, Á. (2022). Networking Between Ethnomathematics, STEAM Education, and the Globalized Approach to Analyze Mathematical Connections in Daily Practices. *Eurasia Journal of Mathematics, Science and Technology Education, 18*(1).

Salmi, H., Thuneberg, H., & Vainikainen, M. P. (2018). Making the invisible observable by Augmented Reality in informal science education context. *International Journal of Science Education, 40*(16), 1987-2006.

Takahashi, A., & McDougal, T. (2016). Collaborative lesson research: Maximizing the impact of lesson study. *ZDM, 48*(4), 513-526. https://doi.org/10.1007/s11858-015-0752-x

Vass V. (ed.) (2008): A Nemzeti alaptanterv implementációja. Oktatási Minisztérium, Budapest. http://www.nefmi.gov.hu/letolt/kozokt/nat_implement_090702.pdf

Wu, Y. J., Liu, Y. T., & Huang, H. M. (2022). The exploration of continuous learning intention in STEAM education through attitude, motivation, and cognitive load. *International Journal of STEM Education, 9*(1), 1-19.

Wenger, E. (2008). Communities of practice: A brief introduction. 2006.

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

This project has been co-funded by the Erasmus+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102.