June 2023

STEAMTeach

Science | Technology | Engineering | Arts | Mathematics

O2: Designing and implementing a Cross-cultural Course programme for preparing professional trainers, in-service teachers and pre-service teachers on STEAM

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

PROJECT

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1 Introduction

Building on the Cross-cultural STEAMTeach professional development framework developed in IO1, and the Hothousing intensive workshop program used in KIKS (Houghton et al., 2022), we provided a two-year course programme for preparing professional trainers, in-service teachers, and pre-service teachers on each of the participant countries. This initiative aligns with the growing body of research that supports the integration of Science, Technology, Engineering, Arts, and Mathematics (STEAM) in education (Quigley & Herro, 2016). The programme was implemented in two main phases and the target audience included teachers in both their pre-service and in-service phases.

While all participating countries started from the common framework designed in Intellectual Output 1, teachers in each country had the opportunity to tailor the implementations to the unique curriculum contexts and needs of their respective nations. That is, the partner organizations utilize these pedagogical principles coherently to design workshops while also demonstrating flexible adaptability to the national education system and traditions. This flexibility facilitated a more effective implementation of the STEAM learning framework within the specific STEAM context.

All partner organizations developed materials for the two-year STEAM programme, including workshops for Introducing Country- and Topic-specific Best Practices in Multidisciplinary Learning and STEAM. The workshops involved teacher trainers, pre-service and practicing teachers, as well as students, in the collaborative development, testing, and evaluation of innovative tools and technologies, inclusive pedagogy models, and comprehensive curricular materials for phenomenon-based and multidisciplinary learning.

2 A common transcultural professional development framework

The methodological principles on designing and implementing a Cross-cultural Course programme were based on the transcultural professional development framework devised in IO1, after a long iteration process.

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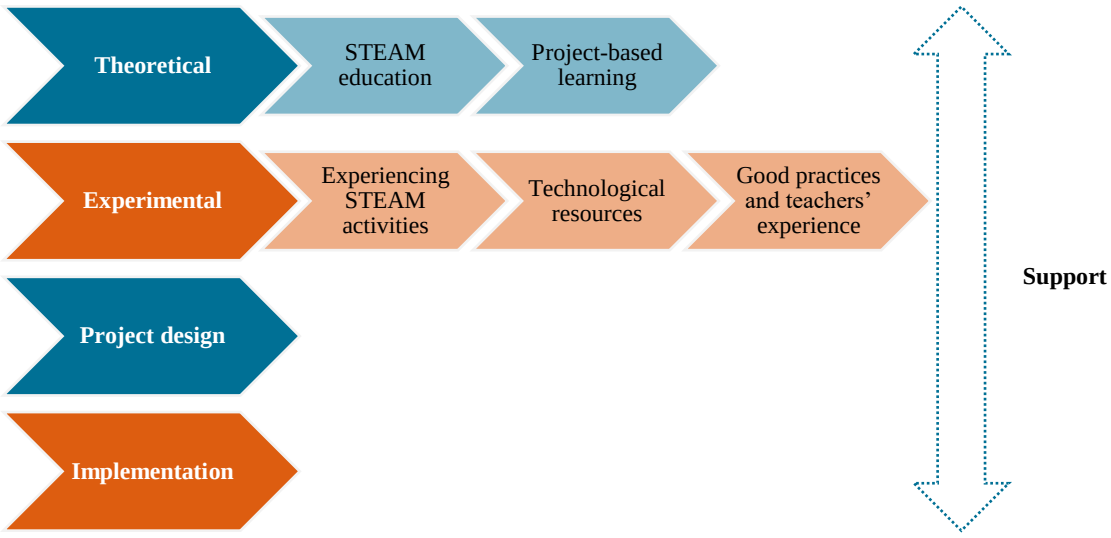
These STEAMTeach framework comprised four dimensions: Theoretical training, experimental training, project design, and project implementation.



Theoretical dimension

In the theoretical dimension, teachers are introduced to STEAM education and the five fundamental principles of project-based learning: content integration, problem-based learning, inquiry-based learning, design-based learning, and collaborative learning (Thibaut et al., 2018) through various sessions.

Experimental dimension

In the experimental dimension, teachers are thoughtfully grouped into collaborative teams to engage with and navigate a series of challenging STEAM activities, simulating the student experience. This active involvement offers them first-hand insights into the difficulties students might encounter during implementation. Examples of the practical dimension tailored for each participating country can be explored through the following link: https://www.steamteach.unican.es/framework-professional-development/.

Project design

In the project design dimension, teachers put into practice the knowledge and skills acquired to design a STEAM activity to be implemented in their classrooms. The

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members of this project have designed several STEAMTeach activities using the following template (https://www.steamteach.unican.es/template/).

Implementation dimension

The implementation dimension of the professional development program refers to the phase in which teachers, following theoretical and practical training and gaining project management skills, teachers are tasked with executing STEAM projects with their students. Throughout this project implementation in the classroom, teachers receive ongoing trainers' and researchers' support. Those in need also receive training in both mathematical and pedagogical knowledge, particularly when it comes to utilizing mathematical software for classroom application. Examples of actual implemented projects will be uploaded are also uploaded in our webpage.

The framework described above was embraced by all consortium partners and tailored to suit the unique characteristics of each context, as well as the specific curricular intricacies of each educational system within each country.

3 Spain

3.1 Designing Cross-cultural Course programme 1 and 2 for trainers and in-service and pre-service teachers (O2.1 and O2.2)

After thorough discussions during preparatory meetings among Spanish trainers, a decision was reached to differentiate the training approaches for pre-service and in-service teachers. This choice was influenced by the prevailing circumstance that pre-service teachers generally lack the opportunity to execute projects within regular lessons. Consequently, for in-service teachers, we implemented all four dimensions (theoretical, experimental, lesson design, and implementation) along with the transversal dimension (support), as elaborated in IO1. However, when working with pre-service teachers, a lesser emphasis was placed on the project design component, and their training did not encompass the implementation phase.

In the Spanish implementation of the STEAM teacher development programme, we have emphasized specific dimensions in alignment with the official curriculum, finally

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outlined by the MEVT (Ministry of Education and Vocational Training) in 2022. Focusing on the mathematics and Science subject, the curriculum defines the STEM key competency through five distinct competencies that are closely tied to project-based learning: Modelling, Computational Thinking, Intra-Mathematics Connections, Mathematical Representations, and Collaborative Work Skills and Positive Identity as a learner. Promoting these competencies, we not only aim to empower educators to effectively integrate project-based learning into their teaching practices, but also enhances educator's ad students' understanding of STEM subjects, equipping them with the skills and mindset needed to tackle real-world challenges in innovative ways.

In-service teachers

For the in-service teacher the four dimensions of the common trans-cultural STEAMTeach framework were followed: Theoretical training, experimental training, project design, and project implementation. The programme took place in a face-to-face and virtual format. It is noteworthy that in the second phase, teachers were encouraged to enrol in the programme with a colleague from their school and from a subject different from the one that he/she teaches.

During the theoretical dimension, the Spanish STEAMTeach trainers introduced STEAM education from a theoretical perspective. In particular, trainers described the origins of STEAM education and introduced the selected learning methodology: project-based learning. The Thibaut et al. (2018) framework was employed to define project-based learning. The last version of the materials employed for dealing with the theoretical dimension in Spain can be found here. These materials include a presentation designed for the transcultural framework of the STEAMTeach theoretical dimension and collect specific information about the brand-new Spanish educational legislation.

The experimental dimension followed the theoretical one. Teachers were tasked with a collection of activities for implementing the five learning methodologies (Figures 1 and 2). For instance, the carpet activity was proposed to exemplify the idea of devising a plan when dealing with a problematic situation (*problem-based learning*) in groups (*collaborative learning*). Similarly, the Radio Gaga activity was implemented to show how scientists, musicians, and mathematicians work (*inquiry-based learning* and *collaborative learning*). The trainer also recommended implementing these activities in regular lessons with students to test how the groups designed by the teacher work

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together. In this way, they could reformulate the groups before working together for several weeks.

Teachers implementing the carpet activity

Teachers implementing the Radio Gaga activity

As part of the experimental dimension, the trainers presented technological resources. In particular, for secondary education teachers Tracker, Tinkercad, and GeoGebra were shown, whereas for primary education teachers, Robotics, Tinkercad and GeoGebra were offered. In the last programme in 2023, we decided to incorporate a slot to collect teachers implementing projects in 2022 and encourage teachers participating in the programme to apply this learning methodology. Three teachers (two from secondary and one from primary) to describe their project, how they felt and how their students felt (presentations 1, 2 and 3).

During the project design dimension, executed after gaining experience from the first workshops, teachers were encouraged to design a project in pairs. We promoted cooperation among teachers to share knowledge from different disciplines, as it was more realistic to train teachers to encourage collaboration than to gain a deep understanding of all disciplines involved in the project (Ortiz-Laso, 2023). The project design dimension was initiated in the face-to-face events, and then there were at least two follow-up sessions in an online format. In these sessions, teachers described their project and posed their

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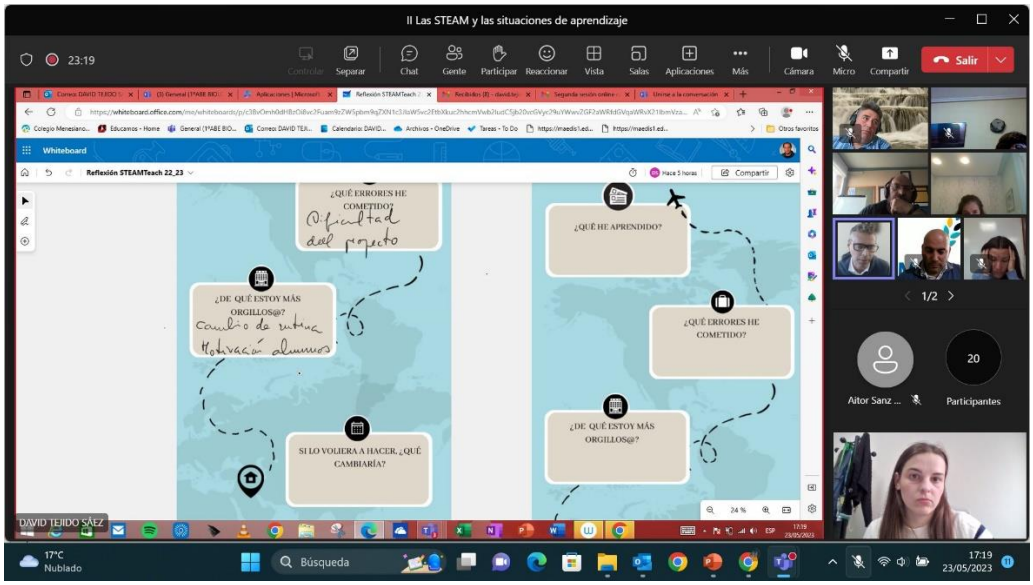
concerns; trainers gave them feedback about these two issues and gave at least one idea for improving the project.

Finally, in the project implementation phase, teachers executed the project in regular lessons with their students. During this period, online meetings between teachers and trainers were scheduled to support them in the implementation. At least one individual meeting per project and one collective online encounter were planned (**¡Error! No se encuentra el origen de la referencia.**).



Collective online meeting with teachers in May 2023

Pre-service teachers

As it was not possible for pre-service teachers to execute the implementation phase in regular lessons, their training was reduced to the first three dimensions of the commune framework. These sessions were a replication of the ones described above. Figure 4 shows how pre-service mathematics teachers implemented the Tracker and GeoGebra modules to then design their own project proposal combining both software.

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Pre-service teachers presenting their project design

3.2 Recruiting trainers and teachers to participate in the above Cross-cultural Course programmes (O2.3)

Enrolment of teachers in the STEAMTeach training courses in Spain was a collaborative endeavour that encompassed various institutions. To be precise, the process of engaging participating teachers was orchestrated by the consortium along with its Spanish collaborators, spanning across a minimum of three distinct institutions:

- The Department of Education of the Government of Cantabria
- The Unit of Scientific Culture of the University of Cantabria
- Schools

The Department of Education of the Government of Cantabria played a significant role in providing training courses and engaging teachers and students in the implementation and testing of our transnational STEAM professional development program. Additionally, the Government of Cantabria officially accredited teachers who participated in the project with training credits.

The Unit of Scientific Culture at the University of Cantabria also supported our efforts by helping to mobilize teachers. They reached out to teachers through emails, recommending our training as a preliminary step to the University of Cantabria Science

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Fair festival—an annual event that serves as a major gathering for teachers and students in the region.

Moreover, teachers played a pivotal role in involving their colleagues in the STEAM training courses, particularly during the second phase. As we anticipated a high teachers' response due to their concerns about STEM education in the newly introduced curriculum, specific enrolment criteria were established for accessing the course. These criteria included:

1. Pairs of teachers from different specialisations
2. Order of registration by date and time

3.3 Workshops for implementing STEAM Course programmes 1 and 2 (O2.4)

The professional development program, consisting of two phases and five primary workshops, was carried out in Spain between April 2022 and May 2023. Comprehensive details about the professional development program are available at: https://www.steamteach.unican.es/spanish-workshops/. Phase 1 comprised three workshops, while Phase 2 included two workshops. These sessions were designed for both in-service and pre-service high school teachers, as well as in-service and pre-service primary school teachers, among others. Specific information (e.g., agenda, videos, photos and presentations) regarding each program tailored for different types of teachers can be accessed through the provided links below:

- In-service high school teachers (1-3 March, 15 March, and 5 April 2022) https://www.steamteach.unican.es/training-for-high-school-teachers/
- In-service primary school teachers (8-10 March, 16 March and 4 April 2022) https://www.steamteach.unican.es/training-for-primary-education-teachers/
- Pre-service high school teachers with specialization in physics, chemistry and technology (7 and 28 April 2022) https://www.steamteach.unican.es/training-for-pre-service-high-school-teachers/
- In-service high and primary school teachers (7-9 March, 28 March, and 23 May 2023) https://www.steamteach.unican.es/las-steam-y-la-creacion-de-situaciones-de-aprendizaje/

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- Pre-service teachers with specialization in mathematics (19 and 26 April 2023) https://www.steamteach.unican.es/training-for-pre-service-teachers/

A total of 88 pre-service and in-service teachers were trained in Spain within the STEAMTeach project. Most of these teachers were in-service high school teachers (41), but pre-service educators from that educational stage (31) and in-service primary education teachers (16) were also involved. The teachers who attended the programme were from educational centres in different parts of the Cantabria region, belonging to state and state-subsidized schools.

3.4 Evaluation of STEAM Course programmes Designing and implementation (O2.5)

The Spanish project focused on the meticulous development and refinement of a Professional Development Framework, a journey spanning two distinct phases of implementation. STEAM trainers worked on a plan to help teachers learn and enhance their skills. This plan had two parts and focused on five important aspects for teaching STEAM: creating models, thinking logically, connecting math ideas, using drawings and graphs, and working together positively.

The project's workshops were like special classes for teachers. They tried out new ideas, saw what worked, and figured out how to teach better. The project's materials were carefully chosen to help students learn in exciting ways, just like in the Spanish school plan. The Spanish STEAMTeach Team played a big role in making these workshops successful. They gathered the best materials to use in the workshops so that teachers could teach better.

Educators participating in the workshops engaged in enjoyable and interactive activities that provided them with insights into the learning experiences of their students in STEAM subjects. This experiential understanding played a significant role in enhancing teachers' abilities to effectively support their students' learning journeys.

There were times when teachers talked about what they learned in the workshops. This helped them get better at teaching. They looked at what they did and saw how it fit with what they knew and what they did in their classrooms. Teachers could also choose the materials they wanted to use in their teaching. They could change things to fit their classrooms better. They shared their ideas and made things better together.

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The Spanish project rendered the process of learning engaging for both educators and students. This initiative resembled collaborative teamwork, where teachers acquired and applied novel concepts, while students exhibited improvements in their grasp of science, mathematics, and related disciplines. Through the Spanish project, the concept emerged that education possesses the potential to be both captivating and valuable for all participants.

4 Austria

4.1 Designing Cross-cultural Course programme 1 and 2 for trainers and in-service and pre-service teachers (O2.1 and O2.2)

The Austrian project team consisted of members of the JKU Linz School of Education, STEAM Education Department. It is to be noted that although the Austrian JKU department has a well-deserved reputation for STEAM and is closely linked with the GeoGebra maths software organisation, there is no formal requirement to undertake STEAM as part of the Austrian curriculum. Therefore, the first challenge was to establish requirements for a STEAM programme taking this factor into account. From questionnaires and interviews with our teacher pool, it was found that teachers should work in multidisciplinary groups as they were currently working in subject-based isolation. Project and problem-based learning were identified as key methodologies. Above all, teachers were time-precious: to reach them we had to be as economic with their time as possible.

The STEAMTeach framework used was that from IO1: theoretical training, experimental training, project design, and project implementation and the content focussing on the STEAMTeach project-based learning framework. Two additional components identified by our teachers and experts that were implicit in the STEAMTeach approach were collaboration and affective learning.

The STEAMTeach project-based framework fitted the requirements of the teachers in which problem and project-based learning were identified as key learning methodologies: Appropriate scaffolded design-based learning rather than pure discovery learning or pure experiential learning is necessary to get a deep understanding of content to be able to

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apply the knowledge in new situations. Evidence-based learning materials combined with well-designed instructional designs really help learners learn. Design-based learning is important to introduce the teachers with 21-century technologies. The best strategy is to give examples. From the TPACK papers written by Mishra and Koehler, it says that so far, the teachers' training program is just talking. It would be better to do real workshops for their projects.

Collaborative groups and networks were deemed essential: To deliver STEAM into the classroom, teachers require the mutual support and expertise to work in multidisciplinary groups reaching into the school. A teacher working alone learning STEAM will be unlikely to succeed. As Thibault et al (2018) previously cited, it is also essential to convince teachers of the value of STEAM and give them confidence and this implies a teacher's perceived benefit of STEAM (Weinhandel et al, 2020).

The affective factor was essential for both students and teachers. This concerns learning that relates to the learner's interests, attitudes, and motivations (Picard, 2004). Real life problem and project-based learning can be motivating and contribute to the affective factor within an appropriate structure Lieban (2019) and Weinhandl (2021). Hence, we anticipated that the Affective factor would be provided by our STEAMTeach approach.

4.2 Recruiting trainers and teachers to participate in the above Cross-cultural Course programmes (O2.3)

The JKU STEAM education department together with the GeoGebra worldwide community allowed us to access a wide pool of potential participants. In the light of the absence of STEAM in the curriculum it was necessary to initially engage with teachers fully committed to STEAM, to lead the way and also those teachers with less or no commitment or indeed experience of STEAM. The strategy was to focus on a core of collaborating teachers who would then extend the activity of others. How this was achieved will be discussed in the evaluation.

Two organisations were chosen:

- *Feldkirch Pädagogische Hochschule Vorarlberg*
- *Innsbruck Pädagogische Hochschule Tirol and Praxismittelschule*

Both organisations were middle schools and were linked directly to a teacher education unit, allowing us access therefore both professional and pre-service teachers.

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In the first school, we worked with a five-person team of professional and - preservice teachers, one only of whom was a STEAM practitioner by choice, again with no curricular or time obligation to undertake STEAM activities.

By contrast, the second school had been appointed by regional authorities to lead the way in STEAM projects, crucially, with time-allocated during the school timetable explicitly for STEAM activities. Nothing was fixed in stone, and indeed the school was eager to fulfil their commitments with our assistance. This team again, was a team of five with both pro and pre-service teachers.

The two teams stayed together over both phases of the project workshops and then further collaborated with each other and to engage further with other teachers and collaborating organisations and above all parents.

4.3 Workshops for implementing STEAM Course programmes 1 and 2 (O2.4)

The two schools both experienced a 2-hour workshop focussing on the STEAMTEACH approach to project-based learning accompanied by examples. The participants were each asked to come up with a project idea which was then examined for its project-based learning features plus other dimensions identified previously in the STEAMTEACH teacher requirements phase, most notably Affective learning. Each of the three projects demonstrated the adoption of project-based learning dimensions suggesting that the first workshop was understood and bought into by the participants. This would be further evidenced in the more collaborative second workshop by which time this was a STEAM project presentation led by the teachers. and explored in the Classroom Implementation.

Workshops Phase 1: Two workshops in November 2023

The first series of 2–3-hour workshops featured an initial-teach discussing the STEAMTeach project overview, the professional development framework and also the requirements and concerns expressed by five of our expert Austrian teachers.

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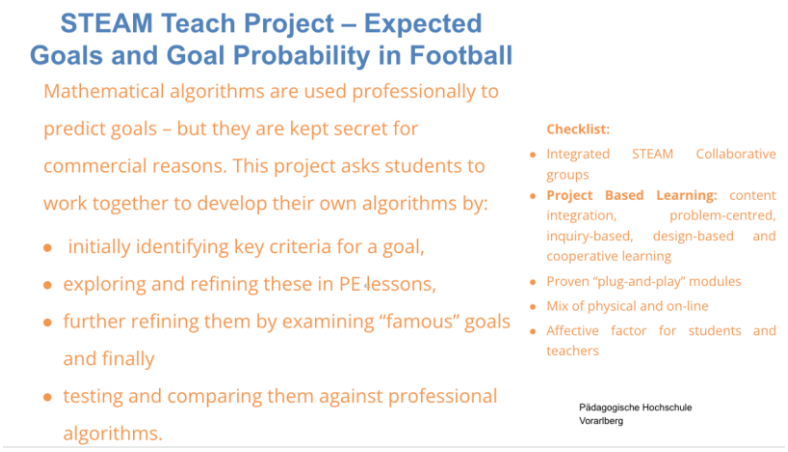
Worked examples were introduced and developed with participants and then they were asked to develop their own project ideas. Teacher trainers worked with teachers in small groups to: develop their own ideas, identify any support requirements of Linz, delivery into the classroom, assessment/grading, collaboration, networking arrangements and next steps, 2 - minute presentation on next steps. The two-minute presentation by participants included the Idea, support requirements, delivery into the classroom, assessment/grading, collaboration/networking arrangements and next steps

These were presented and evaluated with and by participants in a checklist ticking off the evidence and thus understanding or not of STEAMTeach approach. For example, one project idea developed in fifty minutes was around Goal probability in Football and we can clearly see evidence of understanding.



Workshops Phase 2: Two workshops in March 2023

Phase 2 workshops were teacher-driven with the project team as support/evaluators.

In Feldkirch, let it STEAM, let it STEAM, let it STEAM!

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The teacher team consisted of (variable) typically five teachers, pre-service teachers and local college lecturers. The school student teams were school projects students aged 10/11, which is years 5 and 6 in Austria. The project was again observed against the checklist project-based learning features PLUS other dimensions identified previously in the STEAMTEACH teacher requirements phase.

The activity sequence started with paper activities to software to 3-D printing as below:

In Innsbruck, we worked on three projects:

- 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

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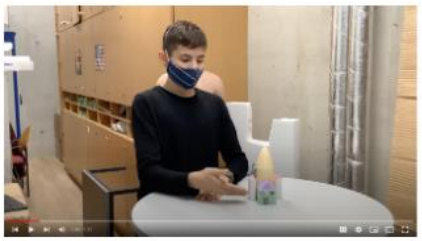


These two workshops resulted in a plenary workshop presentation in Feldkirch featuring the collaboration of both projects featuring the presence of other teachers, parents and community participants:




These workshops were further undertaken in, for example, a JKU University STEAM event for PhD STEAM researchers and virtual attendees in March 2023:

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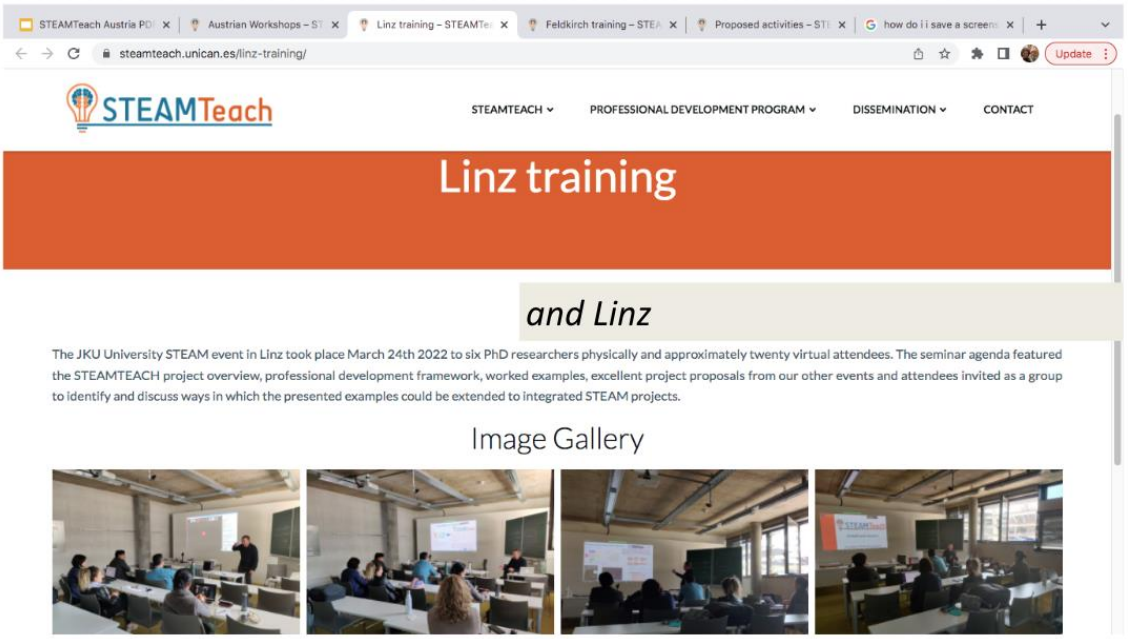

4.4 Evaluation of STEAM Course programmes Designing and implementation (O2.5)

The two-three-hour workshop was evaluated based on teachers' successful comprehension and application of their learning experience. Additionally, its effectiveness as a productive utilization of their time was also assessed. So, from a teacher understanding of the STEAMTEACH project-based learning perspective, we can summarise against the STEAMTeach Project Development Framework:

Problem-based learning context? Students were faced with a variety of challenges developing from starter activities to technological and societal problem challenges from building water rockets to looking at support requirements for living on Mars, through to considering building a better planet and learning lessons from the old one (Earth).

Inquiry-based learning context? The project involved seeking information in a number of areas, making hypotheses and trying out solutions

Design-based learning context? The iterative design-based approach was evident in various of the project outcomes.

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Students collaborated during the implementation phase? The students worked together to create a wide variety of solutions.

From a teacher's perspective of the framework of problem-based learning context, they observed that, yes, they had a problem to solve, to create a model of a house and no further instructions really. They had to find their own solutions.

What changes/modifications would they incorporate in the STEAMTeach approach now that they have implemented STEAM lessons in the classroom? The preservice teachers were happy to get some ideas, they really liked interdisciplinary tasks, collaborating with other teachers.

In future workshops, they would be happy about further examples to get more ideas and would like to test them in the group first to feel safe when implementing STEAM.

Accordingly, we can conclude that the STEAMTeach project-based learning framework worked. The workshops provided both a testbed for local inter- teacher collaboration and also for extending to other teachers, parents and community. The format fundamentally provided a safe opportunity to explore STEAM in a time-effective way.

5 Hungary

5.1 Designing Cross-cultural Course programme 1 and 2 for trainers and in-service and pre-service teachers (O2.1 and O2.2)

The Hungarian partner adopted the cross-cultural STEAMTeach framework from Intellectual Output 1, comprising four dimensions: theoretical training, experimental training, project design, and project implementation. Workshops refined implementations iteratively. To align the STEAMTeach framework with Hungary's context, this partner explored local STEAM education status and gathered best practices. They also developed a teacher toolkit introducing main methodologies based on their educational system: Project-based learning, Cooperative learning, Interest-based learning, and Problem-based learning. During training, Hungarian teachers received a guide on STEAM approach benefits and implementation, a toolkit with diverse resources, and best practices aligned with the aforementioned approaches' principles.

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Regarding project-based learning, the focus was on teachers and students collaborating on extensive projects demanding the application of knowledge across disciplines (Bell, 2010). For Cooperative learning, the emphasis lay in learner interaction, communication, and mutual support to achieve shared learning objectives. Through Interest-based learning, educational content and activities were personalized to align with individual teacher and student interests and passions. Lastly, Problem-based learning centred on presenting teachers and students with real-world challenges or intricate problems as the foundation for learning.

5.2 Recruiting trainers and teachers to participate in the above Cross-cultural Course programmes (O2.3)

The selection of the trainers was based on motivation letter and interview. We work with 5 trainers (Anna Barsy, Csilla Fülöp, Péter Mészáros, Éva Oláh, Tamás Stonawski) on the Cross-cultural Course Programmes on the base of the modules, which they developed. The criteria of recruiting trainers were:

1. National and international experience of research, development and innovation on STEAM education
2. Innovator's mindset, which is based on George Couros' characteristics (emphatetic, problem finders, risk-takers, networked, observant, creators, resilient and reflective)
3. Transdisciplinary or/and interdisciplinary approach, which is based on Problem-based Learning, Inquiry-based Learning and Project-based Learning experience
4. Experience and networking on public and higher education
5. Members of relevant Scientific Committees and Teachers' Association

The selection of the teachers was based on motivation letter and references. Under the umbrella of excellence and equity, we selected the teachers from different parts of the country, especially focusing on the low SES-index. We work with 73 teachers from primary (grade 1-8) and secondary education (grade 9-12) on the Cross-cultural Course Programmes.

The criteria of recruiting teachers were:

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1. Experience of teaching on relevant subject areas eg. Math, Physics, The Arts etc.
2. Innovator's mindset, which is based on George Couros' characteristics (emphatetic, problem finders, risk-takers, networked, observant, creators, resilient and reflective)
3. Attitudes and strong motivation on collaboration with colleagues inside and outside the schools in order to strengthen transdisciplinary or/and interdisciplinary approach and effective networking
4. Relevant prior knowledge (values, beliefs, experience) on STEAM education

5.3 Workshops for implementing STEAM Course programmes 1 and 2 (O2.4)

A professional development programme including two phases and three main workshops was executed in Hungary between November 2021 and February 2023. One workshop took place as part of Phase 1 and two within Phase 2, which reach a significant number of in-service and pre-service high school teachers. Specific information (e.g., agenda, videos, photos and presentations) regarding each program can be accessed through the provided this link below: https://www.steamteach.unican.es/hungarian-workshop/

Workshop 1

A STEAM workshop for Hungarian in-service teachers was organized at Budapest Metropolitan University (METU) on Saturday, November 6th, 2021. Participants travelled to Budapest from various regions across the country. The workshop commenced by introducing the objectives and anticipated outcomes of the STEAMTeach project, along with the training day's purpose and projected results. Following this presentation, the first segment of the day featured a methodological introductory lecture on 'Pedagogical principles and methodological aspects of STEAM education, prior knowledge assessment', led by knowledgeable METU lecturers, Dr. Vilmos Vass and Krisztina Bódis. This presentation incorporated practical examples. Post-module, participants assessed their learning and collectively discussed potential future teaching applications.

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Subsequently, workshops were conducted, dividing participants into three groups. Each group rotated through practical sessions in separate rooms. Three different methodologies were employed by workshop leaders: Project-based learning, Cooperative learning, and Problem-based learning. These methodologies formed the core of teamwork sessions. The workshop concluded with a collaborative evaluation based on participant feedback and reflections. As the training day concluded, Dr. Vilmos Vass briefly outlined forthcoming project tasks and additional pertinent information.

Workshops 2 and 3

Workshops 2 and 3 took place at METU Main Campus (Nagy Lajos király útja 1-9) on March 26th, 2022, and February 2nd, 2023, respectively. These two workshops followed a similar structure to the initial one, but also centeri on mapping participants' prior knowledge through discussion groups where they reflected upon and shared their experiences, receiving specific feedback. Throughout these training sessions, teachers participated in multiple practical segments, such as physics and music (sound), math and music (paper piano), sustainability (School Garden project), and Pantha Rei (flow from fire via gas to water). In these sessions, the trainers focused on enhancing teachers' expertise in various learning methodologies, including project-based learning, cooperative learning, problem-based learning, and inquiry-based learning. They also assisted in designing local implementations, formulating dissemination plans, and fostering networking opportunities.

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5.4 Evaluation of STEAM Course programmes Designing and implementation (O2.5)

At the end of the module, the participants evaluated what they had learned and discussed together what could be used in the future in their teaching. The teachers reported positive outcomes in four of the methodologies employed in the STEAM professional development program: Project-based learning, Cooperative learning, Interest-based learning, and Problem-based learning.

The results indicate that Project-based learning has led to a significant increase in teacher satisfaction, as they have experienced greater enthusiasm witnessing students' active participation and engagement in the learning process. As for Cooperative learning, it has become evident that teachers are finding greater fulfillment in the collaborative classroom dynamics, furthered by the improvement of communication and teamwork abilities among students. Interest-based learning has shown to heighten teacher satisfaction by observing how students' intrinsic motivation is bolstered and how they become more invested in the content. Lastly, Problem-based learning has resulted in higher teacher satisfaction, as they have noted the development of problem-solving skills and the practical application of knowledge in real-world situations. Collectively, these outcomes support the value of these methodologies in promoting teacher satisfaction and enriching the educational experience in the STEAM context.

At the end of the training, he teachers also expressed their competence to apply the STEAM education approach in their classrooms, while also fostering individual and

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organizational curriculum planning and innovative methodology through effective implementation.

6 Finland

6.1 Designing Cross-cultural Course programme 1 and 2 for trainers and in-service and pre-service teachers (O2.1 and O2.2)

The JYU-developed STEAMTeach material was strongly adapted by the Finnish National Core Curriculum for Basic Education (FNAE, 2016), which promotes progressive education through multidisciplinary learning, phenomenon-based learning, project -based learning, and real-world applications. Multidisciplinary learning integrates diverse subjects to offer a comprehensive understanding. This approach is especially influential in STEAM education, which explores the interconnectedness of Science, Technology, Engineering, Arts, and Mathematics for holistic comprehension. Phenomenon-based learning is an innovative pedagogical approach where students study comprehensive real-world phenomena. In STEAM education, this entails examining phenomena like the water cycle from diverse angles – scientific, technological, engineering, artistic, and mathematical. This approach fosters interconnected knowledge and a holistic comprehension of the world. And, Project-based inquiry, a pivotal aspect of the Finnish National Core Curriculum, engages students in actively investigating real-world issues, fostering critical thinking, problem-solving, and collaboration. In STEAM education, project-based inquiry has students collaborating to explore and design, like creating visual illusions that merge knowledge and skills across all STEAM fields.

The JYU STEAMTeach team, part of the Innovative Learning Environments research group, drew from an extensive collection of publications as foundational material for their STEAMTeach materials. These encompass diverse themes including STEAM education, competence development, and student collaboration. These areas intricately linked to the STEAMTeach method, providing a robust theoretical and empirical foundation. For instance, the focus on competence development aligned with the method's emphasis on key competencies as advised by the EU. Likewise, the emphasis on student collaboration echoed the method's commitment to fostering collaborative learning environments (Diego-Mantecón et al., 2021). For more detailed information on the publications and research conducted by the Innovative Learning Environments team, and the relevant

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literature can be accessed here. This resource served as a comprehensive repository of the team's research outputs, providing valuable insights into the theoretical underpinnings and practical applications of the STEAMTeach method.

6.2 Recruiting trainers and teachers to participate in the above Cross-cultural Course programmes (O2.3)

The recruitment of participants for the JYU STEAMTeach workshops was a strategic and collaborative process involving multiple institutions and stakeholders. The goal was to engage a diverse group of participants, including teacher trainers, pre-service teachers, and in-service teachers, who could contribute to and benefit from the workshops. It involved contacting and collaborating with potential institutions to organize and host the workshops, and actively engaging and involving organizations in the workshops. This process ensured that the workshops were relevant, impactful, and beneficial for all participants, contributing to the national and international dissemination of the STEAMTeach project.

The first step in the recruitment process involved reaching out to universities, schools, and other educational institutions, such as the University of Lapland in Rovaniemi, Finland and the Norssi School in Jyväskylä. JYU's STEAMTeach team took the lead in this process: communicated the objectives, content, and potential benefits of the workshops to the potential participants and their institutions, inviting them to participate.

Cooperation with the institutions was a crucial part of the recruitment process. The JYU's STEAMTeach team worked closely with the University of Lapland, Norssi School, and the Regional Administrative Agency of Western and Inner Finland to organize and host the workshops. This cooperation ensured that the workshops were tailored to the needs and contexts of the participants, maximizing their relevance and impact.

Engaging and involving the institutions in the workshops was also a key part of the recruitment process. The institutions were not just passive recipients of the workshops but active contributors to their design and implementation. For example, the University of Lapland hosted the first workshop, and Norssi School hosted the second one. The institutions' active involvement in the workshops ensured they were fully invested in the process, enhancing their commitment and contribution to the workshops.

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6.3 Workshops for implementing STEAM Course programmes 1 and 2 (O2.4)

The workshops were supported by a broad consortium of educators and researchers and have been instrumental in rejuvenating pedagogical practices. JYU's STEAMTeach team sought to bolster the integration of Science, Technology, Engineering, Arts, and Mathematics (STEAM) into teaching methodologies. To facilitate a comprehensive understanding of the STEAMTeach methodology, the workshops were divided into three main sections:

1. **Introduction:** This section involved theoretical STEAM Teach training. It was designed to explore the learners' needs, expectations, and previous experiences regarding STEAM. This stage was crucial for setting the stage for the rest of the workshop, as it allowed the facilitators to tailor the content and delivery to the specific needs and backgrounds of the participants.
2. **Activity:** The second part of the workshop involved the practical resolution of STEAM activities using a variety of tools and approaches. This hands-on section allowed participants to engage with the STEAMTeach methodology directly, applying the theoretical knowledge gained in the first section to practical, real-world scenarios. This experiential learning approach is known to enhance understanding and retention of knowledge.
3. **Individual and Group Reflections:** The final part of the workshop involved consolidating pedagogical knowledge. Participants were encouraged to reflect individually and in groups on what they had learned, identifying areas of strength and areas for improvement. This reflection stage is crucial for deepening understanding and facilitating the transfer of learning to the participants' own teaching contexts.

Workshop 1: STEAMTeach Training at the University of Lapland

Online report with video material and images: https://www.steamteach.unican.es/finnish-workshop/

The inaugural workshop of the series was hosted by the University of Lapland in Rovaniemi on December 7 and 8, 2021. Under the expert guidance of Dr. Kristóf Fenyvesi, a senior researcher at the Finnish Institute for Educational Research, the workshop welcomed the participation of nearly fifty pre-service teachers. The workshop

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was facilitated by Dr. Anna-Maija Partanen, a distinguished researcher and educator specializing in the popularization of mathematics and science.

A notable feature of the workshop was the introduction of two educational board games, 'Wortelmatika' and 'Fraction Bakery', by Dr. Farida Nurhasanah, an Indonesian researcher and STEM/STEAM specialist. These games employed a narrative-driven learning approach to instil fundamental mathematical concepts in early childhood, pre-school, and primary education contexts. Through these games, the workshop participants acknowledged the significance of playful and experiential methodologies in STEAM education.

Workshop 2: STEAMTeach Workshop at Norssi School

Online report with video material and images: https://www.steamteach.unican.es/finnish-workshop-ii/

The second workshop was convened at Norssi School in Jyväskylä, Finland, on January 18, 2023, with the backing of the Regional Administrative Agency of Western and Inner Finland. The event, which attracted more than 30 teachers, was extensively covered by a Finnish Daily newspaper, the *Keskisuomalainen*. This was an outstanding dissemination achievement for the STEAMteach project in the Central Finland region.

The main theme of this workshop revolved around the practical application of STEAM in teaching, exemplified through the construction of a Warka water tower. Teachers assembled their own Warka tower models using 4DFrame STEAM education equipment, fostering a sense of collaboration and creativity. Subsequent reflective discussions enabled participants to understand the diverse educational implications of the project.

STEAM Integration in Finnish Education: the STEAMTeach workshops underscored the progressive approach of Finnish education, where teachers are granted significant creative latitude to tailor their curricula to various learning objectives. Finnish schools advocate a phenomenon-based learning approach, integrating multiple subjects to immerse students in practical projects or simulations. The teachers' engagement in projects like the Warka water tower construction illustrates how project-based STEAM learning can effectively fulfil national and local curricula requirements.

The STEAMTeach workshops co-hosted by the University of Lapland and Norssi School epitomize the concerted efforts of Finnish educators and researchers to enhance teaching

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practices. By integrating STEAM methodologies into pedagogy, they empower teachers to develop students into creative, well-rounded, and skilled individuals capable of making positive societal contributions. With the escalating demand for STEAM education, it was imperative to equip teachers with comprehensive training and resources, thereby fostering a more holistic and dynamic learning environment for students.

6.4 Evaluation of STEAM Course programmes Designing and implementation (O2.5)

The workshops aimed to foster an environment of co-creation, piloting, and evaluation of innovative tools and technologies, inclusive pedagogical models, and cumulative curricular materials. These materials were specifically focused on phenomenon-based and multidisciplinary learning, two key components of the Finnish National Core Curriculum for Basic Education.

The Finnish STEAMTeach Team, a part of the Innovative Learning Environment Research Group at the JYU, played a crucial role in these workshops. The group members contributed significantly to the framework for collecting the materials used in the workshops, ensuring that the resources were relevant, up-to-date, and effective for the intended learning outcomes.

During the interactive, learning-by-doing activities, the participants were able to experience first-hand both the challenges and benefits that their students may encounter when engaging in STEAM activities. This empathetic understanding was invaluable for teachers, allowing them better to support their students in their STEAM learning journeys.

Through the structured reflection sessions, participants were able to consolidate their learning and acquire pedagogical knowledge to maximize the potential of STEAM approaches in their classrooms. These sessions provided an opportunity for participants to analyze their experiences critically, draw connections between theory and practice, and apply their new knowledge and skills in their own teaching contexts.

The participants were also able to select materials pertinent to their activities, adapting the existing resources to suit their unique contexts, and proposing enhancements during subsequent co-creation sessions. They suggested improvements in subsequent co-creation sessions. This active engagement of the participants in the workshops not only enhanced

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their learning experience but also contributed to the continuous improvement and refinement of the workshop materials and methodologies.

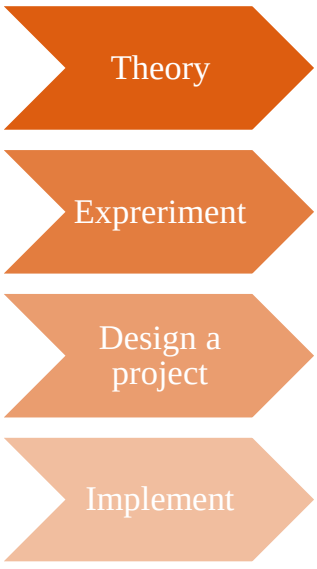
7 Greece

7.1 Designing Cross-cultural Course programme 1 and 2 for trainers and in-service and pre-service teachers (O2.1 and O2.2)

Structure

The rationale of the STEAMTeach training programme in Greece was based on the transcultural professional development framework devised the first intellectual output. In the following, we refer to the structure and the context of the training programme to justify the NKUA's choices regarding the design of the training.

The training programme in all countries (Spain, Finland, Austria, Hungary, and Greece) had some common elements. One of the most fundamental elements was the three dimensions unfolding; theoretical, experimental, project design, and implementation.



There was no need for linear engagement of the trainees to these dimensions, i.e., the project design dimension could start before implementation, and continue after it exploiting the reflection of incidents or observation during the implementation phase. We were supposed to do training courses in two phases of the project, with a phase of classroom implementation between them. So, it was inevitable but also useful that the

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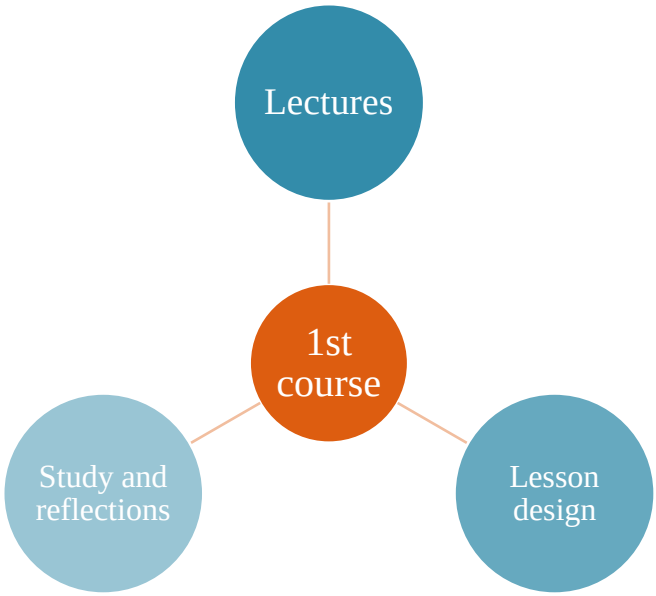
'training course 2' should be affected, mostly in terms of content, by what happened in the 'implementation phase 1'.

In phase 1, each training course would have three parts, as it is shown below:

- The theoretical part with one or two lectures, by experts aiming trainees to have a full scope of the STEAM approach and the related learning approaches (project-based learning, inquiry-based learning, collaborative learning, etc.), based on the STEAMTeach framework.
- The 'study and reflection' part, dependent on the experimental dimension of the course, where trainees would have access to two exemplary lesson plans (activity scenario), designed by NKUA that carried out the STEAMTeach approach in practice.
- A workshop, which was the lesson design part, where the trainees would have the chance to design their own teaching interventions, following the STEAMTeach framework.



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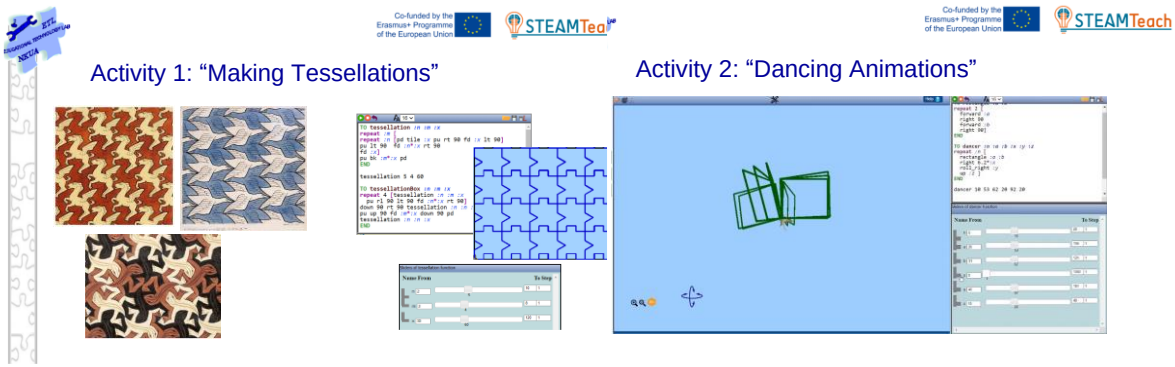
In Greece, NKUA added three additional elements to the training rationale:

- The ‘teachers as designer’ approach as a teacher’ professional development framework (Laurillard, 2012). Trainees were involved in designing their own learning resources based on the STEAMTeach framework.
- The element of integrated STEM/STEAM in the approach of the training (Moore & Smith, 2014).
- The educational exploitation of digital media. Since ETL/NKUA has a remarkable experience in educational design with digital media, a long-lasting involvement and experience in the integration of digital media in schools and teacher training, NKUA chose to exploit this experience. Moreover, the induction of digital media in the STEAM approach is already a step towards integrated STEM/STEAM.

Content

The training programme was conducted over two days. On the first day, the focus was on the theoretical and experimental dimensions of the training. There were plenary lectures on the characteristics of teachers’ training integrating the STEAMTeach approach, which meant that the element of digital media and the importance of the design procedure emerged. After that, two exemplary tasks/lesson plans for students with digital tools exploitation were presented by the NKUA team. These lesson plans were designed by the NKUA team, following the STEAMTeach template (https://www.steamteach.unican.es/activities/). Teachers had the chance to reflect on and discuss the characteristics of these activities. The two lesson plans were titled ‘making tessellations’ and ‘dancing animations’.



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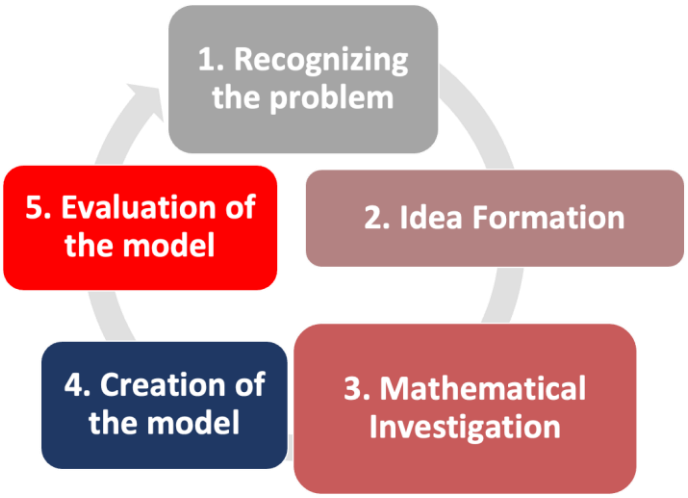
Both lesson plans are based on the project-based learning (PBL) approach, while exploiting MaLT2 (http://etl.ppp.uoa.gr/malt2/), a 3D Turtle Geometry, logo programming environment, with the affordance of dynamic manipulation, which is a product of ETL/NKUA. The activities of students that would be engaged with these tasks followed the next cycle:



Detailed information about the Mathematics-based lesson plans can be found in the STEAMTeach portal (https://www.steamteach.unican.es/activities/).

Refinement

In the shift from phase 1 to phase 2, the course was refined around two characteristics; the implementation dimension was apparent, and the theoretical dimension became more specific (focusing on PBL). As it was obvious, the implementation dimension was not apparent in the training of phase 1, but it became apparent in phase 2 of the training; during the study and reflection part, some of the exemplary lesson plans were designed and implemented by teachers during the implementation phase 1. This was the one direction in which the training course of phase 1 was refined and led to a novel approach in phase 2 training.

Teachers that participated in the implementation phase 1 had designed 6 lesson plans of their own based on the STEAMTeach framework (titled ‘auto-parking’, ‘the playground’, ‘traffic lights’, ‘data handling’, ‘the spirals’, and ‘design tasks for peers’). So, the NKUA team chose and included two lesson plans (‘the playground’ and ‘auto-parking’) in the ‘study and reflection part’ of training course 2. In this way, the experience from the

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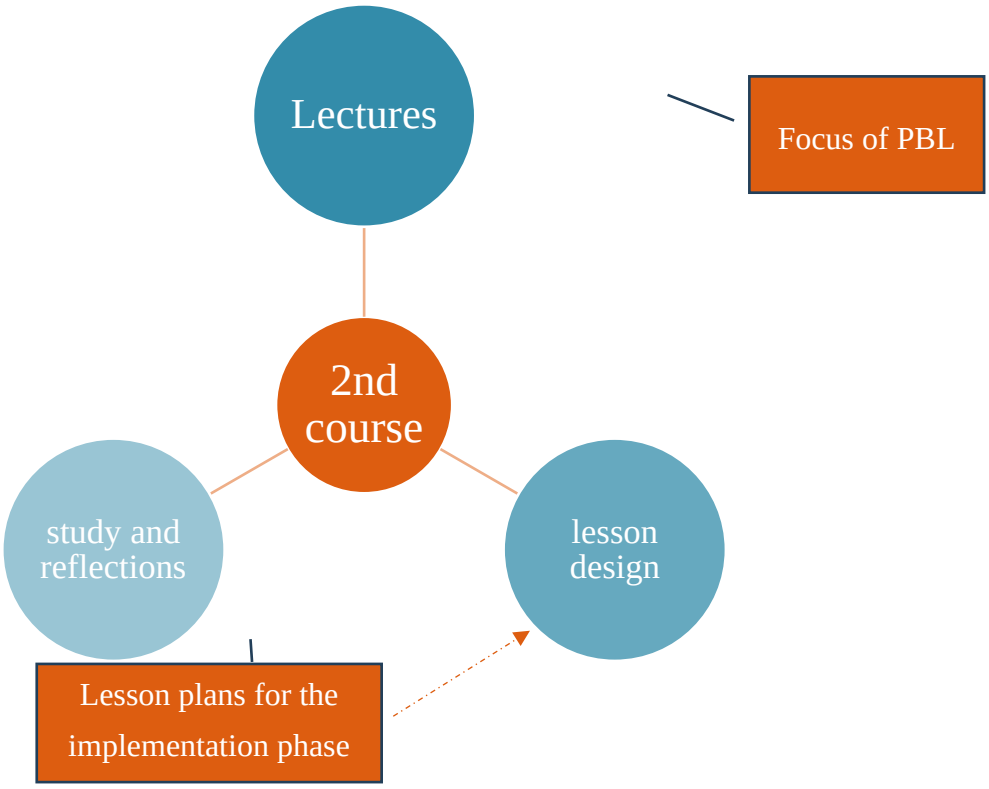
implementation phase 1 had an impact not only on the experimental dimension of training but on the project design dimension since the new lesson plans affected the 'lesson design' of the training, as well.



Another level of refinement had to do with the theoretical dimension of the training, which was realized through the lectures. Since PBL seemed to be more helpful for the teachers of the first course and during the implementation phase 1, during the lectures PBL was presented in detail.

7.2 Recruiting trainers and teachers to participate in the above Cross-cultural Course programmes (O2.3)

To recruit teachers to participate in the training, NKUA reflected on the profile of the participants that would preserve the sustainability and the dissemination of the project products and outcomes.

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- In-service teachers, to have access to classroom implementation for the next steps.
- Teachers that are teachers' trainers, as well, to act as multipliers of the STEAMTeach framework to their trainees.
- Innovative teachers to be willing to implement or even design novel teaching interventions.

Considering the above, the NKUA decided to recruit teachers that came from two pools:

- NKUA invited the Mathematics Teacher trainers in the educational use of ICT. They are highly qualified and experienced Mathematics Teachers in secondary education in Greece, and they have a long-lasting collaboration with ETL/NKUA; ETL/NKUA has designed a training program that has been conducted for over 10 years by the Ministry of Education, called "In-service training of teachers in the utilization and application of digital technologies in the teaching practice" (https://e-pimorfosi.cti.gr/en/). Moreover, ETL/NKUA is responsible for updating the training program's curriculum for the Mathematics teachers and is involved in the teacher trainers' education and certification. So, ETL/NKUA team was optimistic about the commitment of the teacher trainers, not only for participating in the STEAMTeach training course as trainees but for acting as multipliers of the project, as well. At the same time, some elements of the STEAMTeach approach were induced, as best practices, in in-service teacher training in utilizing and applying digital technologies in the mathematics' teaching practice.
- NKUA also invited teachers from the model and experimental schools in Greece. Model and experimental schools is a network of 125 public schools in Greece, that collaborate with the universities to the scope of innovation in education. So, NKUA invited the schools of this network that collaborated with in the past.

Each participant received a formal invitation for joining the 1st training course (phase 1) and the 2nd training course (phase 2), and they registered themselves through the following online formularies:

- https://docs.google.com/forms/d/e/1FAIpQLSeXMWUOQXlRjLmMRiOJ-DYMOQNnm6iEinH6DVcRLp0Q7BJ4cQ/viewform?usp=sf_link
- https://docs.google.com/forms/d/e/1FAIpQLSeXMWUOQXlRjLmMRiOJ-DYMOQNnm6iEinH6DVcRLp0Q7BJ4cQ/viewform?usp=sf_link

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The agendas of the training courses can be found at: https://www.steamteach.unican.es/greek-workshop/

7.3 Workshops for implementing STEAM Course programmes 1 and 2 (O2.4)

The training course of phase 1 was conducted on 28 and 29 of January 2022, in the amphitheater of the Model Junior High-school of Athens, while the second course was held in Varvakio Model Junior High-school and Varvakio Model High-school, on February 17 and 18, 2023.

The participants-trainees of each course are presented in the tables below.

	Training course 1	Training course 2
Male	16	22
Female	11	14
Total number of participants	27	36
Face-to-face participation	16	13
Participation from distance	11	23
Math teacher	21	29
Teacher educator	21	29
Language Teacher	2	2
Informatics Teacher	2	2
Primary teacher	1	1
Teacher consultant	1	3

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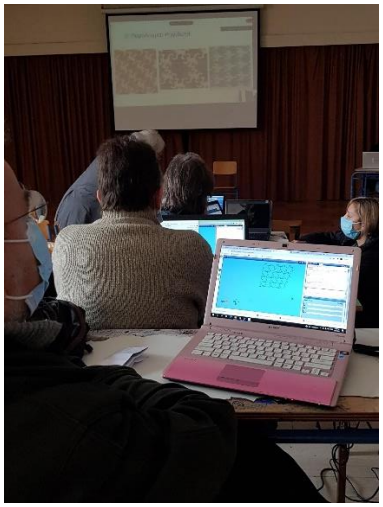
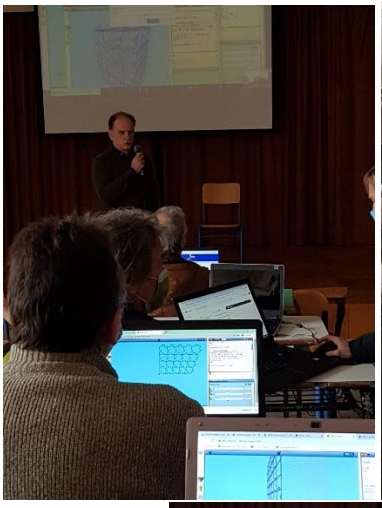
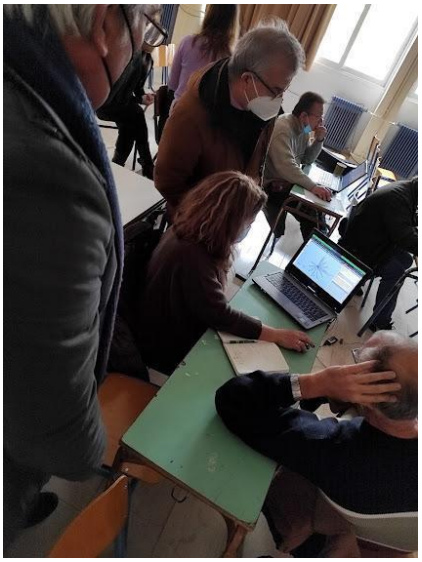
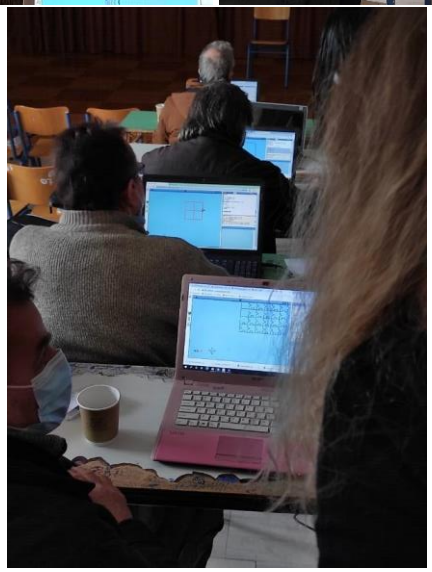
In the following we see some pictures taken during the workshops:



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7.4 Evaluation of STEAM Course programmes Designing and implementation (O2.5)

When designing the training courses, NKUA had set the following goals, in line with the projects' scope:

- To involve as much schoolteachers as possible in the classroom implementation, as a follow up activity of the training.
- To connect the implementation phase with the training course.
- To disseminate STEAMTeach framework, through the involvement of teacher educators in the training.

About the first goal, 6 out of the 7 teachers that were involved in the implementation phase, were teachers of model and experimental schools, that participates in the training course 1. After the training course 2, 13 of the 15 teachers that implemented lessons were teachers of model and experimental schools that were trained.

About the second goal, is seems that the reflection on the classroom implementation phase had some results. In the first phase, among the 10 STEAMTeach lessons that were implemented after the course 1, there were 2 that constituted of original lesson plans by the teachers, based on thew STEAMTeach framework. The rest (8) were lesson plans already developed by NKUA, that the teachers adopted. In course 2 teachers had the chance to reflect on these two teachers' lesson plans (the playground and auto-parking). Then, in the follow up implementation phase 2, there were 5 novel lesson plans that teachers created and implemented. Moreover, what it became clear was that the PBL approach was helpful for the teachers to design and implement their own interventions.

About the third goal, a shred of dissemination was apparent since two teacher trainers used the STEAMTeach framework to make poster presentations on the multiplier event in Athens, but we need more time in order to monitor the real effect.

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8 Conclusion

In this document, we have presented a comprehensive overview of the design and implementation of the Cross-cultural Course program, aimed at preparing professional trainers, in-service teachers, and pre-service teachers in the field of STEAM (Science, Technology, Engineering, Arts, and Mathematics). We initially introduced the shared transcultural professional development framework, which served as the foundation for the program developed by each partner within the consortium.

To elucidate the specificities of the development program, intended to be tested within various contexts, we have provided distinct sections detailing the implementation characteristics in each participating country. Specifically, we describe the minor adaptations made to the program by each partner, the profiles of the trainers and teachers involved in each context, the conducted workshops during the implementation phase, and their subsequent evaluations.

The evaluations reveal that each partner adeptly tailored the development program by emphasizing methodologies that aligned seamlessly with the curriculum objectives. Over the course of the two-year STEAM program, the devised implementation strategies and tools not only augmented the available teaching materials in each country but also enhanced the knowledge and skills of the participating individuals. While varying in certain aspects, all teachers participating in the trials expressed a positive satisfaction with the employed methodologies, the support provided by the STEAM trainers, and the positive feedback received from their students and parents regarding this innovative developmental program.

Overall, we have observed that this professional development program assists in equipping teachers and students with the essential competencies to excel in our advanced technological society, as the new generations face the challenges posed by these advancements.

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