June 2023

STEAMTeach

Science | Technology | Engineering | Arts | Mathematics

O5: PROJECT MULTI-DISCIPLINARY LEARNING EVALUATION (MDLE): COURSE PROGRAMME, DESIGN, TRAINING, TEACHING IMPLEMENTATION, AND INTERNATIONAL COLLABORATION

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PROJECT

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STATUS	Submitted

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1 INTRODUCTION

This ultimate intellectual output encompasses an evaluation report presenting the results derived from course design, implementation phases, and international collaboration. It also incorporates recommendations for future projects in the domain of STEAM education.

For data collection and analysis, we employed a Multi-disciplinary Learning Evaluation (MDLE) approach which allows comprehensive assessments across time and countries, including diverse social and cultural contexts. This approach helped us to identify common trends within the context evaluated and enhance our understanding of trainers' and teachers' knowledge and pedagogical expertise throughout the project. To achieve this, local teams consisting of experts from diverse domains were established, alongside international teams with experts from the same domain. The distinct orientations of these expert teams facilitated the collection and evaluation of both transdisciplinary and interdisciplinary STEAM learning environments.

The analysis and outcomes were regularly documented in the project groups of the partner countries. Then, the local reports were analysed and synthesizing for uploading the main outcomes to our website. In the following, we summarise the results obtained according to the three main objectives of the project:

- **O5.1** Designing instruments for evaluation
- **O5.2** Supervising and integrating the evaluations from IO2, IO3, and IO4 for attaining a coherent project assessment
- **O5.3** Undertaking a global evaluation of project satisfaction and providing recommendations for future STEAM projects

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2 DESIGNING INSTRUMENTS FOR EVALUATION

2.1 The Multi-Discipline Learning Evaluation Approach in STEAMTeach

Prior to the report of the STEAMTeach project evaluation, we must clarify the scope, and the aim of this evaluation, to make clear: a) why we chose this type of evaluation, b) what we expected from the evaluation report, and c) how we can exploit this report.

The scope of the evaluation was related to the objectives of the STEAMTeach project. So, we focused on the evaluation of the STEAMTeach theoretical approach (IO1) as a framework for Teachers' Professional Development (TPD) and as a learning approach for designing and implementing STEAM lessons. The aims of the evaluation were:

a) To describe how the STEAMTeach principles were implemented during the training courses and the classroom implementation phase

b) What came out from the analysis of quantitative data that were gathered during the training processes and the lesson implementations

Given the dual focus of the evaluation (TPD framework and learning approach), the data we produced and collected in each country related to participant teachers' profiles, whether they were trainees or teachers. This encompassed their perspectives on the training course content and context, as well as the influence of the training on classroom implementation and vice versa. Through the analysis of the results, we attempted to better assess the result of the STEAMTeach training programme in relation to the participants' professional needs concerning their competence in implementing STEAM activities. Thus, the evaluation was focused on seeking answers to the following questions:

Q1. How effective was the STEAMTeach training programme, as a TPD activity, in terms of content knowledge and pedagogical knowledge of the teachers?

Q2. How efficient was the classroom implementation phase, based on the STEAMTeach approach?

Though, we shall not disregard the fact that the classroom implementation was a follow-up of the training programme. Much more than this, there was a sequence of activities (Figure *1*, training courses and classroom interventions).

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Figure 1: STEAMTeach sequence of activities.

So, it was reasonable to evaluate the classroom implementation phase in relation to the training courses as a possible two-way interaction. Thus, a third question came up:

Q3. How effective was the sequence of activities with regard to both TPD and lessons?

The evaluation report of the STEAMTeach project was based on answering questions Q1, Q2, and Q3 and reflecting on the STEAMTeach framework in relation to the following:

- Describing the progress of the STEAMTeach training and lessons, in each country, and as an overall procedure.
- Making suggestions for future teacher training programs on STEAM.

The STEAMTeach approach is rooted in multi-disciplinarity, serving not only as a learning context but also as a training framework. Participating teachers from various countries had diverse expertise, with many aiming to integrate lessons without confining themselves to specific subject curriculum objectives. Hence, both in principle (as outlined in the project description) and in practice (as reflected in its implementation), embraced a multi-disciplinary Learning Evaluation (MDLE) approach to be conducted throughout the project. It means that either from the point of view of TPD, or from the point of view of learning, we focused on skills (i.e., problem-solving, inquiry skills, etc.), and procedures (i.e., lesson design, etc.). When talking about the content knowledge of the teachers that participated, we refer to STEAM as content, trying not to describe it through its fragmentation (S, T, E, A, and M).

2.2 The STEAMTeach evaluation toolkit

After every phase of the project (training course or classroom implementation), each partner delivered two reports. See Figure 5 for an overview of each report within the phases of the project.

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- **Report 1 (R*1):** Information about the participant teachers of each country. For the training course (TC), the participants were teachers-trainees of the training courses/workshops. In the case of classroom implementation (CI), the participants were the teachers that designed/implemented lessons following the STEAMTeach approach.
    - **RT1:** For a training course.
    - **RI1:** For a classroom implementation.
- **Report 2 (R*2):** A description of the training/workshops or the classroom implementation in each country.
    - **RT2:** For a training course.
    - **RI2:** For a classroom implementation.

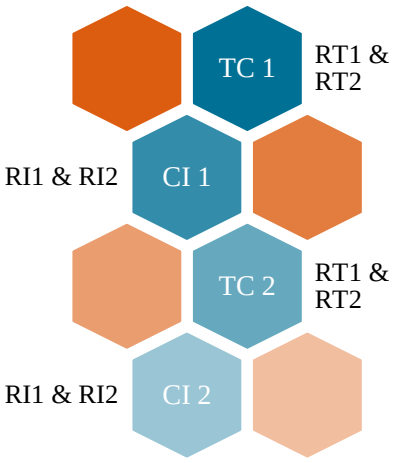

Figure 2: The use of the STEAMTeach evaluation toolkit in parallel with the project's development.

To document these reports (R*1 & R*2), we developed and used a toolkit consisting of two instruments: a questionnaire for R*1 and a set of questions that could be used as a guide for R*2. We call these two instruments "STEAMTeach evaluation toolkit". The objectives of the toolkit usage were:

O1. To take feedback from the training courses and the workshops (1 & 2).
O2. To monitor the in-classroom implementation phase (1 & 2).
O3. The assessment of the project in relation to the above, through answering the questions Q1, Q2, and Q3.

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O4. The consideration of the 'STEAMTeach evaluation toolkit' itself and the development of an evaluation instrument intended for future use by teachers, serves not only as an assessment tool for teaching design and learning outcomes, but also as a tool for introspection while formulating lessons within the framework of the STEAM educational approach.

O5. To provide guidelines for future training programs for teachers in STEAM education.

2.2.1 Evaluation instruments of the training

In this section, we present the instruments of the STEAMTeach evaluation toolkit for the training courses:

R1tc. This is the questionnaire we used for the report RT1 of the training courses. Every participant in each country was supposed to fill it. Then each partner collected the R1tcs of the participants, which was **RT1** (Figure 3).

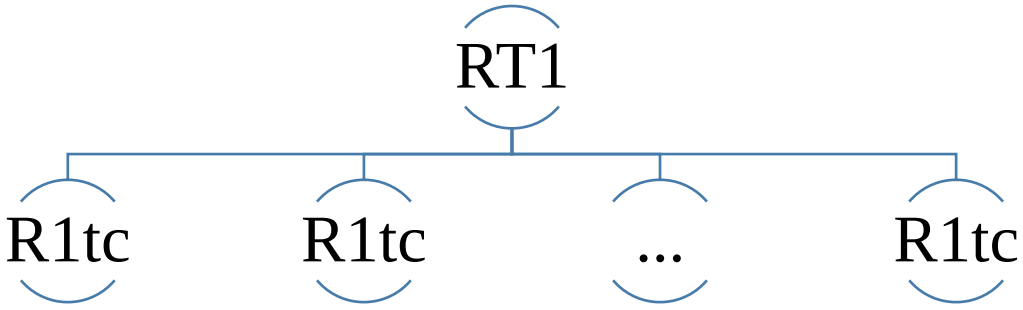

Figure 3: The RT1 report of each country constitutes the R1tcs of all participant teachers

Questionnaire for the report RT1 of the training courses (R1tc)
Part 1
• Participant name • Teacher educator (yes/no) • Age

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- Sex
- In what school stage do you teach?
- What bachelor's degree does you hold (e.g., a Degree in Mathematics or a Degree in Physics)?
- What subject/s do you teach?
- Do you have experience in implementing STEAM activities?
- Do you have experience in implementing other educational innovations?
- What is your specialization (e.g., Mathematics or Art)?
- Do you consider that the theoretical information provided by the STEAM trainers during the workshop is valuable to you?
- Do you consider that the STEAM activities presented to you by the STEAM trainers as examples were useful?
- Do you consider that the experimental part of the workshop where you were proposed to solve a STEAM activity is valuable to you?
- Do you consider that the design part of the workshop where you created a STEAM activity for your students is valuable to you?
- Generally speaking, do you consider that the overall workshop was well-designed and executed?
- Were the STEAM activities executed during the workshop related to the school curriculum?
- Was the workshop useful to you in learning how to integrate content from the STEAM disciplines?
- Was the workshop useful to you in learning how to set up STEAM activities in a problem-based learning context?
- Was the workshop useful to you in learning how to set up STEAM activities in an inquiry-based learning context?

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- Was the workshop useful to you in learning how to set up STEAM activities in a design-based learning context?
- Was the workshop useful to you in learning how to work collaboratively with your peers in STEAM activities?
- In general terms, do you consider that this training has contributed to acquiring knowledge about STEAM activities?

Part 2: Please make a brief description of the training course/workshop. You may use the following questions as a guide

1. Please, indicate in which other educational innovations you have experience.
2. Why do you consider that the theoretical information provided by the STEAM trainers during the workshop is valuable to you? What changes/modifications would you incorporate?
3. Why do you consider that the STEAM activities presented to you by the STEAM trainers as examples were useful? In which aspects do you find these activities useful or un-useful?
4. Why do you consider that the experimental part of the workshop where you were proposed to solve a STEAM activity is valuable to you? In which aspects do you find this part useful or un-useful?
5. Why do you consider that the design part of the workshop where you created a STEAM activity for your students is valuable to you? In which aspects do you find this part useful or un-useful?
6. Generally speaking, why do you consider that the overall workshop was well designed and executed, or not? What recommendations would you make to improve this training?
7. Why the STEAM activities executed during the workshop were or were not related to the school curriculum? What changes would you incorporate in this sense?
8. Why was the workshop useful (or not) to you to learn how to integrate content from the STEAM disciplines? Please explain which workshop aspects helped

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you to learn how to integrate content. Suggest other ways for learning to integrate content.

9. Please explain those aspects that helped you to learn how to set up STEAM activities in a problem-based learning context. Suggest better ways to set up STEAM activities in a problem-based learning context.
10. Please explain those aspects that helped you to learn how to set up STEAM activities in an inquiry-based learning context. Suggest better ways to set up STEAM activities in an inquiry-based learning context.
11. Please explain those aspects that helped you to learn how to set up STEAM activities in a design-based learning context. Suggest better ways to set up STEAM activities in a design-based learning context.
12. Please explain those aspects that helped you to learn how to work collaboratively with your peers from other disciplines. Suggest better ways to improve this aspect.
13. Why do you consider that this training has contributed to acquiring knowledge about STEAM activities, or not?
14. In future workshops, what aspects would you like to be emphasized? In which other aspects would you like to be trained?

R2tc. A set of questions that each partner used to describe the training courses conducted, that is **RT2**.

Questionnaire for the report RT2 of the training courses (R2tc)
• The number of teachers who participated
• The number of teacher educators who participated
• The estimated average age of the participants
• The number of lessons designed/discussed/exploited during the workshops

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- The main learning approach in the lessons (i.e. PBL)
- The most common discipline regarding teachers' expertise
- The main difficulty that teachers faced during the workshops
- The most valuable outcome for teachers

2.2.2 Evaluation instruments of the classroom implementation

In this section we present the instruments of the STEAMTeach evaluation toolkit, which we exploited for the classroom implementation evaluation:

R1ci. This is the questionnaire used for the report RI1 of the classroom implementation. Every participant in each country was supposed to fill it out after implementing a lesson. Then each partner collected the R1cis of the participants, and this collection was **RI1** (Figure 4).

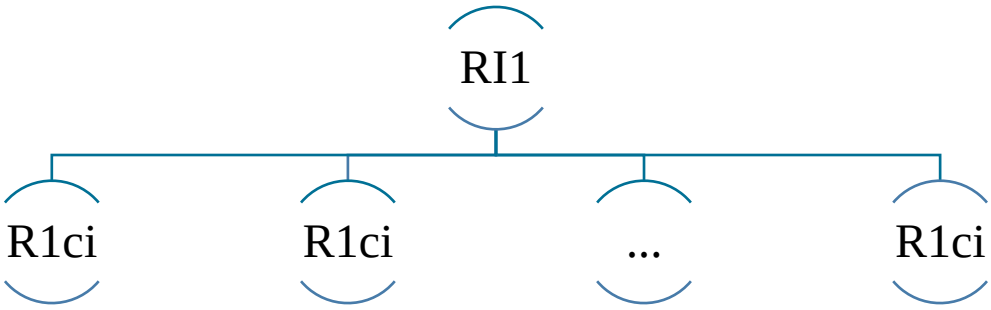

Figure 4: The RI1 report of each country constitutes the R1cis of all participant teachers

Questionnaire for the report RI1 of the classroom implementation (R1ci)

- Participant's name
- Age
- Sex
- In what school stage do you teach?

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- What bachelor's degree do you hold (e.g., Degree in Mathematics or Degree in Physics)?
- What subject/s do you teach?
- Do you have experience in implementing STEAM activities?
- Do you have experience in implementing other educational innovations?
- What is your specialization (e.g., Mathematics or Art)?
- To which subject/s was your classroom implementation related?
- How many students participated in the STEAM classroom implementation?
- What was the duration (in terms of school hours) of the classroom implementation?
- In how many days the classroom implementation took place?
- Were the STEAM activities of the classroom intervention you implemented related to the school curriculum?
- Did you design the classroom implementation in collaboration with colleague(s)?
- If yes, what subject/s do they teach?
- Did you implement the lesson in collaboration with colleague(s)?
- If yes, what subject/s do they teach?
- Was the classroom intervention you implemented related to the framework of problem-based learning context?
- Was the classroom intervention you implemented related to the framework of inquiry-based learning context?
- Was the classroom intervention you implemented related to the framework of design-based learning context?
- Did students work collaboratively during the classroom intervention you implemented?

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- Do you consider that the theoretical information provided by the STEAMTeach trainers during the workshops was valuable to you?
- Do you consider that the STEAMTeach activities presented to you by the STEAMTeach trainers as examples were relevant to the classroom intervention you implemented?

R2ci. A set of questions that each partner used to make a description of the classroom implementations and interventions conducted, that is, **RI2**.

Questionnaire for the report RI2 of the classroom implementation (R2ci)
• Did the participants have previous experience in implementing other educational innovations? If yes, please indicate in which innovations they were experienced. • From the point of view of the participants: Were the STEAM activities of the classroom intervention they implemented related to the school curriculum? In which sense? Please explain briefly. • From the point of view of the participants: Was the classroom intervention they implemented related to the framework of problem-based learning context? If yes, please explain why. • From the point of view of the participants: Was the classroom intervention they implemented related to the framework of inquiry-based learning context? If yes, please explain why. • From the point of view of the participants: Was the classroom intervention they implemented related to the framework of design-based learning context? If yes, please explain why. • Please describe briefly in which way the students collaborated during the implementation phase. • Did the participants consider that the theoretical information provided by the STEAMTeach trainers during the workshops was valuable to you? Why? What

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changes/modifications would they incorporate in the STEAMTeach approach now that they have implemented STEAM lessons in the classroom?

- Did the participants consider that the STEAMTeach activities presented to them by the STEAM trainers during the workshops, as examples, were relevant to the classroom intervention they implemented? Please explain why.
- Please explain those aspects that helped the participants learn how to set up STEAM activities in a problem-based learning context. Would they suggest better ways to set up STEAM activities in a problem-based learning context?
- Please explain those aspects that helped the participants learn how to set up STEAM activities in an inquiry-based learning context. Would they suggest better ways to set up STEAM activities in an inquiry-based learning context?
- Please explain those aspects that helped the participants learn how to set up STEAM activities in a design-based learning context. Would they suggest better ways to set up STEAM activities in a design-based learning context?
- Please explain those aspects that helped the participants learn how to work collaboratively with their peers from other disciplines. Would they suggest better ways to improve this aspect?
- Why do the participants consider that this training has contributed to acquiring knowledge about STEAM activities, or not?
- In future workshops, what aspects would the participants like to be emphasized? In which other aspects would they like to be trained?
- Was the classroom intervention you implemented related to the framework of design-based learning context?
- Did students work collaboratively during the classroom intervention you implemented?
- Do you consider that the theoretical information provided by the STEAMTeach trainers during the workshops was valuable to you?

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- Do you consider that the STEAMTeach activities presented to you by the STEAMTeach trainers as examples were relevant to the classroom intervention you implemented?

In Figure 5, we place the use of each evaluation toolkit instrument within the phases of the project.

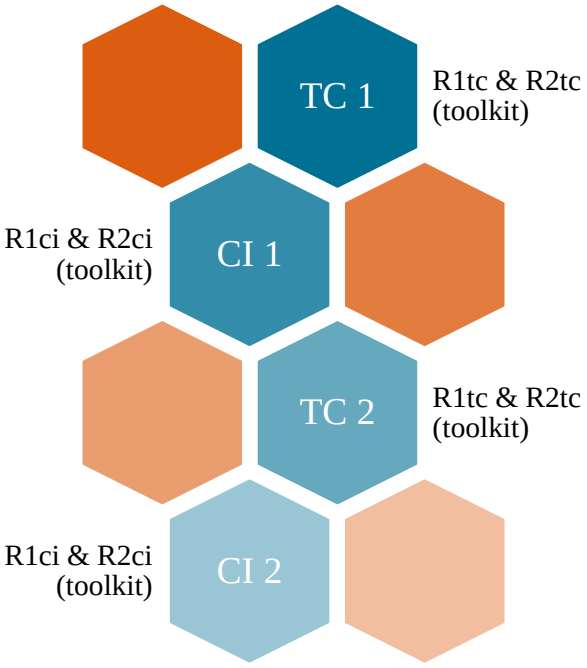

Figure 5: The use of the STEAMTeach evaluation toolkit, in parallel with the project's development

2.2.3 Evaluation report by country and overall evaluation

After collecting all the reports from each partner, we composed a report in which:

- We gained answers to the questions Q1, Q2, and Q3.
- We addressed the objectives O1, O1, and O3.
- We focused on making an evaluation of the project based on the answers and conclusions from the two previous bullets.
- We reflected on the project framework and implementation (training & classroom interventions).
- We set a list of guidelines as a catalogue for future STEAM projects about TPD and teaching (objective O5).

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- We reflected on the STEAMTeach evaluation toolkit, making suggestions for refining it (objective O4).

3 SUPERVISING AND INTEGRATING THE EVALUATIONS FROM THE TRAINING IO2, AND CLASSROOM IMPLEMENTATION IO3 FOR ATTAINING A COHERENT PROJECT ASSESSMENT

3.1 The results of each phase

In this section, we refer to findings from the reports' analysis, and we discuss them based on the STEAMTeach framework and its implementation during the project.

3.1.1 The training Courses (IO2)

The average ages of the participants in the training courses/workshops in all countries varied between 44.8 and 51.5 years old. The lowest average age was in Finland (44.8), while the highest was in Greece (51.5). The average ages of participant teachers from other countries were between the above values.

In Figure 6, we compare the dispersion of the ages in Finland and Greece, the two countries with the youngest and oldest trainees, regarding their average age. It is obvious that there was no remarkable alteration in trainees' ages between training course 1 and 2 in Finland, while in Greece, the dispersion of the trainees' age was modified; the trainees' ages in the second training in Greece was remarkably more homogenous than in the first one.

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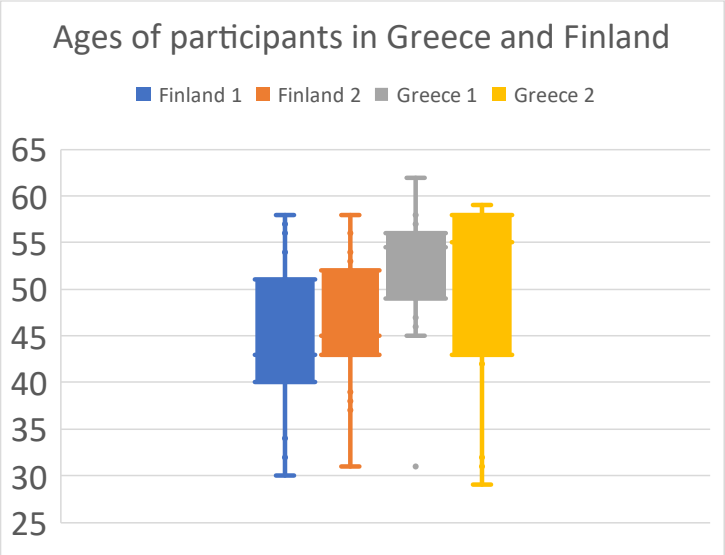

Figure 6: The bar charts of the ages of the trainees' teachers participating in training courses 1 and 2 in Greece and Finland

The difference between the average age between Finland and Greece could be interrelated with the trainees' profiles in Finland and Greece. In both training courses, in Greece a noteworthy percentage of the trainees, were both in-service teachers and teacher educators, who typically are more experienced teachers, meaning that they might be older. In support of this statement, we mention that in the first training course held in Greece, 88% of the participant trainees were not only teachers but also teacher educators. In the second workshop, around 70% of the trainees in Greece were teacher educators; this might be the reason for reducing the average participants' age in Greece. However, the average age of participants in Greece remained the highest among all countries.

Participant teachers in all countries were experienced in implementing innovations based on their own statements. However, after the training, when the question was about STEAM activities, around 50%-55% of the teachers in most countries that had already stated themselves to be experienced in implementing innovations did not consider themselves as experienced in implementing STEAM activities (Figure *7*). In Greece, this percentage was lower; around 1 out of 4 teachers that considered themselves experienced in educational innovations said the same about STEAM activities. In Spain, it was vice versa; around 65% of the teachers considered themselves experienced in innovation and thought of themselves as experienced with STEAM activities.

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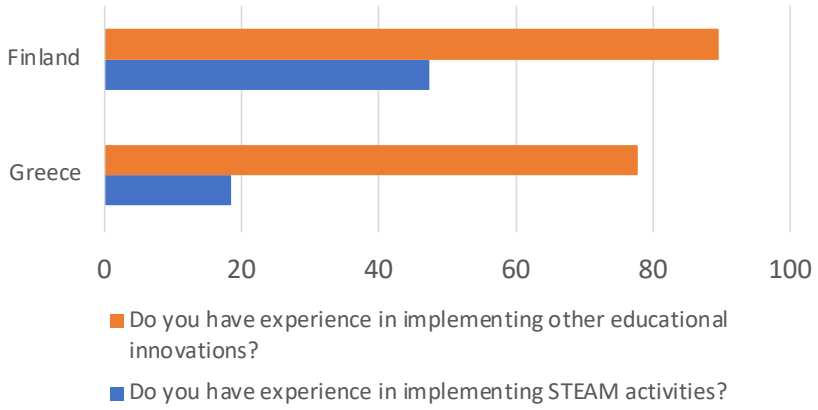

Figure 7: Teachers' experience

So, in all countries, the participants in both phases of the training considered themselves experienced in educational innovations, which at least was indicative of their positive disposition to the training programme and classroom implementation, as well. In Greece, trainees stated that they were less familiar with STEAM, which was documented by the description of NKUA partner, that was responsible for organizing the training; they had not participated in the past in a training oriented towards TPD in relation to STEAM. On the other hand, based on UC reports (the partner responsible for the Spanish training programme), most trainees in Spain have participated before in a TPD related to STEAM, in one way or another, but with a different twist. In fact, around 25% of them had participated in the Open STEAM Group (https://www.opensteamgroup.unican.es).

At this point, it is noteworthy to see the answers to the questions in Figure *8*. Although Spanish teachers were more experienced in STEAM training, it seems that the degree of satisfaction with the training, regarding the STEAM content, was like their Greek colleagues that had not had such an experience. Moreover, focusing on the question, "Do you consider that the design part of the workshop where you created a STEAM activity for your students is valuable to you?" we observe that the answer 'YES' is higher in Spanish teachers than in Greek ones.

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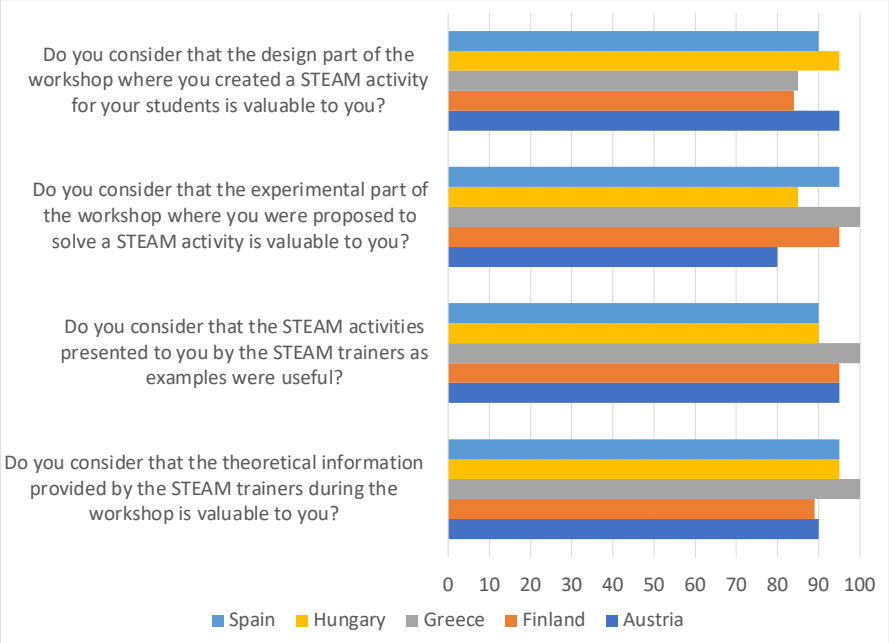

Figure 8: Answers from the second phase of the training

The Spanish trainees mentioned that the design part of the training courses helped them to learn to delimitate the objectives of the projects, establish guidelines for their students, and control the time for proposing or guiding projects successfully. They considered STEAM projects too open, thus students and teachers could lose control of their actions and fail to accomplish the expected objectives. During the design of the projects, the teachers also became aware of the importance of a well-established organization of tasks or learning scenarios, of a justified distribution of work among students, of a cautious choice of the kind of learning activities to be exploited in the classroom, to avoid this kind of turnovers. During the design parts of the workshops, teachers also considered the difficulty and importance of evaluating the process when working collaboratively. Most of the questions in the last course were related to evaluation because of the Spanish educational situation.

From these observations, we could conclude that the component of 'design' during the training workshops was one of the strengths since the more experienced teachers mentioned it. Another advantage of the training -in all countries- was the exemplary activities that were presented to the trainee teachers. For example, Finnish teachers appreciated this kind of hands-on experience and recognized that this was a good example of how STEAM learning can answer many different learning goals set by the national and local curricula. This is another point of interest; the potential of the STEAMTeach

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framework to provide access to the curriculum, using STEAM as a vehicle. This potential differs from one country to another, but we will discuss it later. In Figure *8*, it seems that the content of the training course was satisfactory for all countries' teachers, in terms of theory and examples. Based on the high rating by Greek teachers, we could say that the training course is beneficial for teachers who are not yet experienced in STEAM, without being less useful for more experienced teachers around STEAM.

Trainees in all countries mentioned the usefulness and feasibility of the experimental part of the training. The teachers considered the experimental sessions one of the most valuable parts of training courses as they were experiencing the same difficulties that their students would face when executing the activities. In the experimental part, the teachers were involved in addressing challenges, having the role of students. This helped the trainee teachers become aware and identify the troubles that their students could face while addressing the same challenges. Some activities proposed for teachers in the programme were replicated in regular lessons with their students. For example, in the case of Spain, these activities included Radio Gaga and Modelling objects in movement. However, the experimental part seemed to be of even greater value due to the design part of the workshops.

Regarding the learning approaches introduced through the STEAMTeach training to deliver STEAM education (Figure *9*), it seems that in all countries, teachers considered project-based learning useful. Concerning design-based learning, inquiry-based learning and problem-based learning, Greek teachers' satisfaction was lower than project-based learning. From the qualitative data produced during the Greek workshops, it seems that the low degree of satisfaction was connected to two factors. The first one was that the examples used by the NKUA training team were mostly related to project-based learning. The other factor had to do with the consensus of the trainees in Greece that project-based learning was like a guide that supported them in designing a STEAM lesson. The importance of project-based learning was highlighted in the case of Finland, too.

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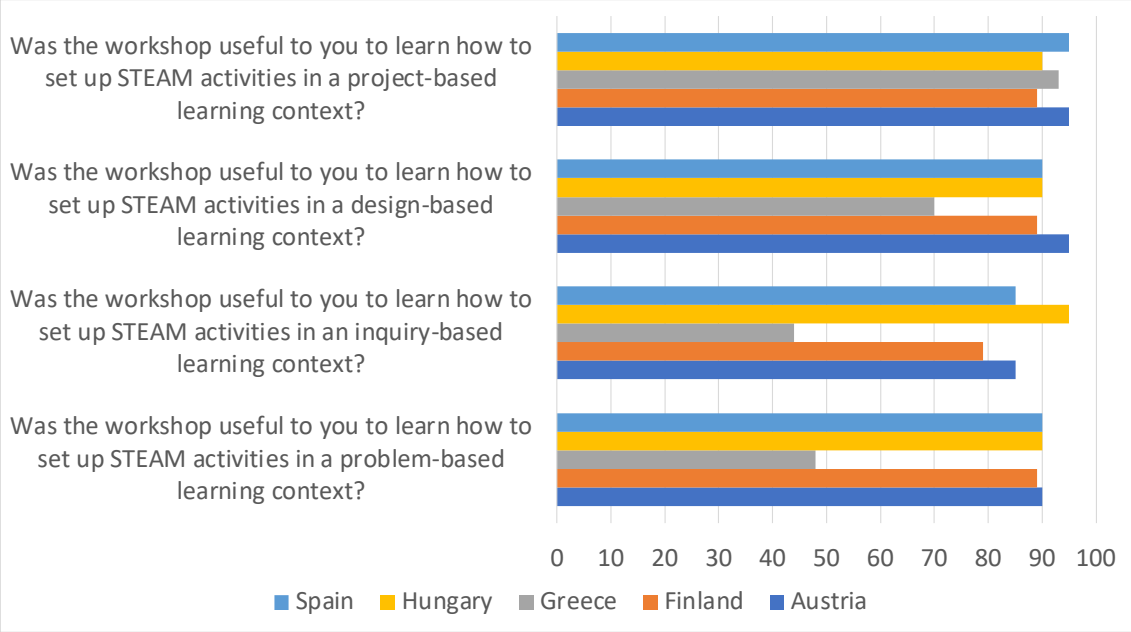

Figure 9: The learning approaches presented in the training, to be related to STEAM, based on the STEAMTeach framework

Moreover, from the case of Spain became apparent that elaborating on STEAM projects is a challenge that implies applying inquiry-based learning and problem-solving skills collaboratively. So, in practice, we should not exclude a learning approach, from the STEAMTeach training programme. The Spanish trainees realized that during the experimentation phase of their workshop. So, apart from the connection between the design and the experimental part of the training, which made both seem valuable, there was a connection between the experimental part of the workshops and learning approaches that were presented to the teachers (which mostly belonged to the theoretical part of the training), where the experimental part helped the teacher to realize the added value of each learning approach.

In Figure 10, we see that while teachers in Austria consider the STEAMTeach activities related to the curriculum, they are concerned about integrating STEAM content into their lessons. In Greece, the situation is vice versa; trainees are mostly concerned about the STEAMTeach approach connection with the curriculum. So, this diversity may be indicative of the systemic differences that are well rooted in the educational system of each country; It might have to do with the regulations of each country, the guidelines provided by the stakeholders, the different curricula, etc.

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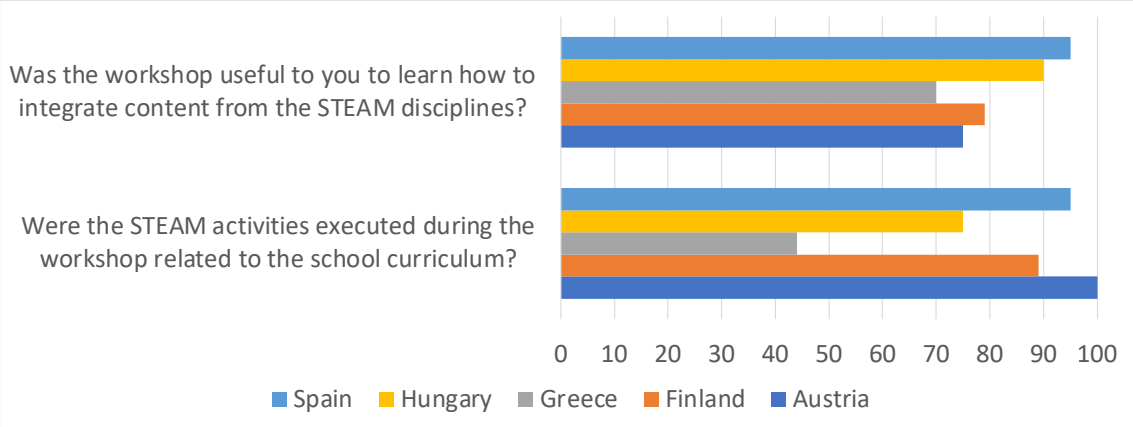

Figure 10: STEAM and the curriculum.

In relation to the curriculum, the Spanish teachers attending the training courses valued this theoretical training due to the uncertainty generated by the new curriculum that promotes project-based learning and STEM content integration. Still, the teachers stated that this was a complex approach that required knowledge and skills from different subjects and, thus, difficult implementation in the classroom. Often, teachers suggested that although theoretical sessions about the meaning of STEAM are necessary to put this approach in context with the content and objectives of the Spanish curriculum, practical lessons and workshops are required to exemplify the complexity of integrating content from different subjects to solve a particular problem or real-life situation.

In Finland, teachers thought that in STEAM, Art is very important since it contains a creative expression, including music, creative writing, and arts expression in drawing or painting. They also appreciated the group work-centred way of working. From their point of view, the skills developed in these kinds of actions directly support the needs of the curricula, and it is noteworthy since it might not be the case in other countries. Finnish schools have the transversal topic of sustainability in the curriculum and "phenomenon-based learning", in which more than one traditional study subject is combined to learn from projects based on real-life scenarios or simulations of them Hence, the water tower experiment was a good example of this type of project-based STEAM learning.

So, it is hard to shape a training programme, which would confront all these obstacles, universally, since the situation differs from country to country. Finally, the participants

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evaluated the programme as valuable for their professional activities, and their TPD in relation to STEAM education.

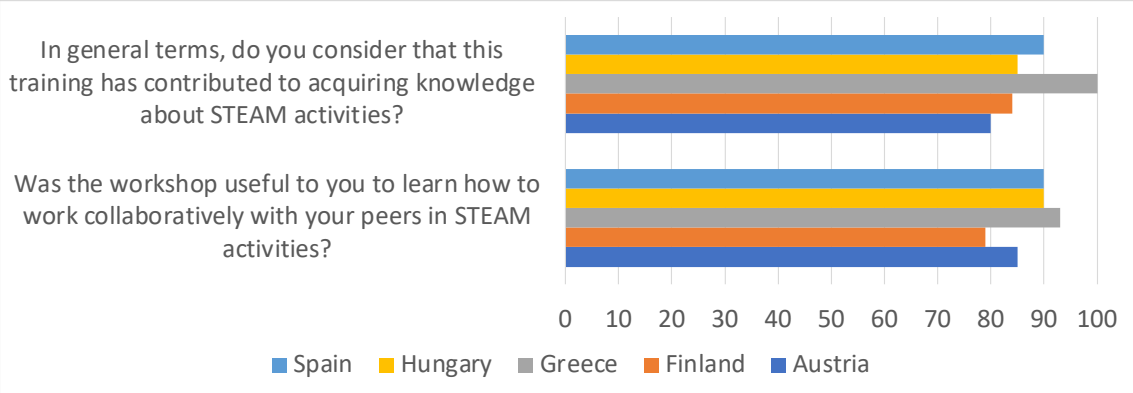

Figure 11: Evaluation of the training in general

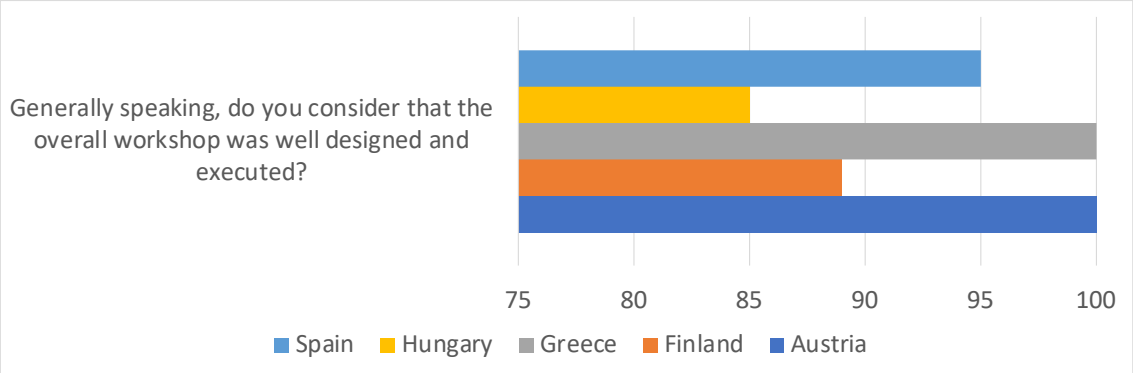

Figure 12: Evaluation of the workshop's organizing

3.2 The classroom implementation (IO3)

From the evaluation of the training courses, it became apparent that there were a lot of common elements in all countries, and we will discuss them in the next section (5.3). In this section, we will describe the characteristics of the classroom implementation of the project, where the conclusion is a bit different; with regards to the classroom implementation, there were documented remarkable differences between each country.

What was the motivation for classroom implementation in each country? In Spain, about 75% of the teachers participating in the first implementation had previous experience in integrated education, while in the second phase of the implementation, most of the

teachers did not have experience in STEAM education. This was because many new teachers wanted to gain experience right after the reform of the Spanish curriculum, in which STEAM project-based learning was incorporated as a methodology to be conducted in the classrooms. So, in this case, there was a clear motivation related to the feasibility of the STEAMTeach method and the promptness of understanding better the novel elements of the curriculum. In Finland, most of the teachers were familiarized with project-based learning, so the motivation had mostly to do with getting to know more innovative examples of how project-based STEAM teaching was supposed to be incorporated into Finnish teaching (i.e., the Warka water tower could work as an example). In Hungary, the primary motivation was to implement interdisciplinarity in a feasibly way into their lessons. In Austria, most of the teachers that participated in classroom implementation were theoretically familiar with STEAM education and they wanted to integrate their experience through implementing lessons. In Greece, most of the teachers were designers of educational material already, so they wanted to expand their capability of designing activities, to STEAM. So, the common motive of the teachers to participate in the training was TPD, but with a different focus in each case.

About the learning approach of the lessons that were implemented, project-based learning was the most popular in Greece and Finland (along with phenomenon-based learning), while inquiry-based learning was more frequent in Austria and Hungary. In Spain, most activities were framed in the inquiry-based and problem-based learning approach, as it is one of the main objectives enacted by the Spanish curriculum. All the teachers felt comfortable with this approach. The teachers found this methodology helpful for teaching students how to apply the concepts learned in the lesson to real-life situations or problems. One of the Spanish teachers reported: “I really find crucial teaching the applicability of the subjects for students greater valuing the content learnt at school. They become more motivated in learning than when doing things out of context”. This is a difference between the Spanish and the Greek case; Greek teachers were not at all familiar with project-based learning. However, they had a consensus that through project-based learning, they would manage to design STEAM activities. Since their main motivation was to design activities, they used project-based learning.

According to the teachers’ views, what students’ skills and competencies had the chance to be developed through classroom implementation? There was a consensus in all countries around the development of competencies modelling skills, computational

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thinking skills, the use of technology (in general), collaborative work, and socio-affective skills. However, in Finland and Hungary, the most common skill was creativity, while in Spain, teachers did not comment it, and in Greece and Austria teachers rarely referred to it. Problem solving skills were mentioned only by teachers in Spain and Greece, while experimentation was only mentioned by teachers in Austria and Greece.

Another issue indicative of the different approach in each country was the collaboration among teachers. Teachers expressed different ways of improving collaboration during the project design or implementation. In Spain, teachers work more systematically on it; to improve the quality of the project design, they mainly proposed increasing the number of hours for facilitating collaborations with teachers from other disciplines. They were inspired by the weekly meetings assigned in the Spanish system for each specialization at the secondary education level. Other strategies went further, and they did not only aim to improve the design of the project but also its instruction. In this line, two teachers instructing the same subject at the same school but with different backgrounds (one is a physicist and the other a biologist) requested their management team three years before the STEAMTeach project to set the timetable for their biology subject. One of those two teachers explained: "We realized that we do not have the same knowledge, and thus our practice could be improved if we teach together". In Finland, teachers were working collaboratively from the beginning of the classroom implementation, despite the difference in their expertise. In Austria, teachers' collaboration had a form of distributing the work to achieve a common plan; they distributed the work not only during the preparation of the lesson but in the classroom activities. In Hungary and Greece, teachers mostly collaborated in the preparation of the activities to be implemented, like a brainstorming discussion before the implementation. They shared their views of a common theme and ideas, but in the classroom they acted separately, giving different twists to the same activity. Especially in Greece, they worked collaboratively in the design phase of the activities. However, in the classroom the standard design very often ended in diverse in classroom instruction.

About the classroom interventions and their relationship with the curriculum, there was diversity as well. Spanish teachers considered the interventions' activities related to the Spanish curricular aims. Especially in the second intervention, the teachers recognized that most activities aimed to meet the evaluation standards of the new curriculum. One of the teachers stated: "I really value doing projects which incorporate school content and

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school evaluation standards, as it will benefit national student evaluations for accessing the university". In Finland, teachers stated that the implemented activities could even be part of the curriculum. On the other hand, in Austria and Hungary, teachers were not so convinced about it, without stating that they could not use them for their teaching in regular lessons. In Greece, teachers had a consensus on this issue; the activities that they implemented were not suitable for implementing the curriculum, although they were valuable for their students. A common characteristic in all countries was that in the second implementation phase, teachers stated that the activities were more related to the curriculum than in the first. Since the proposed activities for classroom implementation in the two phases were the same, we conclude that they were modified or redesigned to be more related to their professional needs, i.e., implementing the curriculum (Figure *13*).

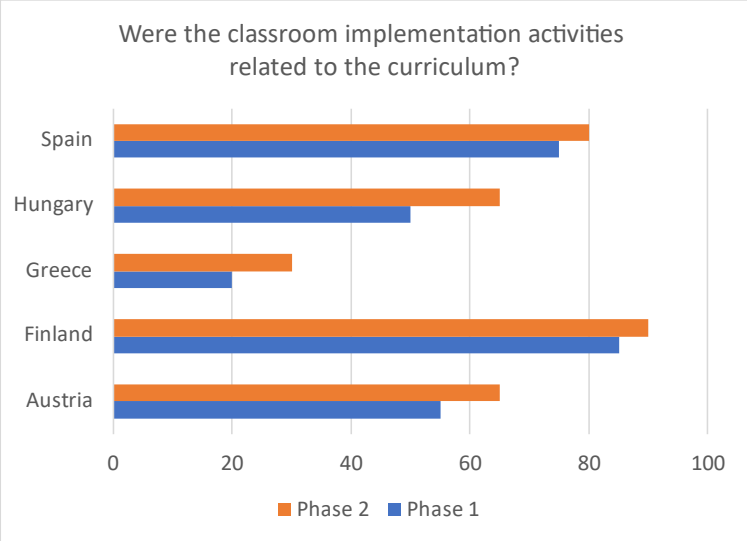

Figure 13: The views of teachers around the degree of the classroom implementations' activities and their relation to the curriculum

Finally, one common characteristic of classroom implementation in all countries was the collaboration between the students. Mostly, two ways of collaboration were observed: groups working independently to attain common projects and groups working on separate tasks before joining them to attain a single project. In the first one, the whole classroom was divided into groups, and each group worked independently to attain the project goal. In the second one, collaboration emerged when students, divided into groups, worked on separate parts of their project, and then joined them. It is noteworthy that all lessons implemented by the teachers incorporated collaboration by design. It was something that teachers did on purpose.

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3.2.1 An overview of training and implementation

In this section, we discuss the interplay between the training and classroom implementation, of the STEAMTeach project, in all countries, based on the teachers' views and the evaluation results. The teachers generally valued any aspect of the STEAMTeach methodology as positive that could even motivate their students. That was probably why teachers from all countries focused on project-based learning (PBL). It is remarkable that in Greece, even though they have not used PBL before, all classroom interventions incorporated PBL.

In all countries, teachers with different backgrounds highlighted different methodologies. Chemists and physicists have more facilities for employing the inquiry-based learning approach, whereas engineers tend to like the design-based learning approach more. Mathematicians were more confident with the problem-based learning approach but they tried to avoid real-world problems involving many contextual factors. They had many difficulties in providing a problem-based learning context which to apply STEAM education. These teachers were feeling confident reproducing activities involving content from two disciplines (e.g., physics and mathematics) but encountered hitches in providing a real context. The reason was that teachers are used to working with ideal mathematics in their lessons, and they lack mathematical contextual knowledge and techniques. For example, they did not know mathematical techniques often applied in the carpentry context to build up a closet. During the professional development programme, they experienced how to work in different contexts through experimental activities. For example, in the case of the carpentry one, they learned that it is necessary to buy 10% extra material for woodcuts and imperfections. In another case of programming Arduino, they talked to transportation specialists in order to program a traffic light or with an ergonomics specialist to make a vehicle that parks automatically. Learning to apply STEAM content in specific contexts was a difficult endeavor. Only after several sessions, the teacher started to reproduce activities with similar content to the ones experimented with during the professional development programme. In Greece (as we have already mentioned before), Mathematics teachers exploited PBL around socio-scientific issues, as a 'vehicle' of implementing original STEAM activities. However, teachers in all countries faced difficulties in exploiting the STEAM content in activities involving project-based design. So, even though PBL was a suitable learning approach for

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implementing STEAM, the parameter of design made the PBL more complicated to implement. We will address this issue below.

However, as mentioned in the previous section, adopting a single learning approach in the STEAMTeach project was not effective. The capability of teachers to follow different approaches in diverse learning situations and environments, on purpose, would be valuable. For instance, from the Spanish training it came up that inquiry-based learning could be effective for a STEAM learning context, where the teachers are asked to reproduce activities in which science adopted a dominant role and experiments were used to test or to prove principles. For example, they undertook experiments to learn about the Archimedes principle of pushing an object under the water to understand that the resistance force is equal to the weight of the fluid displaced by the body and acts upward at the center of the mass of the displaced volume. In Spain, they carried out this experiment to get enough information for constructing appropriate platforms in the floating nest project.

As mentioned before, PBL was recognized by teachers as an effective learning approach to implementing STEAM activities. However, the element of project-based design was an obstacle, as it seemed to be complicated for teachers to be carried out. In this point, the principles of design-based learning were valuable for the teachers during classroom implementation. During the interventions, the teachers normally used the design process as a motivational aspect within the STEAM activity; in fact, the construction of artefacts or prototypes turned out to be very stimulating for the students. So, it was feasible for them not to exploit project-based design, but to limit the design element as a motivation for students' engagement. The theoretical reference to design-based learning during the training was useful.

About the feasibility and the appropriateness of what training in relation to the classroom implementation, teachers that participated in both training and implementation, especially valued the theoretical sessions of the workshops at the beginning of the training. As they progressed through the professional development programme, they started reporting that the practical sessions, together with some theoretical aspects, were very helpful for implementing the projects. One of the teachers in Spain stated, "the practical sessions with theoretical advice were very useful because only during these sessions we face problems that are not likely to emerge during the purely theoretical ones". What it seemed

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to be happening was an interplay between theory and practice; after the practical sessions of the training, teachers were more self-confident in implementing methodologies and had discussions on learning theories. This was even more apparent after the classroom implementation phase. So, there was a continuous increase in the teachers' involvement in STEAMTeach practices, in parallel with the development of the programme.

Which characteristics made that involvement increase through the different phases of the project? In the first phase, the training, participants considered that the activities presented during the STEAMTeach workshops were not only good examples of the method but suitable to be executed in regular lessons, as well. Some activities were directly implemented, such as the ones proposed as initial activities (out of the project context) for testing the suitability of the group distribution. For example, in Spain, 'Radio Gaga' and 'Carpet' were the first activity of the projects 'Mathematics and Music: a perfect combination' and 'Sustainable Architecture', respectively. In Greece, the 'tessellations' activity was something that could be implemented in the classroom implementation phase since it exploited education resources from the school curriculum. So, the exemplary activities used for the experimental part of the training were important for the involvement of the teachers, not only in the practical workshop with hands-on and design sessions but to boost them during the next phase, the classroom implementation. In this way, the project was seen by participant teachers, as a unity, and they saw their participation in it as a continuous activity of their TPD, not separating classroom interventions from training.

During the classroom implementation, some needs regarding the training came up. In almost all countries, there was a need for sustainable support during the implementations, both in the classroom and outside of the classroom, as part of the learning community. In several project implementations, the STEAM trainers repeatedly supported teachers in their classroom and outside the classroom, providing advice on both project design and implementation. Moreover, most teachers demanded more strategies and sessions to learn to manage the collaborative learning approach as well as to learn to design rubrics or ways for assessing their students within a STEAM project-based approach. Some of them also demanded more sessions to manage collaborative learning. Most teachers -in all countries- implementing projects in regular lessons corroborated the opinion expressed after the workshops and confirmed that they would like more training related to students'

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evaluation. There was a consensus on the question: “How could we assess the learning outcomes of a STEAM-based lesson?”.

4 UNDERTAKING A GLOBAL EVALUATION OF PROJECT SATISFACTION AND PROVIDING RECOMMENDATIONS FOR FUTURE STEAM PROJECTS

In the section O5.2, we expatiated the main points of the evaluation report of the project regarding the training courses (IO2), the classroom implementation (IO3), and the interplay between them. In the present section, we will make an overall reflection on this report by answering:

a) How effective was the STEAMTeach training programme, as a TPD activity?

b) How efficient was the classroom implementation phase, based on the STEAMTeach approach?

c) How effective was the sequence of activities, with regards to both TPD and lessons?

Focusing on the satisfaction and needs of teachers that participated in the programme, and through these references we are trying to provide **recommendations and guidelines** for future STEAM projects.

The overall degree of STEAMTeach participants’ satisfaction seemed to be positive. To document this statement, we will refer to the key advantages of the programme based on participants’ views. We **recommend** that these elements of the programme remain as **the invariants in case of a future STEAM project.**

The content of the training courses. It was appropriate for beginners and experienced teachers, as well. It was connected to practice, as proved by the classroom implementation phase.

The structure of the training courses. The interaction between theory, experimental (suitable examples of activities) and design parts was valuable for teachers. They were

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introduced in a physical and effective way to STEAM education. The phases of the training worked as a cycle, but they were not entrenched; there was an interplay between not consecutive phases of the cycle (Figure *14*).

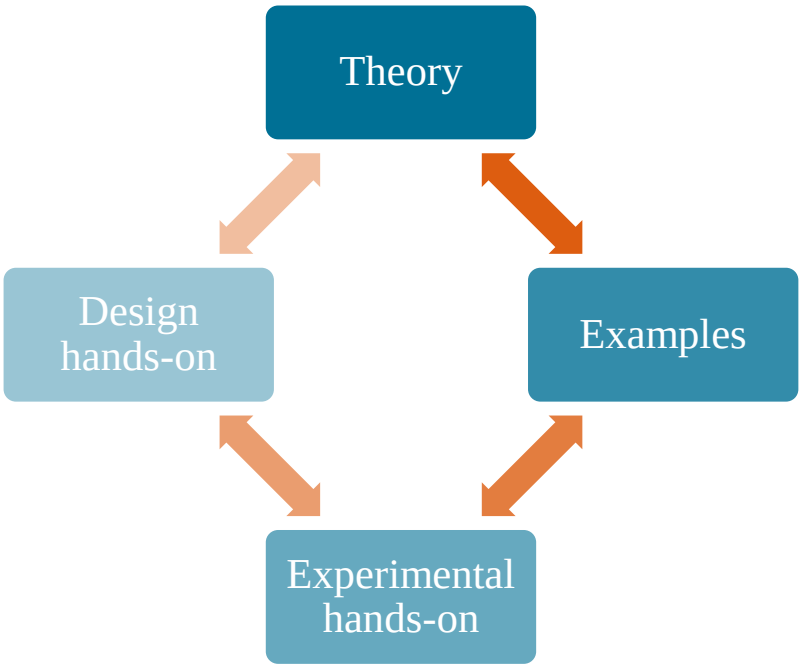

Figure 14: The cycle of the training course

Drawing connections between training courses and the implementation phase. These connections made the programme function as a unity. In fact, the classroom implementation phase was a part of the training, while the training course acted as the design part of the lesson. The elements of the programme that underpinned these connections were:

- The feasibility of the exemplary activities of the training. Most of these examples were implemented in the classroom during the next phase.
- The experimental-design part of the training. Teachers made the first steps for preparing their own teaching interventions.
- The use of the STEAMTeach activity template for classroom implementation. (https://www.steamteach.unican.es/template/). This template acted as a document to think with and reflect on the practices and theories discussed during the training while preparing the teaching intervention.

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- The connection of (learning) theories and practice. After the classroom implementation, they characterized the theoretical part of the training as being valuable to them.
- In relation to TPD, what became apparent from the interplay between training and classroom interventions was that it was not appropriate to view the content knowledge and the pedagogical knowledge of the teachers as separate components to be developed.

The diversity of learning approaches. During the training, teachers became aware of a set of learning approaches. Initially, it seemed to be confusing, but after the teaching interventions, the diversity of the learning approaches was not only useful but feasible too. That is, while PBL could be used as a guide to design a STEAM activity, design-based learning could be useful to prepare a motivating activity, inquiry-based learning was feasible for curriculum integration of STEAM lessons, etc.

There were some characteristics of the programme that **we recommend being strengthened in future STEAM projects** to make it more effective, with regard to teachers' needs.

Reinforcing the interplay between training and classroom implementation. The first classroom implementation could be a part of the training course. It was obvious from practice that the classroom intervention influenced the teachers' stance on the training. In this way participant teachers could see the project as a unity. Their participation in it can be seen as a continuous activity of their TPD, not separating classroom interventions from training.

Exploit group sessions. Another thing that seemed to be of added value was the exploitation of group sessions, where teachers could collaborate or just discuss their ideas and approaches. Teachers recognized that the group sessions -which they mostly organized as their own initiative- with other colleagues and trainers allowed them to consolidate the knowledge acquired during the workshops. So, in future projects, the group session could be adopted by the programme in more than one phase:

- During the experimental and design phases of the training. However, there should be a concern from the part of the organizers about involving all the participant teachers in the group activities.

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- During the implementation phase. A lesson study approach could be adopted to exploit the characteristics of a learning community.

Training outcomes sustainability. Teachers valued having the opportunity to be monitored during the project design and implementation. Even more, they expressed their need to have feedback on their practices after the training. Much more than this, the trainers could organize a reflective workshop, one year after the participant teachers' last training to give them feedback on the practices during the school year.

Trainees to act as multipliers. In some cases, trainees of the STEAMTeach training courses were teacher trainers, too, in another context (i.e., in the use of ICT). In these cases, it seemed that they acted as 'trainers' or 'multipliers' of STEAMTeach practices, for their own trainees. So, in future projects, the role of the multiplier could be useful.

Reinforce the trans-cultural elements of the programme. Although diversity between different educational contexts was not an issue during the training course, it became apparent during the classroom implementation phase. Then, when we looked back at the training, we detected some nuggets of diversity in the experimental parts of the training. This diversity seemed to be related to the different approaches to the curricula. Though it is difficult, we could try to establish some niches of trans-culturalism in the programme. The trans-cultural elements could be useful in at least two cases: a) to establish international collaboration between teachers in the field of STEAM education, b) to be able for the trainers to compare the training in different countries and make conclusions on possible interactions between the national programmes.

Finally, we briefly reflect on the "STEAMTeach evaluation toolkit".

The toolkit was valuable for:

- The description and evaluation of the training courses.
- The documentation and the evaluation of the classroom implementation.
- Capturing the interaction between training courses and the implementation phase.
- Writing down the pros and cons of the programme.

We used the results to form some recommendations and guidelines to refine the training programme for future projects. Moreover, it was simultaneously gained was very useful feedback on the teachers' personal needs as trainees.

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For future projects, we propose two ways of using the toolkit:

- To gain information and make more modifications to the training programme. For this purpose, we could use the toolkit as it is.
- To gain feedback on the participants' training needs. For this purpose, we suggest using only R2tc and R2ci since the brief report by each teacher was enough as a tool for reflecting on decisions when designing lessons following the STEAM educational approach.

5 CONCLUSION

This intellectual output has presented the description of the 'STEAMTeach evaluation toolkit' itself, along with the development of an evaluation instrument intended for future use by teachers. This instrument not only serves as an assessment tool for teaching design and learning outcomes but also aids in introspection while creating lessons within the framework of the STEAM educational approach.

We elaborated on the attributes of the engaged educators and trainers in each country, in addition to outlining the steps of the implementation process. Additionally, we provided an overview of the training courses or workshops conducted, including the evaluation instruments utilized for both training and classroom implementation assessments. We presented the utilization of the evaluation tool throughout the project phases, with a country-specific evaluation report and an overarching assessment. In particular, we provided the results obtained from the evaluation of the training courses (IO2) and the classroom implementations (IO3), together with an overview of training and implementation.

The intellectual output concludes with a comprehensive assessment of project satisfaction and offers recommendations for forthcoming STEAM projects. In terms of the overall analysis, we have taken into account the content and structure of the training courses, the interrelation between these courses and the implementation phases, as well as the diversity of learning approaches employed. Concerning the recommendations for future projects, we have emphasized the importance of strengthening the interaction between training and classroom implementation, enhancing the transcultural elements of the program, leveraging group sessions, and ensuring the sustainability of trainers' support.

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