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RoboSTEAM Final Report

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1. Introduction

This Final Report describes the project activities, outputs and organisation for the first year of the RoboSTEAM project [1-8]. It describes some of the issues presented in the final report although some of the issues are not described so deeply such as the transnational meetings or the budget. Specifically, the topics that we dealt with in this document are:

- Project summary.
- Description of the project.
- Project management.
- Implementation.
- Follow-up.

2. Project summary

Digital society requires new ways of dealing with the coming robotization of the European economy. Computational Thinking [9-17], that is, the ability of facing problems and formulating solutions in a way that a computer can process has been foreseen as a fundamental competence to be taught to future and current students.

Computational Thinking competence is usually associated to STEM (Science, Technology, Engineering & Mathematics) [18-21] or STEAM (Science, Technology, Engineering, Arts & Mathematics) education [22]. In fact, it is in these areas where major employment opportunities are expected, and society is making a great effort to make them more appealing to students in order to increase the vocation in these fields. The use of Physical Devices and Robotics (PD&R) [23-25] has been probed a good tool in STEAM education and many successful experiences have been reported in different media.

However, there are few experiences and evaluations of the teaching methodologies for developing computational thinking competence using PD&R, and even less dealing with the transnationality of these techniques.

This project will define a methodology and a set of tools that will help learners to develop computational thinking by using/programming PD&R in pre-university education stages. The project will also improve teacher education, providing them with a framework for easy STEAM integration in different educational contexts by providing guidelines for good practices and lessons learned adapted to different contexts. All these products will have been tested in different countries and cross-validated in different higher education institutions.

The consortium, besides its transnationality (8 partners from 4 different countries and 2 associated partners), was gathered to ensure the whole value-chain needed for generating applicable knowledge and to be able to transfer that knowledge and sustain it after the end of the project. It includes five Higher Education Institutions with different backgrounds and three schools.

Universidad de Salamanca will provide its experience on methodological aspects. The educational technologies research group at the University of Eastern Finland will contribute with its background designing ICT curricula for challenged learning environments based on open and distance education and with their expertise for the dissemination. Polytechnic Institute of Bragança will be focused on the transferability of professional skills. The Institute of Vocational and General Education at the Karlsruhe Institute of Technology will provide the point of view of the vocational education. The three schools involved, and the UEF Teacher Training School, will provide the point of view of schools by testing and evaluating the outcomes developed. In addition, they will exchange students in order to understand if the same tools and methods can be used in different socioconomic environments. Finally, Universidad de León, which coordinates the project, will bring its experience on robotics for education forward [26].

3. Description of the project

RoboSTEAM project is defined to facilitate integrating STEAM [22] and the development of computational thinking in schools by using Physical Devices and Robotics (PD&R) [23-25, 27]. In order to do this it is necessary to know how to define challenges for integrating STEAM, how is possible to assess STEAM and computational thinking related competences [12, 13, 28], the set of competences that could be promoted by applying challenges based on PD&R, the available tools and how to use them. This means that the main objective of this project is the definition of a knowledge base to facilitate integrating STEAM and computational thinking by using robots. This will be carried out by developing pilot programs, gathering good practices and tools, and defining learning actions and educational resources for teachers.

The progress of the project to achieve this objective has been properly achieved during the project, despite the difficulty caused by the late granting of the project and the cut down on the working plan (O1 and O4 were removed) and budget originally requested. Moreover, the COVID-19 breakdown implies an important issue to be addressed to facilitate project completion. According to the specific subobjectives of the proposal (that were not associated to O1 and O4):

- **Analyse the different existing activities that deal with STEAM integration.** This has been achieved during O2.A1. with the definition of a systematic mapping to collect and analyse the existing works related to the application of PD&R in STEAM education. It has involved the review of 242 in the main scientific libraries such as IEEE, Springer Link, ACM DL, Web of Science and Scopus. In addition, during COVID-19 pandemic situation a new study was necessary because the problem of schools lockdown in this case a new systematic review was carried out about robots simulation as the task O2.COVID19_1 [29].
- **Define some challenges and instruments to facilitate STEAM integration and computational thinking development.** During O2.A4 and O2.A5 [30] the project partners have defined the concept of challenge for the project, the granularity of the challenges, templates to describe the challenges at the different levels and also the kits to address them. Moreover, each partner has provided one or two or more challenges and kits descriptions. In this case during COVID pandemic situation also some tools have been adapted to facilitate challenge address online (it is shown in O3.COVID19_1 report [31]).
- **Define metrics to evaluate both the integration and the competence development.** Although this is linked to the results of O1, it has been addressed during O2.A2 [32] considering the works in the literature and also the experience of the partners involved in the project. In addition, the metrics

and tools to apply them has been employed during the piloting, as is described in O2.A5 [30] and in A3 [33] and A4 [34] reports. Moreover the adapted tools during COVID situation have been tested and validated taking into account this metrics in O2.COVID19_2 [35].

- **Define educational resources for in-service teachers and future teachers.** The project is progressing in this objective by the definition of the RoboSTEAM ecosystem (O3.A1) [36] that includes a portal, LMS, Zenodo Community, Institutional Repository and Social Media Components. Regarding how to work with the ecosystem it is described in O3.A3 report [37] and the population of the ecosystem with resources is described in the report of O3.A2 [32]. In addition during both project years the environments are properly maintained and populated [38].
- **Establish guides for the definition of integration STEAM challenges by using PD&R.** This part has been addressed during O2.A5 [30] and O2.A6 [39], based on the experience of the pilots completed during the project. Specially it defines possible granularity of challenges, kits, how they have been applied, how they have been assessed and the results obtained.
- **Publish the obtained results in order to involve other educational institutions of the same and different contexts.**
  This has been done during all the project by following the dissemination strategy and specially participating in different educational events such as the TEEM 2019 and 2020 International Conference, HCCI International 2020 or EDUCON 2020, participating in local events and publishing information about the project in social media.

This means that Output 2 is completed and also two additional tasks were carried out. Also Output 3 has been completed because the ecosystem [40, 41] has been designed, implemented, populated of resources and maintained. In addition, during O3 some tools were adapted to COVID-19 in the new task. The reviewer can access to the RoboSTEAM portal (http://robosteamproject.eu/), the Zenodo Community (https://zenodo.org/communities/robosteam/?page=1&size=20), the Institutional Repository (https://repositorio.grial.eu/handle/grial/1519), or the LMS (http://robosteamproject.eu/). With the latter the reviewer can access to all the project process, management, documents, conference minutes, etc. Please use the following credentials (user: roboSTEAMEvaluator, password: e_roboSTEMProject2019). Regarding the other activities some will be described in the next sections such as the management, quality assurance, dissemination, etc. It should be noted that, until the 30 of September there were 2 transnational meetings and a monthly videoconference meeting that facilitate the project coordination.

3.1. Participants

RoboSTEAM main target groups are:

- Teachers and school staff concerned with actions for integrating STEAM through challenges where PD&R is used.
- Staff of the partners institution.
- Students (secondary school level).
- PD&R developers.

These different stakeholders are involved in the project during several phases. Some of the participants are selected during the project phases but others are engaged with the project through the dissemination events.

The selection of teachers and students is linked to pilot phases and to the schools involved in the project. Pilot 1 and 2 should involve the secondary schools included in the project. The teachers are selected by the scholar institution taking into account their knowledge about what is Challenge Based Learning [42, 43] and if they have carried out actions for integrating STEAM. It is not necessary for teachers to have a technological background.

The students selected to participate in the pilots are aged from 12 to 16. The reason to do this is that secondary education has a common curriculum in most European regions and because students do not have many elective subjects so their knowledge in the same age-range should be similar and could be compared. For the pilots, a sample of all the school students will be directly involved, the criteria to select them will be given by the teacher without any constraint.

These schools, teachers and students will be not the only ones involved in the project because the local multiplier events that each partner carries out in their country and the mainstreaming final conference aim to engage both more schools and therefore more teachers and students.

Regarding the PD&R development we have selected Arduino because it is one of the project associated partners, it is focused on applying PD&R to education and it is one of the most popular companies in this regard all around the world. However, this does not mean that after the dissemination activities other PD&R developers can be involved.

Beyond the teams involved by each partner in the project, a training action is scheduled so other staff of partners' institutions can learn about the project and participate later in the local dissemination events. This staff is selected taking into account their experience working with schools and in integrating STEAM actions and their interest in the project.

At the end of the project the number of participants was 6429. As commented in the project proposal the stakeholders of this project were to be reached in different ways. In this case we have targeted 6429 persons distributed in the following way:

- 1042 students that participated in the diagnosis phase of pilot 1 (described in O2.A6 and in A3).
- 96 students that participated in the pilot phases 1 and 2 (number obtained from O2.A6).
- 16 students participated in the pre-pilot carried out at the IPB in 2019 summer camp (O2.A5).
- 18 teachers involved in the pilots (O2.A6).
- 4 researchers that supported AEEG pilots1 and 2 (O2.A6 and A3/A4).
- 38 persons involved in Hackathon (E1).
- 70 persons involved in Mainstreaming Event (E2).
- 6 persons involved in German Local Multiplier Event (E5).

- 3 persons involved in Finnish Local Multiplier Event (E6)
- 5096 new users in the web page attending to Google Analytics reports.

Some of these numbers, especially those related with the diagnosis phase or the local multiplier events could have been improved but the COVID situation restriction and lockdown have an important impact in part of the numbers, but the quality of the project, as all the activities have been carried out, even in an online way, was not affected.

4. Project Management

The activities proposed by the project for the management and implementation were Project Management, Quality Assurance, the Piloting Phases and the Dissemination. Below we have a detailed description of what we defined until now:

- A1. Project Management. Overall project management tasks include monitoring the progress of all work done and the budget and resources used and ensuring the timely completion of deliverables. This requires of:
    - A Project Management Handbook [44] defined in the first month of the project, describing the project management structure and procedures (structure, organization and communication), the planning and the contact information.
    - An internal communication platform (Moodle Based Environment). As part of the RoboSTEAM Ecosystem implementation, a platform was defined to facilitate the project Management and communication among the project partners.
    - Signature of the consortium partnership agreements. Each partner has signed its agreement, which in some cases has required of administrative work preparing and adapting the agreements to each specific institution needs.

    - Financial monitoring and payment to the partner organizations. The part of the money each institution needs is transferred to them following a specific distribution pattern based on the partners completed work.
    - Meetings organization. 2 Transnational meetings (hold at Bragança and Karlsruhe), 2 virtual transnational meetings due to COVID-19 and 16 videoconference meetings.
    - Collection of data and reporting on the project implementation.

  To ensure the proper working of the project several progress reports have been published.

- A2. Quality Assurance. This activity is focused on ensuring that all the activities, resources and objectives planned in the proposal are correctly executed, used and achieved. During this year the actions carried out regarding quality assurance were:
    - Creation of the Quality Assurance Plan [45] in the month 2 of the project that describes the purpose of this plan and the key performance indicators about quality.
    - The definition of a space in the LMS where the partners can discuss quality issues.
    - Distribution of meeting evaluation and internal monitoring questionnaires. Two questionnaires regarding meetings were delivered (one per transnational meeting to find out participants opinion) and one regarding the first year of the project (designed to assess partners' satisfaction and provide feedback regarding project).
    - Reporting on the monitoring activities. By providing the partners with the results of the questionnaires and the internal reports about quality in the LMS section defined to this aim.

The COVID-19 situation had a huge effect on the project development and in the project management too. We tried to postpone the activities that were cancelled due to the situation but at the end, when we decided to go on in a virtual way, we informed the rest of the partners in the virtual transnational meeting in September 2020. The new scenarios opened at that time were presented and related to the financial consequences of each or them. For this final report, the partners have been informed of the final situation, where we have been able to adjust the budget to the new situation with a positive outcome for all of us.

4.1. Project Monitoring

ROBOSTEAM has 7 partners, a number which is manageable with an agile and relatively lean structure.

The management structure has been mainly designed to:

- Effectively facilitate and manage the interaction of the different groups in the Project.
- Successfully integrate different backgrounds from academy, schools and technical environments.
- Ensure that the generated results along the project are quality controlled and effectively exploited.

The management structure was defined in two documents at the beginning of the project (M2), Project Management Handbook and Quality Assurance Plan, with the purpose of ensuring a good communication flow both internal and external, the timely execution of project goals, the progress control of each intellectual outputs, the coordination of the different project activities and the implementation of quality control mechanisms. In addition, the management structure covered administrative, financial and exploitation aspects.

Staff involved

The project has been designed through a participatory approach, so all the organizations contributed to the set-up of the project structure, budgeting and timing. All project partners had a responsibility to deliver high quality results, to implement the project activities appropriately and to participate in the monitoring and evaluation activities. The project coordinator, University of León, had the main task to ensure coordination between all partners. This work involved ultimate responsibility for the quality of the work. University of Salamanca led the A2 Quality Assurance activity, according to the project proposal. The main commitments were to prepare the Quality

Assurance Plan and the monitoring tools, to coordinate their application along the project and to prepare the relevant reports. The Steering Committee: composed of one representative of each organization, as supervisory body for the project execution, it was responsible for monitoring the achievement of the objectives of the project, taking decisions regarding the project implementation.

The dimensions of monitoring and evaluation.

The project monitoring and evaluation process contemplated both formative and summative dimensions.

- Formative evaluation refers to a continuous monitoring of the quality of the processes involved.
- Summative evaluation refers to the more traditional approach to evaluation, i.e. to judge and assess the match between the expected results, the resources used, etc.
- Lessons learned - in addition to summative and formative aspects, the project evaluation also focused on identifying lessons that can be learned from the project, both in terms of operational and management aspects, and in development terms.

Monitoring schedule

Monitoring and evaluation, from the formative perspective were an ongoing process throughout the project, but they were intensified at different points within the project, before periodical internal and external reports (interim report at M12, M24 and M29), and in general after meetings (Bragança (Portugal), 15-16 February 2019, Karlsruhe (Germany), 30 September - 2 October 2019, ROBO-STEAM 28 September 2020 Virtual Transnational Meeting, ROBO-STEAM 24 March 2021 Virtual Transnational Meeting) and multiplier events.

Quantitative and Qualitative indicators

Regarding the quantitative indicators used it can be divided in:

- Management:

  - Time metrics (research hours for a task, number of reports, time to perform a task, etc).
  - Cost metrics (budget a specific date/planned budget).
  - Coordination - Metrics (number of coordinating meetings, coordinating threads in the forum, coordinating messages in the forum, etc.).
- Dissemination impact metrics: scientific publications (papers, projects, etc.).
- Divulgation impact metrics (events, interventions, visits).
- Resource evaluation metrics (publications on the repository, downloads).
- Pilot activities impact (students, teachers, experiences, number of answers).
- Training course for teachers' impact (participants, trainers, feedback, etc.).
- Exchange of students' metrics (participants, students, etc.).

Regarding the qualitative indicators we have used:

Project Management Indicators:

- Quality of project management arrangements.
- Effective management and leadership qualities demonstrated by project coordinator.
- Effectiveness of the process of monitoring and evaluation.
- Quality of the dissemination process.
- Implementation of the work plan.
- Integration of project activities into the department's/ institution's development plan.

Consortium's Engagement Indicators:

- Strong commitment to the project by each partner.
- Agreement amongst partners.
- Effective and on-going communication amongst partners and with other agencies.

- Trust amongst partners.
- Development of positive attitudes.

Consortium's Work Indicators:

- Structure of the project.
- Quality of the project.
- Quality of project materials/products.
- Quality of the promotion of the European Dimension.
- Innovation and variety of approach.

4.2. Evaluation

USAL, supported by the project coordinator and the Steering Project Management Committee, was in charge of the implementation of the activities agreed in the Quality Assurance Plan and in the updated version defined in March 2020 when the health emergency forced to replan part of the activities.

At internal level, the monitoring and evaluation processes highlighted a very high quality of collaboration during the project among partners. According to the final quality report, which collects a complete overview of the project progresses and products, all the questionnaires received very good feedback, and this clearly indicates that all partners communicated and worked effectively, created good partnership based on trust, support and mutual understanding about project aims and the responsibilities of each partner. Also, the level of satisfaction with the project implementation and the developed outputs are an important indicator of the project's success.

About the implementation of tasks, the internal quality processes has been run in particular at each meeting during the first 18 months and then they were transferred online due to the restrictions of mobility for COVID-19. Anyway, the internal evaluation process has progressed appropriately and on schedule and was based on the following indicators:

Indicators to evaluate IOs (from stakeholders' feedback):

- Process quality perception.
- Progress quality opinion.
- If the results have been published in scientific journals.
- RoboSTEAM methodology and tools usefulness perception.
- RoboSTEAM methodology and tools usefulness opinion.
- Satisfaction of the members about RoboSTEAM environment.
- Analysis of the answers about tools.

Indicators about Evaluation of the of the achievement and their extent in terms of effects on the target groups:

- Feedback from teachers and students.

Indicators about Pilots and training:

- Feeling of students and teachers about the activities.
- Perceived usefulness of the activities carried out in the pilots.

Indicators about mobilities:

- Feeling of students and teachers about the activities.
- Perceived usefulness of the mobilities.
- Usefulness of the tools applied during the mobility (O2.COVID19_2).

4.3. Difficulties found during the project

During the second year of the project, more specifically during month 18, COVID-19 crisis arises, this means that this year several tasks were interrupted, delayed and/or changed. In order to do so the project was extended twice, first until the end of 2021 (M27) and a second time up to 31st March (M30). Reviewing the different activities, the situation was the following:

- A1. Project Management. The expected reports during the second project year were produced, the monitorization of the project continued and some of the meetings were carried until M18 when the pandemic situation implied that travelling was impossible. Until this month there were 4 videoconference meetings, and from then until month (M23) another 7. In addition, as it was not possible to travel, the two last transnational meetings were held virtually. The M18 meeting was delayed to M24 and the final project meeting to M30. In any case, monitorization has continued and specially the coordinators have increased their contact with the Spanish Agency.

- A2. Quality Assurance. Quality assurance has continued, although the transnational meetings have been not assessed as they have not been carried out. It has been adapted to the new situation.
- A3. Pilot Phase 1. This phase was completed up to M18 by most of the partners up to 60%. As classes were discontinued it should be finished during the first extension, that is up to the 31st of December. The social distance and the high online workload that the students had required have implied an important effort for them and the teachers.
- A4. Pilot Phase 2. As for A3, by M18 around 50% of this phase was completed. Also, this activity requires to be delayed in order to be completed and present some problems such as that the students involved in the first pilot cannot always participate in the second because they have finished their courses and were not in the institution in the next courses.
- A5. Dissemination and mainstreaming have continued both in academic contexts and in social and local media. Although virtual activities were more important in this new context.

Regarding the outcomes:

- O2.A5 – Application of the kits to STEAM challenges in the defined contexts. It was completed up to a 60% in M18 and was finished during the project extension as it requires the pilots to be finished.
- O2.A6 – Evaluation of the experiences. Only the pilots in one of the partners institutions was finished before the health emergency, so the activity can be considered completed in a 20% up to this month, the next month's extension allows the partners to complete this task.
- O3.A4 – Environment maintenance. Changes were made to correct errors and facilitate the connection between the different components, new collections

were added (including one related to COVID-19 adapted tools) and updates in the software.

Regarding the multiplier events they have been carried out in the last months of the project, with serious restrictions regarding COVID-19 and social space, this means that to achieve the expected audience the events should be repeated several times in many cases. Regarding students exchanges, all except C6 were completed as expected. Specifically, it was possible to complete C2 (during M13), C3 (during M14) and C4 and C5 that take place the same week of the M17. C6 was scheduled at the same time of the third transnational meeting, but it must be carried out virtually in M28. Also, C1, the training event cannot be also carried out as expected and it was developed virtually in M28.

One exchange, the training week and the transnational meeting need to be carried out virtually, so the project coordinator asked for an amendment on the project proposal, so the grant devoted to such actions could be moved to the existing intellectual outputs. The idea was to extend both outcomes with some tasks that were named as COVID activities. These are:

- O2.COVID19_1. Identification of online tools to continue with the project experiments. In this task the universities in the partnership have carried out a Systematic Mapping Review about the existing tools to be applied for simulating robotics virtually. The idea is to facilitate tools for schools that make it possible to address challenges such as the proposed project even in COVID times, that is virtually or in blended contexts.
- O3.COVID19_1. After the identification of these tools, the project universities propose two possible tools to be applied; SUFFER and HIL prototype. Both of them were adapted to be applied virtually and later the idea is to test them with the schools during the Hackathon and C6.
- O2.COVID19_2. Test the tools during C6. The schools of the partnership tested the tools during C6 and helped to report problems that should be addressed and improve them to be applied in the specific pandemic context.

5. Implementation

5.1. Methodology

The project will be managed using a process methodology (PRINCE2) [46]. All the partners have broad experience on collaborative projects and many of them have worked together before, so a smooth development of the project can be assured. This methodology will supervise all the activities planned in the project: meetings with stakeholders, development of materials, local and multi-site events, teachers training, students exchange, dissemination, and management of the sub-projects. Something shown in the progress reports, in the quality reports and in reports related with the project pilots such as A3 and A4. Prince2 defines a methodological framework, but some tasks could follow specific methodologies, such as the use of SCRUM [47, 48] when developing/adapting tools during O3.COVID19_1 or in the literature systematic reviews carried out in O2.A1 or in O2.COVID19_1.

During the discussions while putting together this proposal, one of the major concerns of all applicants was making the results really applicable when the project was over. We think that the outputs of this project may achieve this goal in the long term because we have carefully designed the whole value-chain from research groups on robotics and also in education technologies, going through groups with wide experience on transferability, schools to test an evaluate the products, and associated partners to support the process.

In the same way, the dissemination activities are designed to ensure impact of the project. A multi-site hackathon will be organized to involve students, teachers and researchers. More classical events will be organized at each location with the local associated partners to ensure the dissemination of the project.

Finally, we think that this project will contribute to increasing the number of STEAM vocations in the EU by promoting computational thinking as a valuable tool in different areas. We also would like this project to cause an increase in the use of ICT in different areas of secondary education, which will, in turn, help to trigger modernization and to reinforce education systems response to the main challenges of today's world (employment, economic stability, etc.).

5.2. Tasks distribution

The distribution of tasks has been maintained according to the project proposal. All partners participated in all the output tasks, although some of them had a greater number of hours. It should be noted that all partners provided competencies and assessment tools in STEAM contexts (O2.A2 [49]), described testing contexts (O2.A3 [50]), provided challenges (O2.A4 [51]) and participated in the design of the piloting (O2.A5 [52]) and the development (O2.A5 [30]). Regarding the COVID-19 activities of O2, the universities were more involved in the systematic review carried out (O2.COVID19_1 [29]) and the schools in testing some of the adapted tools for the pandemic situation in O2.COVID19_2 [35]. Regarding O3, some were more focused on the development and maintenance of the ecosystem and others collaborated by testing the system [31, 38, 53-55]. All of them have provided resources to include in the ecosystem. Beyond these tasks some more details about each partner involvement:

- ULE. It was in charge of the project management. In addition, given the technological background and robotics expertise it was responsible for O2 and participated in the rest of the outputs. In O2, ULE led the systematic mapping definition (O2.A1), the definition of the challenge concept (O2.A4), facilitated gathering competencies and assessment methods (O2.A2) and the evaluation of pilot results in (O2.A6). In O3 ULE led the design and implementation of the ROBOSTEAM environment (O3.A1) and the implementation/adaptation and the deployment of the activities oriented to be used in COVID situation (O3.COVID19_1) and the testing of such tools in C6 (O2.COVID19_2).
- AEEG, CIC, IER and UEF secondary school. These schools participated in all the outputs providing their point of view as final users of the outcomes defined during the project. They were involved in O2 as the schools that hosted the pilots, they described the particular features of their context, the competencies and assessment methods they use or they know, challenges to be applied, and developed pilots 1 and 2, participating also in the evaluation in O2.A6. These

partners also participated in the students' exchange and in the training week. In O3 they worked testing the ecosystem and populating it. Regarding the COVID tasks they participated, providing feedback about possible tools to use and the new context in the educational institutions and in testing the adapted tools during C6.

- IPB. This partner, also with expertise in PD&R, participated in O2 leading the definition of competencies related requirements depending on age and cultural contexts (O2.A2), participating in the rest of the tasks and specially in the systematic mapping (O2.A1). In O3 in the definition and maintenance of the learning environment (O3.A1) and leading the definition of user manual and tutorials (O3.A3). It should also be noted that they led a pre-piloting carried out during a summer camp in Bragança as part of O3.A5 to test the concept of mini-challenge and nano-challenge. Moreover, they hosted the Hackaton (E1) carried out in M25 and implemented one of the COVID tools that was tested in that event (O3.COVID19_1).
- KIT. This partner provided their educational expertise in all the outputs. In O2 KIT worked in all the tasks, specially in the definition of competences and instruments (O2.A2) and in the identification of context for the piloting and in the definition of challenges (O2.A3). In O3 this partner has contributed by compiling STEAM challenge tools and guides (O3.A2). It led the pilot carried out in Carl Benz School and its evaluation, hosted the E6 dissemination event and participated in the Systematic Literature Review of O2.COVID19_1.
- UEF. This partner, with both a technological and pedagogical background, has participated in all outputs. In O2 in all the activities, with more hours devoted to the definition of age and cultural context dependent competences (O2.A2). In O3 it participated in the compilation of STEAM challenges tools and guides (O3.A2). Beyond their role as a school mentioned above it also participated in the Systematic Review of O2.COVID19_1 and hosted virtual exchange C6 and the local multiplier event E6.
- USAL. This partner, with broad expertise in several related learning projects [56-60] and with a pedagogical and technical background, was in charge of O3

and participated in all the rest of the outputs. They led the systematic review carried out by COVID-19 (O2.COVID19_1) and were also in charge of quality management as commented above.

There are two entities involved in the project as associated partners that could be included in this section:

- Arduino Verksatd. They have provided to ULE extensive catalogs with their components and kits, just in case they can be employed in the challenges.
- Carl-Benz school. This is a German school that is interested in the project and has participated as the testing educational context for KIT, with their 16-year-old students' classes. That is it is involved in A3 and A4 and in O2.A5.

6. Follow up

6.1. Project Impact

The project as a whole was expected to produce a broad impact through the delivery and publication of the intellectual outputs, the implementation of training courses for in-service teachers, and the results and the dissemination plan.

Taking into account the final beneficiaries of the project are the students, the schools, the businesses, and the society. We can assert this because RoboSTEAM project: 1) aims to increase quality of education and training in Europe and beyond by trying integrating STEAM and facilitating computational thinking development; 2) promotes STEAM and computational thinking competences acquisition which will cause that students be more prepared for labour market; 3) facilitates assessing the acquisition of some competences related to digital skills; and 4) makes possible a more strategic and integrated use of ICTs and open educational resources (OER) [61] in education, training and youth systems.

Initially, the impacts on the direct beneficiaries during the project were:

- I1: STRENGHTENED PROFILE OF TEACHING PROFESSIONS: Transfer of competences, knowledge, pedagogic and didactic tools, focused on integrating STEAM and computational thinking development.

- I2: TEACHING INNOVATION: Introduction innovative teaching approaches based on the use of challenge-based learning methods and by applying PD&R.
- I3: IMPROVING STUDENTS EMPLOYABILITY: The literature and previous experiments has shown that by integrating STEAM and developing computational thinking competences the students (future professionals) will be more prepared for the labour market, so their employability will be higher.
- I4: ATTRACT STUDENTS TO STEAM AND ICT: RoboSTEAM project will attract students to STEAM and ICT by the use of PD&R to solve open challenges. PD&R has become something that attracts young students independently of whether they have or not a technical background.

When talking about direct beneficiaries and target groups, the resulting numbers of the project are as follows (please, take into account that these are real numbers, while last year we upload just an estimation):

- Participants:
  - Research team: it is composed by the members of each partner staff (managers, researchers and technical). A total of 20 people.
  - Extended research team: these researchers come from partner institutions and were recruited during the project development (35 participants approx.). They include trainers for teaching and learning activities.
  - Number of schools involved in the piloting: 5.
- Target groups:
  - Teachers and staff involved in C1. Initially planned: 18 - Final number: 40.
  - Teachers involved in the pilot phase. Initially planned: 10 - Final number: 18.
  - Teachers involved in the second pilot phase. Initially planned: 10 - Final number: 18.
  - Students (secondary school level). Initially planned: 3150 - Final number: 1042.

- Students and teachers involved in the hackathon. Initially planned: 38 - Final number: 38.
- Teachers and potential teachers involved in the local multiplier events. Initially planned: 120 - Final number: 79.

- Stakeholder:
  - Other stakeholders and policymakers (expected in E2): Initially planned: 70 - Final number: 70.

We would like to point out that the difference in numbers in the only case that we have less that was in the diagnosis phase was motivated because students are tired of fulfilling forms after the COVID-19 breakdown.

6.2 Impact at local, national and international levels

At local (school) level, the desired impact was the improved provision of digital skills related to STEAM and computational thinking for both staff and pupils and an increase in the numbers and skill levels of teachers who can respond to the demands of the new curricula either now or in the near future.

At a regional level, the desired impact was to increase the numbers of teacher trainers who can support teachers who want / need integrating STEAM and develop computational thinking in the classrooms through the development of groups and networks of skilled teachers and teacher trainers who can act as multipliers. Broadening the curriculum and aligning it with the needs of the economy will increase the quality of education at regional level. It will also promote the development of entrepreneurial skills to support those regional economies.

At a national level, the impact should be an education system better aligned to needs and opportunities of the labour market. In order to do this, it is necessary to involve policy makers and other stakeholders that will have the opportunity to know about the benefits and recommendations for integrating STEAM and developing computational thinking competences. With this knowledge and being aware of the cost/benefit ratio national educational systems can be changed to integrate some of RoboSTEAM outputs.

At European level, the desired impact is that the project, by integrating STEAM, will contribute towards a more strategic use of ICT by education which will in turn help trigger modernisation and reinforce education systems response to the main challenges of today's world (employment, economic stability etc.).

The following information shows the direct impact of the different activities developed during the project:

- Local level: 66 participants in the pilots, 82 local participants in the multiplier events and 5 news in local media (see Dissemination Report M29 for details)
- National level: 40 participants in the training week, 84 participants in the exchange events, one talk in Tarragona, Spain (Seminario Interuniversitario de Investigación en Tecnología Educativa) and another one in Madrid (Seminario sobre Enseñanza de programación en niveles preuniversitarios).
- International level: One publication in the International Conference on Human-Computer Interaction (HCII 2020), four papers in the TEEM Conference, two papers in the EDUCON Conference, a presentation in the Universidad Católica de Santa María (Perú) and another one in the Central South University of Changsha (China), a book chapter in "Information Technology Trends for a Global and Interdisciplinary Research Community" and a journal paper in "Computer Applications in Engineering Education".

6.3 Dissemination

Dissemination activities started at the beginning of the project; they continued throughout its implementation and beyond the end of the contract, thus supporting the longer-term impact and sustainability of the project results.

The dissemination plan was divided into three main types of activities: dissemination event strategy; academic strategy and social events strategy; press media strategy and learning/training strategy.

- Dissemination event strategy provided four kinds of events: 1) online and face to face events; 2) local dissemination events whose aim was to engage stakeholders both from school and other scenarios (E5, E6). Four events took place, one in each of the partners countries involved in the project; 3) Hackaton for defining new challenges and test the outputs (E1); 4) mainstreaming conference (E2), aimed to present the project outputs and outcomes to both practitioners and policy makers and to publicly present the RoboSTEAM environment and its tools and activities. These events will be also transmitted via web streaming to extend the target audience.

- Academic strategy. As several of the partners were universities and their researchers used to participate in conferences related with eLearning activities, the team members presented the project outcomes in those forums. This has been done in local and national level (e.g.: local educational innovation journeys, SIIE - Symposio Internacional de Informática Educativa) and on an international level by presenting the project at TEEM (Technological Ecosystem for Enhancing Multiculturality) International Conference which is leaded by USAL. Each university presented the project at least in a national conference.
- Social networking strategy. In M2 UEF (which is in charge of dissemination) created accounts in several social networks such as Facebook, Twitter, LinkedIn and also in the Erasmus+ publication channels. The partners of the project feeded the social networks with two publications related with the project per month. In addition, RoboSTEAM environment was conceived as a social networking infrastructure with public, restricted and private spaces, possessing the capacity to directly link to other social networks and both personal and institutional profiles in those social media. This will multiply the dissemination effect of the activities developed within the RoboSTEAM network.
- Media strategy. During the first three months of the project, branding for RoboSTEAM project was produced. It was employed to define press releases, newsletters, and event presentations for media. Each project partner contacted local newspapers in order to facilitate dissemination (5 news were published).
- Training strategy. The project aimed to create outcomes that can be employed to train teachers in addressing challenges as the ones proposed by RoboSTEAM project, so the project has defined learning activities with which teachers and education students will have the possibility to learn about RoboSTEAM, some of these outcomes were presented in the training week (C1) as workshops and the slides have been published in Zenodo.

Feedback from the participants has been collected in the multiplier events and after each meeting with the partners. All the information is available in the dissemination and quality reports.

6.4. Use of the projects results

All the RoboSTEAM outputs are produced using free and open source software solutions, from the technological environment and its components to the educational resources and materials, be they created by the partners or produced inside the project development with the schools support. The PD&R kits and specification have been created under open-source hardware licenses.

All the intellectual outputs produced during the project have been licensed under Creative Commons Attribution - NonCommercial- ShareAlike 4.0 International Licenses.

The only restrictions envisaged are that some training materials e.g videos on YouTube, presentations on Slideshare, may require a password if they contain content showing children undertaking activities in a classroom and where the children may be identified. In these cases, the material will not be in the public domain but available to teachers and teacher trainers on request.

The Zenodo platform and the E+PRP have been used to provide access to all the production of the project, except for those that include personal information, that according to the General Data Protection Regulation cannot be shown. There are also some reports that are not being made public because there are publications pending on their content.

6.5. Potential of the Project

The project has dealt with very relevant topics for different areas but specially with STEAM integrating and the development of digital competences such as computational thinking. These are the more demanded competences in the context of the so-called 4.0 Industry, and in robotics in particular. The introduction of different types of collaborative robots (cobots) in the industrial sector will require at least basic computational thinking abilities in future workers in the manufacturing. In the same way, service mobile robots will soon be part of our lives and the interaction with them will require the STEAM abilities developed in this project.

The robotization and digitalization of society require that both the workforce and the population in general have digital skills. New methodologies for teaching these competences have been developed and tested in this project. They could be corroborated in other projects. They should also be tested at a larger scale. In the same way, they have been tested in a limited number of countries, they should be extended to cover different regions and social environments. In the same way, this project has been focused on a particular application of computational thinking to robotic kits, but computational thinking abilities, key for the understanding of the digital world, can be developed and applied in different areas.

In summary, any effort or outcome such as the ones produced by this project can be the seed for possible new approaches. In addition, the resources published and the description of the ChBL methodology can be applied in other educational contexts both in Secondary Education and in different fields such as Higher Education and Vocational thinking. The development of computational skills and the integration of STEAM is something required also in such contexts. Moreover, this could be extended also to more complex application fields such as for people with special needs, that of course would need to be prepared for the digital society and the industry 4.0.

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