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STEAM, inclusion and engagement through makerspaces: the voice of students and teachers

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Abstract

Over the past few decades, there has been a growing interest in tinkering and making, also driven by environmental concerns that define this era. This has led to the rise of creative recycling, facilitated through Do-It-Yourself practices enhanced by digital technologies and practiced in equipped spaces, where commonly used tools and materials are shared by small communities. These makerspaces have also been established in schools, contributing to the adoption of active learning methods, which research shows to be highly effective. The European Erasmus+ "Steam2Go" project aims to create a mobile makerspace that is easily transportable, equipped with pedagogically effective instructions and detailed descriptions of consistent educational experiences. The goal is to make the teaching of STEAM subjects more active, engaging, and inclusive. The pilot experiments conducted with mobile makerspaces involved students (N=184) and teachers (N=15) from various school levels and grades across four partner countries (Cyprus, Greece, Italy, and Poland). The research, conducted through individual questionnaires completed by all participants at the end of the activities, focuses on perceptions and beliefs related to the empowerment achieved by students and teachers. The findings reveal a high level of enjoyment, a perception of improvement in STEAM subjects as well as transversal skills, and a positive appreciation of the Open Educational Resources, which transform the mobile makerspace into an effective educational tool.

KEYWORDS: School, Maker Education, Inclusive Teaching, Active Learning, Empowerment.

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1. Introduction

Makerspaces are equipped environments where people cooperatively experiment with innovative solutions for designing and making artifacts with unique characteristics, in a contamination of do-it-yourself, art, invention, and play. This DIY almost always makes use of digital technologies, but also involves the use of more traditional tools, enhances poor and recycled materials, and finds in the web the most appropriate tool for research and for sharing ideas and products (Honey & Kanter, 2013).

Makerspaces implemented in schools are in line with the characteristics just defined, require students to practice the skills they have acquired, allow them to acquire additional ones in itinere, and are supported by the convergence of several constantly growing factors (Halverson & Sheridan, 2014; Rouse & Rouse, 2022; Vuorikari, Ferrari & Punie, 2019).

First of all, it is necessary to consider the evolution of the Maker Movement, a movement that, in opposition to the consumerism that particularly marked the last decades of the past century, recovers from the 1960s and 1970s an attention towards reuse, repair and creative assembly, nowadays enhanced by the increasingly availability of easy-to-use and low-cost technology (Hatch, 2013; Unterfrauner, Hofer, Pelka, & Zirngiebl, 2020).

Second, trying one's hand at a makerspace means practicing not only skills related to the curricular

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disciplines – such as Science, Technologies, Engineering, Arts & humanities and Mathematics (STEAM) – but also many of the skills considered fundamental for the years to come: creativity, critical thinking, problem solving, communication, and collaboration. Skills sometimes considered "new" to school systems, but now recalled by all international frameworks (Frydenberg & Andone, 2011; WEF, 2015; 2023).

Finally, makerspaces also appear to constitute inclusive and effective contexts in which those teaching methods that the scientific literature shows as most conducive to skill acquisition are implemented. In fact, through a cross-curricular learning-by-doing approach, structured within a comprehensive experiential learning cycle (Kolb, 2014), they can promote intrinsic motivation and participation in dynamic communities of learners (Blikstein, 2013) and, at the same time, break down stereotypes and geographical and socio-economical obstacles frequently perceived in STEAM disciplines.

The Erasmus+ "Steam2Go" project aims to spread the Makerspace Movement in schools in the four partner countries – Cyprus (CY), Greece (EL), Italy (IT) and Poland (PL) – throughout the creation of a mobile makerspace model, that can be wheeled from classroom to classroom, equipped with low-cost technologies and other more traditional tools, plus a set of Open Educational Resources (OERs), including handbooks and guidelines for teachers, but also presentations and worksheets for students to develop the experience in itself and for guide the implementation of a replicable model.

This paper presents the results of the pilot applications of this mobile makerspace, conducted in schools, in order to validate the quality of the designed experiences, the suggested devices and the resources provided. To do this, the research focuses on perceptions and beliefs related to the empowerment achieved by students and teachers, through the detection of four aspects: (i) school practices related to STEAM prior to the introduction of mobile makerspaces, (ii) students' level of enjoyment during the experience with mobile makerspaces, (iii) students' level of perceived progress (in STEAM subjects as well as in other not suggested areas), and (iv) aspects of improvement and/or new ideas of using mobile makerspaces. Furthermore, the sustainability of the project is verified by asking teachers their intention to replicate the experiences with the mobile makerspace in different classes or schools, and the level of agreement or disagreement regarding the design of the experience.

2. Materials and Methods

The research is based on two questionnaires, administered to the participants in a mirror manner, to explore the aspects indicated above from two different points of view: that of the students and that of the teachers. Both questionnaires end with a specific section on personal data, and the questionnaire addressed to students specifically investigates their personal interests in relation to STEAM subjects, also asking about future intentions in continuing academic studies or seeking a career in STEAM areas.

Most of the questions are closed-ended, according to a 4-point scale, in which participants are asked to express the degree of agreement relative to the referenced statements. A fifth point is introduced only in cases where the student or teacher may need to state that the item is not relevant to their context.

Within each discipline, to bring us closer to the teachings planned in the schools, the questionnaire goes into detail about the different areas: for example, within Science, Biology, Chemistry, Physics are distinguished; within Arts, Painting or Sculpting, Architecture, Music, Dancing or Performing Arts, Photography or Filmmaking, Other Arts are made explicit. In all the questionnaires, however, given the age of the participants and the countries' school systems, the technology-engineering disciplines are included in one chapter, and then distinguished amongst Mechanics, Electronics, Electrical engineering, Informatics, and Automation.

The open-ended questions are mainly about appreciations, suggestions for improvement, further ideas that can be developed, and are categorized inductively through a content analysis (Berelson, 1952; Mayring, 2004; Merriam, 1998), conducted independently by two researchers. After an initial alignment phase, the level of agreement between the two evaluators is high, with a Cohen's (1960) Kappa of 0.90.

3. Results

3.1 The sample

The pilots involve a total of 184 students and 15 teachers. Girls represent 36% of students, boys 60% (a 4% prefer not to declare their gender), and the average age is 16.0 years with a StdDev of 3.4 years. Among teachers there is parity in gender representation and the average age is 48.7 years with a StdDev of 8.4 years. More information can be found in Table 1.

Teachers – though with different distributions by country, partly determined by different school systems – teach technical and scientific disciplines (Computer Science, Technology, Electronics, Mathematics, Physics). Two-thirds of them have more than 10 years of teaching experience, the remaining have between 1 and 7 years experience (Figure 1).

The pilots monitored cover 7 experiences among the 12 proposed in the project handbook, chosen on the basis of the ages and skills already acquired by the students.

The experiences are evenly distributed across the different subject areas within STEAM and by levels of complexity (Table 2).

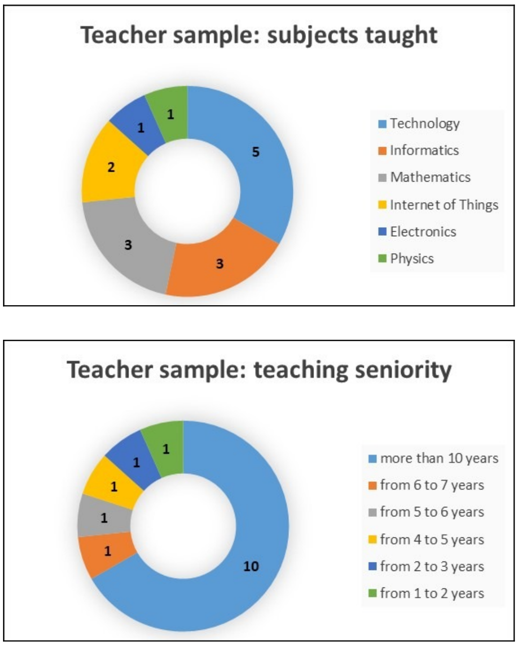

Figure 1 - Distribution of the teacher sample by subjects taught and teaching seniority.

Table 1 - Distribution by gender and age of participants – students (S) and teachers (T) – involved in the pilots.

			GENDER			AGE		
		TOT	**W**	**M**	**N.D.**	**Min**	**Max**	**Avg**
CY	**S**	38	19	15	4	12	14	12.3
	T	3	2	1	/	40	47	41.5
EL	**S**	20	11	8	1	13	15	13.4
	T	2	/	2	/	48	62	55.0
IT	**S**	61	5	53	3	17	28	19.4
	T	6	1	5	/	34	63	51.2
PL	**S**	65	31	34	/	14	16	14.8
	T	4	4	0	/	42	50	45.8
	S	**184**	**66**	**110**	**5**			**16.0**
	T	**15**	**7**	**8**	**/**			**48.7**

3.2 The students personal interests

The interests toward STEAM of the students participating in the pilot experiments are investigated directly, through discipline-specific questions, and indirectly, through questions related to intentions to pursue further education and job aspirations in STEAM areas.

Regarding interests, multiple choices are given. Considering the sample as a whole, it emerges that the areas of greatest interest are Mathematics and Technology/Engineering both with 51% of expressions in favor (although a 14% state that they have never studied Technology/Engineering). Within the Technology/Engineering area, students express the highest degree of interest in Computer Science (66%) and Electronics (58%).

This overall picture, however, flattens out the differences found across countries:

- Cypriot students prefer Mathematics (66%) and Arts (61%), while confirming a high interest in Science (59%) and Technology/Engineering (58%) (Figure 2);
- Greek students report that Mathematics is clearly the discipline of greatest interest (85%), followed at some distance by Science (65%), Technology/Engineering (57%) and Arts (53%) (Figure 3);
- Italian students particularly like Mathematics and Technology/Engineering (59% both), followed by Science (43%) and Arts (39%) (Figure 4);
- The picture is significantly different for Polish students, who prefer Science (43%) and Arts (40%), followed by Technology/Engineering (37%) and to a very small extent Mathematics (25%) (Figure 5).

Declared interest in different STEAM subject areas does not result in similarly high prospects for further study or employment in the same domains. The area with the highest percentages overall is Technology/Engineering, both in terms of interest in continuing their studies in higher education (37%) and employment intentions (48%). Again, the aggregate analysis of the data flattens out the differences found in individual countries (the first percentage always refers to interest in pursuing studies, the second to that of the intended field of employment):

- Cypriot students direct their study and employment prospects predominantly toward Mathematics (53% and 53%), followed by Arts (50% and 58%), then Science (45% and 42%), and finally Technology/Engineering (37% and 39%) (Figure 6);
- Greek students express their preferences toward Arts (55% and 45%), followed by Mathematics (50% and 35%) and Science (40% and 40%), while in the Technology/Engineering area there are the lowest percentages (25% and 25%) (Figure 7);
- Italian students are most interested in Technology/Engineering (52% and 79%) and, to a much lesser extent, interested in Science (18% and 23%), Mathematics (18% and 21%) and Arts (15% and 18%) (Figure 8);
- Finally, Polish students return a fairly uniform picture, for Science (32% and 23%), Technology/Engineering (26% and 31%), Arts (20% and 20%), and Mathematics (17% and 18%) (Figure 9).

Table 2 - Distribution of experiences carried out in the pilots conducted among the four partner countries.

Experience name	Main disciplinary area	Student target age	Level of difficulty	Carried out in pilots
Solar robot	STEM	13-14	Low	Cyprus
Edward Hopper	Arts	13-17	Low	Greece
Musical keyboard	Arts	13-17	Low	Greece, Italy
Weather station	STEM	15-18	Medium	Poland
Plant watering system	STEM	15-16	Medium	/
Theremin	Arts	16-18	Medium	Italy
Alarm system	STEM	15-16	Medium	/
RPi & Scratch Traffic light	STEM	14-18	Medium	/
Arduino traffic light	STEM	15-18	Medium	Italy
MicroBit & MakeCode traffic light	STEM	14-18	Medium	/
Raspberry Pico & Python traffic light	STEM	16-18	High	Italy

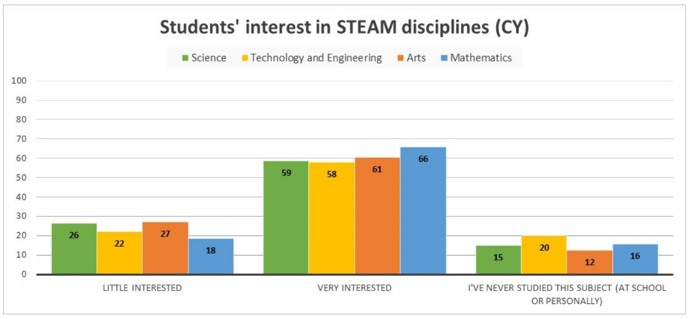

Figure 2 - Interests toward STEAM disciplines declared by Cypriot students.

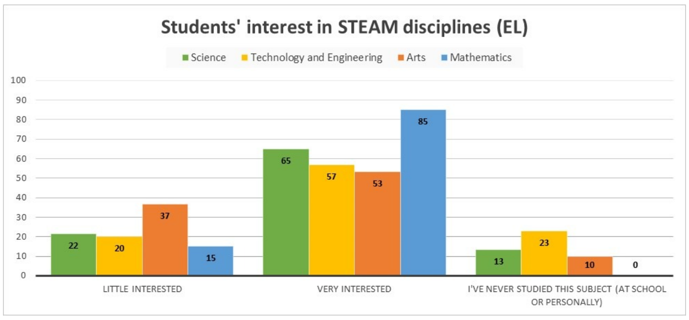

Figure 3 - Interests toward STEAM disciplines declared by Greek students.

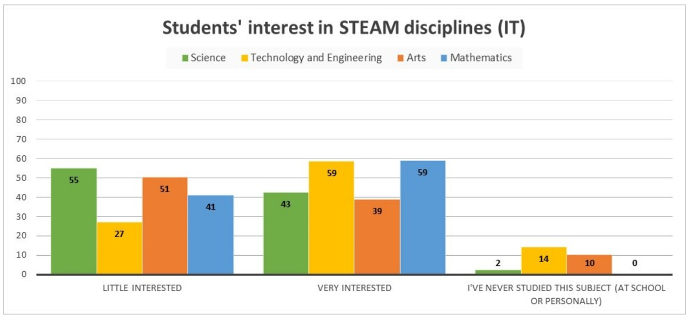

Figure 4 - Interests toward STEAM disciplines declared by Italian students.

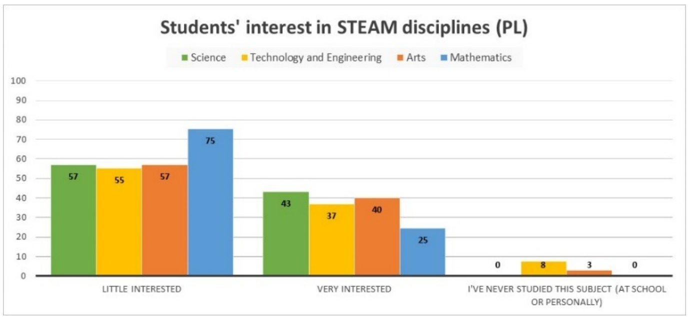

Figure 5 - Interests toward STEAM disciplines declared by Polish students.

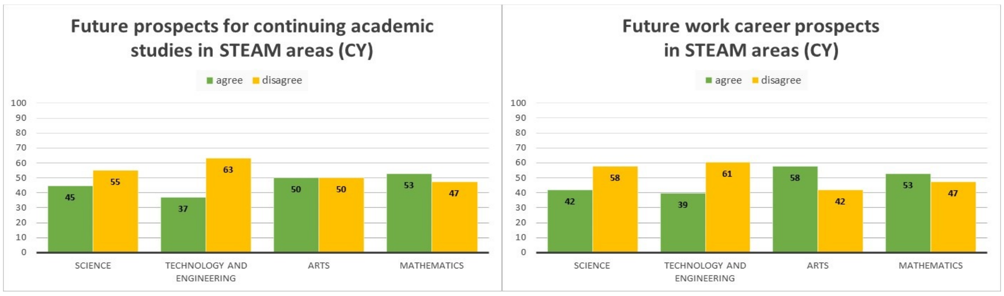

Figure 6 - Distribution of future prospects for continuing academic studies and work career in STEAM areas of Cypriot students.

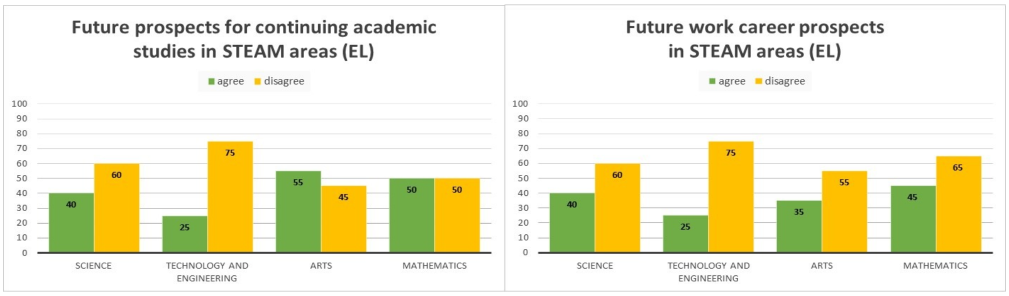

Figure 7 - Distribution of future prospects for continuing academic studies and work career in STEAM areas of Greek students.

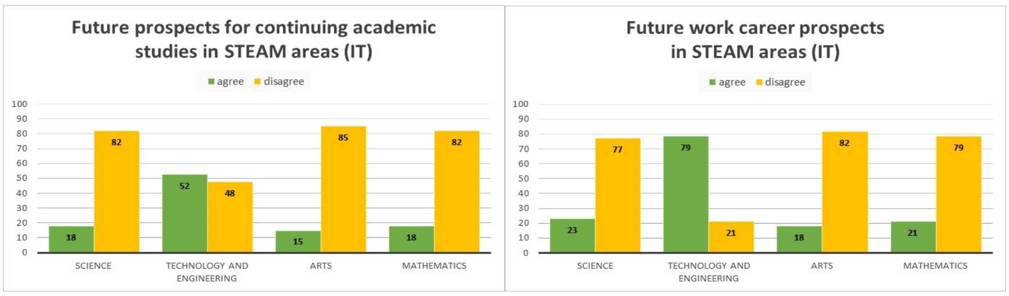

Figure 8 - Distribution of future prospects for continuing academic studies and work career in STEAM areas of Italian students.

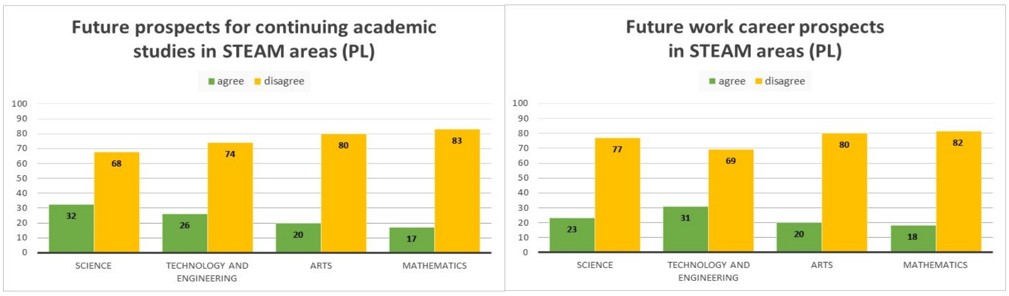

Figure 9 - Distribution of future prospects for continuing academic studies and work career in STEAM areas of Polish students.

3.3 School practices

The first question on teaching practices asks students, for each discipline, for an estimate about how frequently (never, rarely, frequently, always) they feel that the content covered in school was related to real-world applications.

52% of the students perceive that Technology/Engineering is frequently or always related to the real world. Conversely, 54% of the sample perceive that examples of real-world application are never or rarely given for Mathematics. Again, however, it is appropriate to examine the data by country:

- According to Cypriot students, they very frequently receive examples about the connection between STEAM disciplines and the real world. For Sciences, 92% of students believe they frequently or always receive examples. However, for Arts, which is the discipline where students perceive the least connection to the real world, the percentage of students who chose frequently or always is 76% (Figure 10);
- Greek students' perceptions differ the most from the global results. Mathematics is perceived by 85% of students as a discipline frequently or always approached in a concrete way, while for Technology/Engineering only 60% of students frequently or always collect examples of connection to the real world (Figure 11);
- In the Italian sample, 64% of students say that in the technological-engineering disciplines they receive examples that connect the discipline to the real world, only 34% in Mathematics. The percentages referring to Science (28%) and Arts (7%) are even lower, but in this case the percentage of students who do not have these two subjects in their curricula significantly affects them (Figure 12);
- Few Polish students believe that the disciplines are treated with reference to the real world. The percentages of those who respond frequently or always ranged from 28% for Arts to 20% for Mathematics (Figure 13).

The next questions are related to the connection between Arts and STEM. A large proportion of students show that they like this connection: 62% say they feel more involved in practical STEM activities when these are integrated with Arts; 70% feel that it is possible to make creative and useful artifacts using STEM knowledge. Analyzing by country, we find that it is mainly Cypriot and Greek students who consider this interdisciplinarity important:

- for Cypriot students the percentages are both 82%;
- for Greek students 70% and 90%;
- for Italian students 57% and 77%;
- for Polish students 52% and 51%.

Only 34% of the sample, however, say that in their daily STEM teaching the involvement of Arts is frequently or always expected, with significant differences by country (Figure 14): it is stated by

- 82% of Cypriot students;
- 85% of Greek students;
- only 10% of Italian students;
- only 12% of Polish students.

Regarding the integration of Arts in STEM, a mirror questionnaire is submitted to the teachers and they confirm what the students expressed. Two-thirds of teachers say that they do not frequently provide activities that integrate disciplines, and the picture within each country also exactly matches students' perceptions: Cypriot and Greek teachers say they are more committed to this front than Italian and Polish teachers.

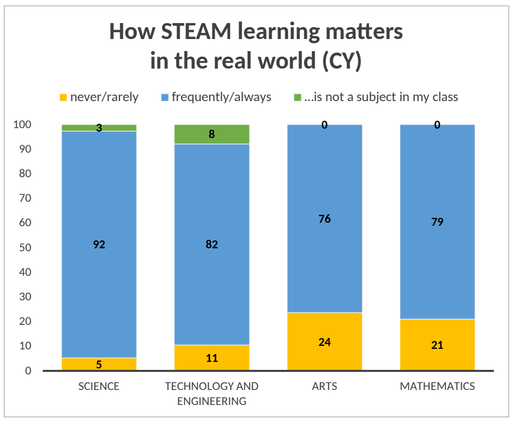

Figure 10 - Cypriot students' responses to the question "How often in your class do you get examples of how STEAM matter in the real world?".

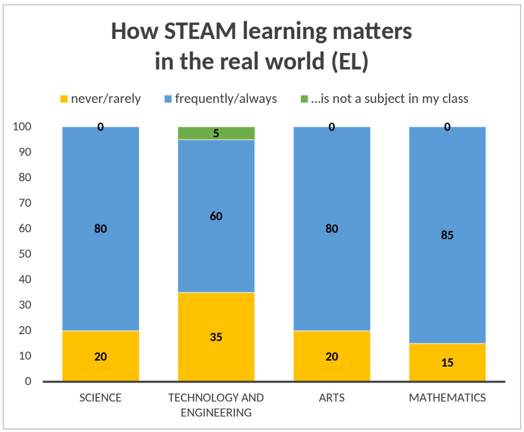

Figure 11 - Greek students' responses to the question "How often in your class do you get examples of how STEAM matter in the real world?".

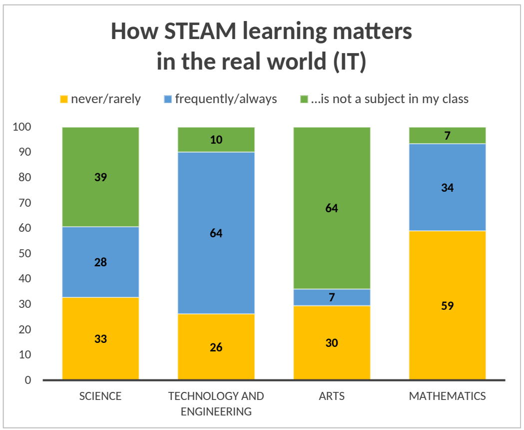

Figure 12 - Italian students' responses to the question "How often in your class do you get examples of how STEAM matter in the real world?".

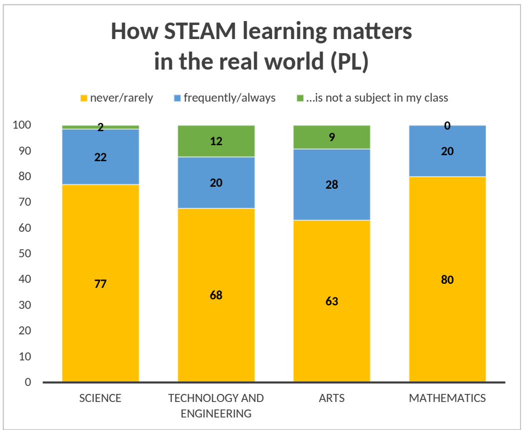

Figure 13 - Polish students' responses to the question "How often in your class do you get examples of how STEAM matter in the real world?".

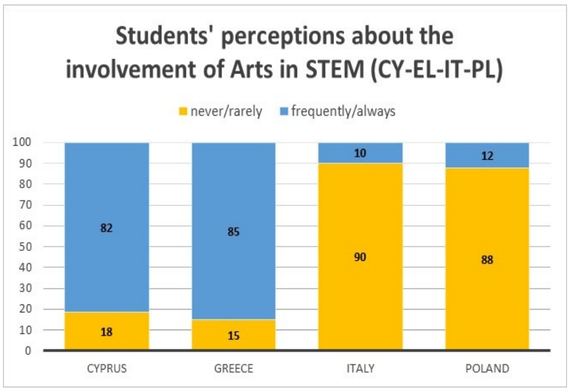

Figure 14 - Students' perceptions (among the four partner countries) about the involvement of Arts in STEM lessons.

3.4 The mobile makerspace experience

One section of the questionnaire focuses on the experience with mobile makerspaces, paying attention to satisfaction and any improvements in skills, through a verbal rating scale and some open-ended questions. This dual mode allows for a better capture of attention points that the project team might not have anticipated or underestimated.

In terms of enjoyment, students liked the project because it was fun (84%), allowed easy retrieval of materials (82%), prompted creativity (79%), and induced greater motivation to work (65%) (Figure 15).

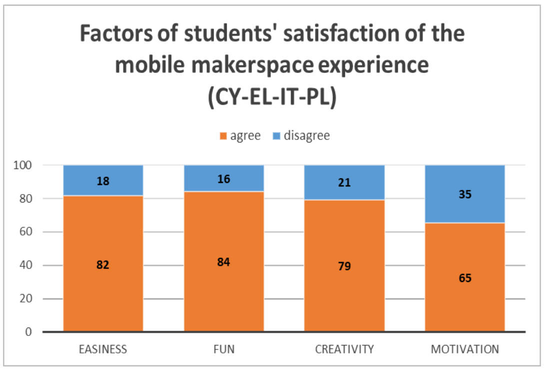

Figure 15 - Factors of students' satisfaction (among the four partner countries) of the mobile makerspace experience.

Cyprus, Italy, Poland, taken individually, express percentages substantially overlapping with those at the overall level; Greek students, involved essentially in projects with an appeal toward artistic disciplines, report creativity to a very large extent (95%).

A homologous questionnaire is submitted to the teachers who led the experiences and, after observing the students in action, they provide fully equivalent responses.

It is also recorded that according to students and teachers, the use of mobile makerspaces produce an improvement in skills in STEAM areas, self-rated as significant in Science by 53% of students, in Technology/Engineering by 72%, in Arts by 35%, and in Mathematics by 33%. Looking at individual countries, the improvement is perceived as significant:

- To a greater extent for Cypriot students, in Science and Technology/Engineering for 79% of students, in Arts for 63%, in Mathematics for 66% (Figure 16);
- In Sciences for 60% of Greek students, in Technology/Engineering and Arts for 70%, in Mathematics for 65% (Figure 17);
- For Italian students, the nature of the experiences conducted is very much affected, with a low presence of Sciences and Arts, so that significant improvements occur in Sciences for only 13% of the students, in Technology/Engineering for 70% (peaking here), in Arts for only 8%, in Mathematics for 25% (Figure 18);
- For Polish students in Sciences according to 72% of students, in Technology/ Engineering for 69%, in Arts for 28% of students, in Mathematics for only 17% (Figure 19).

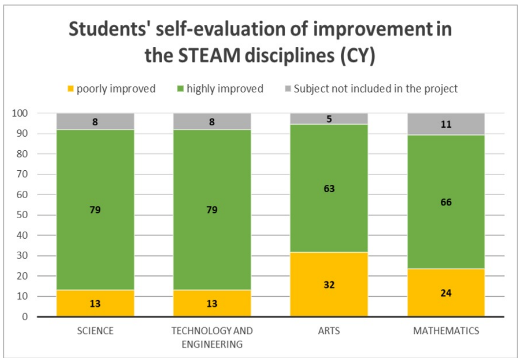

Figure 16 - Cypriot students' self-evaluation of improvement in the STEAM disciplines after the mobile makerspace experience.

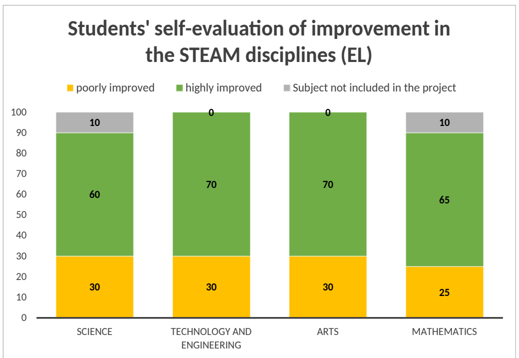

Figure 17 - Greek students' self-evaluation of improvement in the STEAM disciplines after the mobile makerspace experience.

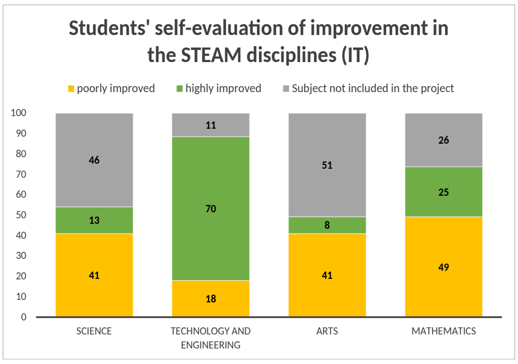

Figure 18 - Italian students' self-evaluation of improvement in the STEAM disciplines after the mobile makerspace experience.

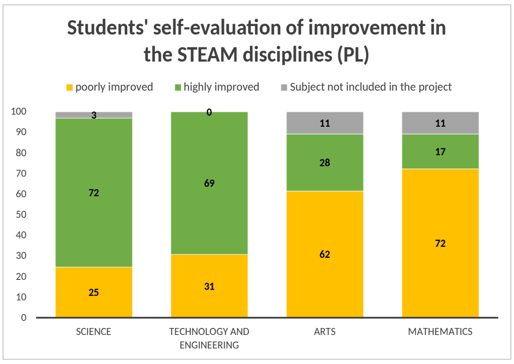

Figure 19 - Polish students' self-evaluation of improvement in the STEAM disciplines after the mobile makerspace experience.

To the open-ended question "Are there any other competencies/skills (not mentioned above) that you have improved thanks to the practice with the mobile makerspace?" 29% of students respond by referring to skills not directly related to the disciplines, but of a more cross-cutting nature. Students indicate two areas of improvement that they consider most significant: (i) in the sphere of cognitive skills, such as creativity and problem solving, the ability to focus or skills in design, linking them to the opportunity to engage in learning-by-doing; (ii) in the sphere of social skills, such as communication and interpersonal skills, leadership management, autonomy in work, linking them to the exercise of peer collaboration.

Teachers, too, in a questionnaire exactly matching the one proposed to students, are asked about their perceptions of improvement in students' skills as a result of their experiences with mobile makerspaces, and report in almost half of the cases that they have detected changes in the development of soft skills. The most frequently cited skills involve problem solving skills, also supported by improved ability to search for information, as well as an acquired ability to organize work, both independently and in collaboration with peers.

The questionnaire also offer students an open-ended question regarding the positive aspects of the experience with mobile makerspaces. The responses lead to results consistent with the previous statements. 20% of the responses refer to generic satisfaction factors (adjectives such as fun, interesting, engaging, useful, satisfying, practical); 22% focus on the acquisition of knowledge, skills, and competencies directly related to STEAM disciplines; 32% mention skills not directly related to disciplines, but of a cross-curricular nature, of which 14% refer to cognitive skills (problem solving, planning, error management) and 18% refer to social skills (collaboration and peer relationships); 13% appreciate the use of laboratory methods and innovative tools compared to those commonly adopted; the remaining 13% do not give significant responses (e.g. “don’t know”, “don’t have anything specific to state”). Some specificities are noted in individual countries:

- For Cypriot students, 23% of responses refer to positive personal feelings experienced during the experiences, citing general factors of satisfaction. 26% cite acquisitions of knowledge, skills, and disciplinary competencies as positive aspects. 36% report achievements related to soft skills (within which 21% addressed cognitive skills and 15% social skills), 3% mention the practical and innovative nature of the methods adopted. The remaining 13% are the evasive responses;
- For Greek students, 37% of the responses involve what are succinctly termed positive personal feelings, in which are gathered the perception of enjoyment, interest and greater generic pleasantness of the whole experience; 30% refer to new acquisitions and improvements in STEAM skills; 33% state acquisitions and improvements in soft skills (13% cognitive in character and 10% social in character); 7% the use of new methods and materials; only 3% are categorizable as no-answers;
- Italian students limit generically positive feelings of satisfaction to 11% of their responses; in 12% of responses they mention benefits at the level of disciplinary skills; in 46%, however, they report acquisitions and improvements at the level of transversal skills (20% cognitive and 26% social); in 19% of their responses they say they particularly appreciate the methodological approaches, which are more practical and linked with the real world. The remaining 12% can be categorized as “no-response”;
- Finally, Polish students, in 22% of the responses attribute the positive personal feelings (of fun, involvement, interest, etc.) to the meaningfulness and pleasantness of the experience with mobile makerspaces; in 28% they gain and improve their knowledge, skills and competencies in STEAM; in 20% they gain advantages in soft skills (6% cognitive and 14% social); and 14% report that they appreciate the methodological elements of novelty (more practice and interaction) compared to the regular course of lectures. There is also a fair percentage – 17% – of “non-responses”.

The teachers who led the experiences are also asked similar questions. Two-thirds of the teachers are in their first experience with makerspaces, and 14 out of 15 are satisfied and inclined to repeat experiences with the mobile makerspace either in the same or different classroom settings. Teachers report numerous strengths of the mobile makerspace and associated OERs:

- The guidelines provided to support each experience. The learning scenario, i.e., the project sheet created for each experience, is unanimously recognized, by the entire sample of teachers, as a quality tool, well-structured and functional for teaching, relevant, and appropriate in its timing;
- The open and problematizing approach given to the proposed activities. Indeed, for each one there are questions of engagement and others of reflection;
- The engaging and challenging approach of the activities contained in the handbook, which foster work autonomy and sustain student motivation;
- The organized and easily accessible availability of materials and tools.

3.5 Suggestions of improvement

With the perspective of wanting to gather specific and timely feedback from those who participated in the pilots, the questionnaires addressed to students and teachers include an open section in which possible suggestions for improvement could be entered.

45% of the responses are generic or evasive (“don’t know”, “don’t have suggestions”, etc.). Otherwise, the following are reported among the main items for possible improvement:

- a greater availability of time (27%), both to conduct each experience and to be able to increase the number of experiences conducted;
- a richer supply of components and instrumentation (e.g., tablets and personal computers) (18%). In particular, proposals include the inclusion of a 3D printer;
- a better organization of working groups (10%), with a reduced number of members per group and with groups homogeneous in ability;
- a reduction in the amount of time spent on introductory explanations to some phases of work (1%).

The different combination of specific experiences addressed among those proposed in the project handbook, the different school systems and the different implementation contexts require an analysis of the data for each individual country:

- For students from Cyprus, most of the answers (51%) focus on the opportunity to equip the makerspace with additional devices, specifically computers, tablets and 3D printers; however, it is not indicated whether this could be functional to the activation of smaller groups that could work in parallel, or whether it serves to broaden the typology of experiences, or other. 14% of the answers concern the need to have more time, to dedicate not only to the processes of building the artefacts, but also to the entire design and organization of the implementation phases. 8% suggest the inclusion in the handbook of projects that would open up greater spaces for creativity. The remaining 27% of the answers are not significant (e.g. "I don't know");
- Among Greek students, 33% focus on the nature of the projects, urging the presentation in the handbook of a greater number of experiences, accompanied by very clear information and the proposal of technical solutions to control different devices. 10% of the suggestions concern the composition of the work groups, proposing a limited number of members with the same skills and/or age. Only 5% refer to the provision of additional devices or components and 5% also concern the request to increase the projects in the handbook that stimulate creativity. 48% do not provide significant answers;
- For Italian students, the most frequently provided suggestion concern the nature of the projects (25%), to extend their duration, increase their number during the school year, increase their complexity in order to cover more classes. 7% of the answers concern the composition of the groups, proposing greater homogeneity in terms of skills. 5% suggest proceeding with the enhancement of technical pre-knowledge strictly related to the study path. 3% of the answers contain the suggestion to open up to projects that greatly enhance creativity. The suggested improvements are not many, while 61% of the answers are completely empty or not significant;
- Polish students report details of the equipment provided inside the makerspace (6% of the answers); the possibility of having more time available to carry out the experiences (3%); the reduction of the start-up phases (3%); the reduction of the number of participants in the groups (2%). However, 86% of the other answers are empty or not significant.

Teachers are also asked to provide suggestions for improvement, both in relation to the technical aspects and in relation to the pedagogical aspects of the experience conducted with the mobile makerspaces. A large part of them state that they have nothing to add. For the technical aspects, the following suggestions are made:

- The indication of QR codes to guide more immediately in accessing the supporting documentation;
- The inclusion in the mobile makerspace of additional components and materials in terms of quantity and type.

For the pedagogical aspects, the following suggestions emerge:

- The specification of a time range to be dedicated to the various phases of the project that allows for more flexible management of time in relation to the different class groups;
- The assignment of specific roles to the members of the work groups;
- The gradual articulation and increasing difficulty of the learning objectives of the various projects that allows for an adaptation of the same teaching proposals to more and different school levels;
- The formulation already in the handbook of advanced and creative proposals, such as a solar-powered drone or an electric candle.

4. Discussion and Conclusions

The research presented in this paper is the result of the validation process of a mobile makerspace and related OERs, designed within an Erasmus+ project, intended for use in schools as pedagogical tools. The aim is to democratize STEM education and support the development of transversal skills through training paths based on problem-solving with a workshop approach. The introduction of Arts "increases learner empowerment, interest, and engagement; and students' ability to make connections and transfer knowledge" (Huser et al., 2020, p. 1).

A convenience sample of secondary school students from the four partner countries was chosen to study the project pilots. When asked directly, the students expressed a high interest in all STEAM subjects; however, their preference for further study or employment in these areas was not particularly high, with a primary focus on Technology/Engineering. Students described the usual teaching practices in their classes as somewhat abstract and disconnected from the real world. Furthermore, they perceived that the introduction of Arts into their education could improve their learning, though Arts are often not integrated with STEM in school, as confirmed by the teachers who led the pilots.

It was in this context that the experiences with mobile makerspaces took place, during which the voices of both students and teachers were collected, crucial for understanding what they considered relevant to their learning and teaching experiences.

The students' comments still reflected an approach based on individual disciplines, with a persistence of separation between them. While they expressed a desire for school to be more connected to the real world and for a transdisciplinary approach, suggestions for improvement included proposals for homogeneous group work, remarks strictly related to their specific school context, and requests for expanded makerspace equipment aligned with the school's focus.

The experiences with the makerspaces were very positively received by the students, who found them fun, easy to use, and a catalyst for creativity. In the proposed formats, they were seen as effective in channeling engagement toward the study of STEM subjects. Some students also suggested spending more time on activities to gain more hands-on experience, while others asked for a more experiential handbook. In response to their questionnaire, teachers also reported satisfaction with the students' engagement during the workshop activities.

The analysis then shifted to self-assessment of learning. Students believe they have improved their skills in STEAM, particularly in Science and Technology/Engineering. The students' self-assessment also shows improvements in transversal skills: those mentioned by them (in response to an open question) are problem solving, expression and creative production, collaboration with peers, autonomy, engagement. Since the same improvements are also perceived by the teachers, all the prerequisites exist for a future evaluative study on the actual achievement of competence development goals, and awareness of these acquisitions.

The pilots were carried out in schools with a significant proportion of socio-economically and culturally disadvantaged or often gender marginalised people, especially in relation to STEM, who were able to benefit from unusual tools and experiences. The study did not reveal any peer differences in the results achieved, although this is not sufficient to state that the educational interventions conducted promoted full inclusion.

The teachers' comments highlight the need and importance of supporting hardware and software tools with guidelines that illustrate their pedagogically relevant use: in this sense, particular appreciation was given to the "learning scenario", a design sheet that not only describes in detail each experience, in its various phases and in its technical prerequisites, but also precisely underlines its purposes and objectives, application strategies, points of attention, subsequent openings and, in full makerspace logic, also suggests the stimulus questions for the teacher in his role as coach.

Looking ahead, several research directions are emerging, being addressed in different countries in relation to specific interests and contexts of use. For example, this includes developing a series of scenarios to encourage the challenging use of various hardware platforms for more technically advanced projects compared to those in the initial development phase, or leveraging prototyping opportunities to support entrepreneurial thinking. The research group at the Università degli Studi di Firenze is working in two directions: testing the model in Primary Schools and developing tools to capitalize on the experiences conducted.

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Authors' contribution

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