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Pursuing Social Justice in Educational Robotics

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Abstract: In educational systems that make their first attempt to incorporate STEAM concepts in their teaching, educational robotics is typically the place to start; robotics kits are purchased, and a small group of pupils is typically selected to develop a project and perhaps to also take part in some local or national robotics competition. Whilst this can be a very stimulating and rewarding experience for the participating pupils, it does little to introduce STEAM to the rest of the pupils in the school. In this article, we present our work towards a more fair and socially just approach to educational robotics. Compared with the conventional approach to educational robotics, our work introduces the following novelties: (A) shorter educational programs so that equipment can be re-used, (B) out-of-school implementation so that the programs are accessible to pupils from all schools, even from those schools that do not have teachers willing to be involved in STEAM programs and (C) scaling via the training of teachers who then act as multipliers of our action. The approach was applied, before being interrupted by the COVID-19 pandemic, in a specially developed innovation hub, and the initial results are reported herein. Based on those findings, the potential of our approach to achieve a broader societal impact is highlighted.

Keywords: educational robotics; innovation hub; social justice

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1. Introduction

As we aim to prepare our children for the challenges of the mid- to late 21st century, STEM and STEAM courses are emerging as important components of modern education. Among the many forms these can take, educational robotics is the most popular one and the one typically tried first, in various age groups and at all levels of education before university [1].

Particular focus is given to educational robotics in primary education, as that is the point where pupils are old enough to be able to comprehend the concepts and at the same time young enough for the experience to have maximum impact for their later academic and personal development [2]. However, we should also underline that when at the level of the specifics of implementing educational robotics for primary education, there is no gold standard to follow. Instead, a very wide variety of choices is available [3], with teachers intuitively (as opposed to based on data or theory) choosing the approach they hope will be the most suitable for their pupils.

This increases the load on teachers, as well as the responsibility they assume, as every decision about the courses falls upon them. This is not the only issue prohibiting the broader implementation of educational robotics; the high cost of the equipment, the reluctance of teachers to embark on a teaching path for which they have not been trained and have no support, low social awareness, etc. are all factors that make educational robotics accessible only for a few privileged children, while the majority have no similar opportunities.

In this work, we propose an approach that seeks to promote social justice in educational robotics by making the courses a realistic option for more, ideally for all, pupils who might be interested in them. To achieve this, we re-define the scope and goals of the courses, shifting from the construction of large-scale projects to achieving satisfaction and building confidence; we alter the design and organization of the courses, and we move the

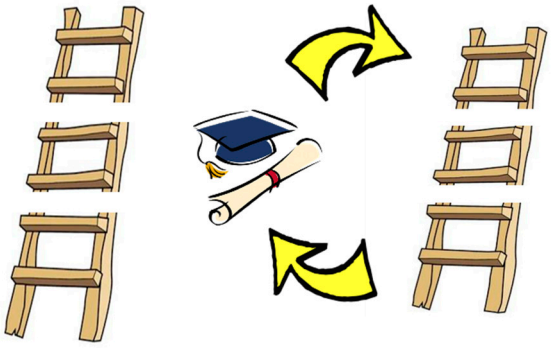
implementation from the school environment to an external venue. We also address the issue of scaling up in order to reach more children via the establishment of a network of teachers and schools that offer educational robotics courses.

The remainder of this article is organized as follows: In Section 2, we delve into issues of social justice and intergenerational mobility, establishing the motivation for our work. Section 3 explains how educational robotics is typically approached in Greece today and identifies areas of concern. Building on that, Section 4 outlines our proposed approach, covering issues such as the design principles for the educational programs, the supporting educational material and the organization of the operation of the facilities where the courses were offered. In Section 5, we demonstrate how our proposal has been put to practical application via the development of six new educational robotics programs and their pro bono offering to pupils in our area. Section 6 is dedicated to the issue of scaling up, explaining how the training of teachers allows us to reach a larger number of pupils. In Section 7, we explore the societal impact the implementation of our approach has already achieved and discuss its potential for even wider application. Finally, in Section 8, we list our concluding remarks and plans for future work.

2. Motivation

As the article's title suggests, our work is motivated by a pursuit for social justice for our young ones; more specifically, we are interested in making sure that—to whatever extent might be possible—all children are given the support and opportunities that will provide them with a fair chance at the pursuit of a fulfilling and happy life.

If we imagine society as a ladder, as depicted in Figure 1a, each one of us is at some level. Being on lower rungs corresponds to lower social status, reduced financial resources and greater uncertainty about the future. For example, undocumented immigrants and homeless people might be placed at the very bottom. At the other end, we find the most privileged members of our society, those for whom social recognition is a given, finances are not a problem and the resources that might be required to deal with any potential future hardship are already guaranteed. The owners of the most prominent businesses in the country are examples of who we might find at the higher ends of the social ladder.



(**a**) (**b**)

Figure 1. The social ladder that we hope will lead our children to an easier and happier life. (**a**) Society does not provide equal opportunities to all; rather, class origins greatly define one's potential as they define the starting point, and climbing to a higher status is not facilitated. (**b**) Education is an exception to this rule, as it can allow for anyone to re-set their starting point higher than their origins mandate.

More than social mobility, which refers to one's movement between different levels in the social hierarchy during their lifetime, in this work, we are more interested in intergenerational mobility, i.e., the relationship between the socioeconomic status of parents and the status their children will attain as adults [4]. Perhaps with the exception of those who already see themselves as sitting at the very top of the social ladder, we all dream of a future for our children that is brighter and easier than ours. However, this is far from guaranteed. In fact, it has been shown that the larger the resource distance between classes, the less

likely it is that mobility from one to another will occur [5]. In other words, the chances for children to truly escape their predetermined boundaries are slim. This is because although children of high- and low-income families are born with similar abilities, they face with different obstacles and are afforded different opportunities [6].

Although to some extent this was always the case, this is more pronounced today. Whilst people born before the 1950s enjoyed increasing rates of upward mobility and a decline in the strength of the link between class origins and destinations, later generations have experienced more downward mobility and little change in how origins and destinations are linked [7]. One tool against this inequality is education. Whilst the restauranteur's child has a greater chance of becoming a restauranteur, the fisherman's child of becoming a fisherman and the prime minister's first-born male child of one day becoming a prime minister (an example that holds particularly true in Greek society), via education, the farmer's child can become a doctor and start a career at a higher socioeconomic status, as depicted in Figure 1b.

This may in fact be our most effective tool for battling this type of injustice, as roughly half of the association between class origins and destinations is mediated via educational attainment [8]. But are we really achieving this goal? Since education was highlighted as an important factor in determining children's future socioeconomic status, families—particularly upper middle-class families—have shifted towards investing more heavily in their children's education. As a result, children from lower-income families attend public schools, such as the one presented in Figure 2a, while more privileged children may attend private schools, such as the one presented in Figure 2b, and receive more attention and opportunities. The family's financial status affects not only the child's chance of accessing higher education via the quality of primary and secondary education that the child will receive but also the success the child will have in higher education and the value the child will receive from it [9]. In this way, the already existing inequalities are actually being reinforced in the educational system [10]. This well-documented phenomenon is known as inequality of educational opportunity (IEO) [11].

(**a**) (**b**)

Figure 2. Not everyone has the same opportunities in education. For example, (**a**) public schools, even the best of them, have a much higher ratio of pupils to teachers, whilst (**b**) most private schools are able to provide each pupil with more personal attention and individualized support.

Thus, today, in the pursuit for social justice, it is not enough to provide education to all; intergenerational social mobility now depends on our success in narrowing the inequalities in the education provided [12].

In this work, we focus on the provision of STEAM education to all, specifically the provision of courses of educational robotics. With STEAM being heralded as the education of the future, and educational robotics being its most prominent expression, it is only natural that many families are interested in providing this option to their children, hoping to thus provide them with the best opportunities for developing their skills for the future they will live in.

However, as with so many other promising aspects of education, the meaningful implementation of educational robotics demands a cost that is prohibitive to many. Once

again, it is the most privileged children who have access to educational robotics courses, either via their well-funded schools or at home, whilst most children from lower-income families have no such opportunity.

It is our role, as educators and also as active citizens in a society that aims to reduce inequality, to provide further opportunities for the children that are lacking them, in this specific instance by creating a setting in which every child, no matter how under-privileged, will have the opportunity to be exposed to the wonders of educational robotics.

3. Current Situation

Currently, educational robotics is not part of the official curriculum taught in Greek schools, but it has a range of implications; we herein list the four most important.

3.1. Teaching Staff

Although it is not mandatory, educational robotics can be included in learning as part of the time that has been reserved for project-based activities; it is up to the teachers to decide how to use that time. Technology teachers are of course the ones best prepared for the task. Unfortunately, with technology courses covering a very small part of the curriculum in primary school, technology teachers typically have to work for multiple schools to fulfil their minimum teaching requirements. Having to spend so much of their time commuting between schools greatly limits the additional time they are willing to volunteer for each school. On the other hand, general primary school teachers, i.e., those who have been trained in pedagogy and are assigned to a single class for the duration of a school year, typically have little to no technical training [13] and are afraid or unwilling to explore topics such as robotics or programming.

As a result, the number of schools whose staff include a teaching member with the desire and ability to embark on the organization of educational robotics courses is limited.

3.2. Equipment

Not being part of the official curriculum, educational robotics does not have a budget allocation. Thus, it is not easy for a school to acquire the required equipment. With STEAM gaining in prominence, there have been some programs aimed at providing relevant equipment to schools of primary and secondary education, but these are not blanket programs: they do not cover every single school. For example, the prefecture of Peloponnese recently implemented a program aiming to support the implementation of educational robotics in every region in the prefecture. This may sound promising in theory, but in actual practice, educational robotics kits were given to only one primary and one secondary school per region, as shown in Tables 1 and 2. In total, equipment was provided to only 5 out of 182 primary schools (2.75%) and to 5 out of 74 secondary schools (6.75%). For the other schools, the purchase of equipment is only possible if the majority of parents agree on it and decide to fund it themselves or if a sponsor is found.

As a result, the number of schools that actually have access to educational robotics equipment is limited.

Table 1. Primary schools in the prefecture of Peloponnese that acquired robotics equipment.

Region	Total Number of Schools	Schools with Equipment
Arcadia	22	1
Argolis	29	1
Korinthia	49	1
Laconia	29	1
Messinia	53	1

Table 2. Secondary schools in the Prefecture of Peloponnese that acquired robotics equipment.

Region	Total Number of Schools	Schools with Equipment
Arcadia	12	1
Argolis	10	1
Korinthia	15	1
Laconia	14	1
Messinia	23	1

3.3. Educational Material

However, even in the cases where a school is lucky enough to have both the equipment and the willing teaching personnel, the implementation of an educational robotics program is far from straightforward. Courses that are included in the official curriculum are accompanied by (a) specification of which age group of pupils they should be offered to, (b) specific goals to achieve during each year of teaching, (c) books for the pupils, (d) a detailed teaching program explaining what has to be taught at each part of the year, (e) training for the teachers every time the detailed teaching program is altered or the books are updated, so that they know exactly how to approach teaching the course and (f) an online database of related exercises that they can use.

None of these exist for educational robotics. Therefore, it is up to the teacher who runs such a course to decide which ages of students it will be provided to, what the goals of the course will be and exactly how to approach it. No training is available, no books are provided and no database of potential projects to implement can be used for assistance.

As a result, the teacher has to create it all from scratch, also bearing the responsibility if, for example, the school administration or the parents are not happy with the course. Moreover, if for any reason the teacher has to abandon the project (due to illness, being transferred to another school, etc.), then the project has to be abandoned by the pupils as well, as it is not easy for someone else to reverse engineer what has already been taken place, re-imagine what was planned for the future and seamlessly take over.

3.4. Reach and Satisfaction

Finally, assuming that a robotics course is indeed implemented in a primary school, it has a limited reach. Given that typically only one or very few robotics kits are available, only one or very few projects can be developed in parallel. Typically, at the beginning of the year the teacher will choose a team of five or six pupils, or a few teams of five or six pupils if more kits are available, they will select a topic together, they will co-design a robotic solution and then they will devote the rest of the year to developing it. Usually, the completion of the project is timed to coincide with some regional robotics competition, so that the children have an opportunity to present their work. Having mentored a winning team looks good on the teacher's CV, which can result in either augmented pressure on the children to perform or, more often, in the teacher implementing most of the project with little involvement of the pupils, caring only about achieving an impressive result that can stand out in a competition.

As a result, on one hand, the educational robotics courses never reach most of the pupils in schools, and on the other hand, those pupils who are involved in educational robotics projects do not always gain the confidence and satisfaction that comes from having accomplished something on their own.

4. Proposed Approach

Our proposal, which we outline in the following, aims to address the four weaknesses in the way educational robotics is currently implemented in Greece that we identified in the previous section. For the ease of the reader, we use the same structure and explain separately how our overall approach addresses each of these weaknesses.

4.1. Teaching Staff

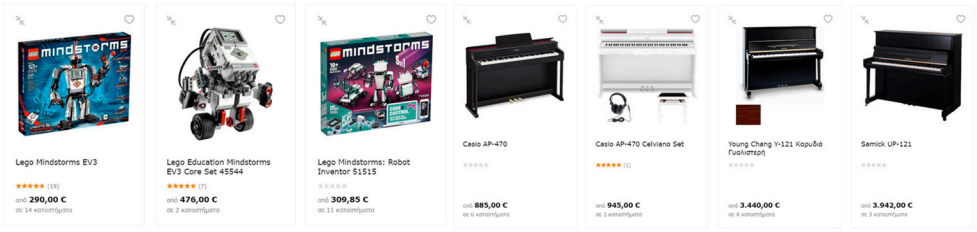
Any efficient large-scale activity requires the uninterrupted involvement of properly trained individuals who have a broad view of the overall project and who over time become even better in their roles via the accumulation of experience. Following this principle, in our approach, we require that teachers with a strong technical background, such as technology teachers with a first degree in computer science, be involved in all stages of the design and implementation of the provided courses.

We have already explained in the previous section that this type of teaching personnel rarely has any free time during teaching hours. We address this by planning for our educational robotics courses to run in the evenings, when schools are closed, so that the involved personnel do not have any parallel teaching obligations and/or the need to commute between schools.

This has the added benefit that at that time pupils are also not in school, which means that they are able to attend robotics courses after hours even if one is not offered at their own school.

4.2. Equipment

Our aim is to offer the opportunity to attend educational robotics courses to every single young child. Of course, purchasing educational robotics equipment for everyone is highly unrealistic. We see in Figure 3a some of the most popular but also cheapest educational robotics kits currently available on the Greek market. For some perspective, the prefecture of Peloponnese has more than 100,000 pupils. Clearly, it is not possible to fund the acquisition of a separate kit for each child.



(**a**) (**b**)

Figure 3. Some types of courses require very expensive equipment. (**a**) The cost of educational robotics kits can be prohibitive for many families; (**b**) the same is true for musical instruments such as pianos.

This is not an unsurmountable obstacle, however. In fact, we can learn from the experiences from a field that has already successfully addressed a similar problem involving even more expensive equipment needs. As we see in Figure 3b, pianos, even the most sensibly priced ones, are very expensive for the average upper middle-class family and probably prohibitive for anyone below that socioeconomic level. Still, children from almost any social background can learn to play the piano if they want to.

This is made possible via music schools. The purchase is made once, for the school, and any child can visit the school and take courses with a piano, paying a very low fee. Those who in this process find this to be their true calling may decide to go ahead with the personal investment of purchasing a piano for their own home, but others do not need to. Following the same approach, instead of attempting to provide distinct robotics sets for each pupil, our approach entails establishing a robotics education school where pupils can attend robotics courses without having to buy the equipment themselves.

For this approach to be possible, the ways of using the equipment needs to be altered. Music schools are able to operate the way they do because at the end of each session, the equipment is free to be re-used by the next student. The multi-month project approach conventionally followed in educational robotics courses does not allow that, as a team's construction must not be meddled with until it has been completed—and sometimes even after that so that it can be presented in competitions.

Our method includes the design of stand-alone sessions of educational robotics, at the end of which the equipment can be disassembled and returned to its original state. This way multiple pupils can be taught using the same equipment in consecutive sessions.

4.3. Educational Material

One weakness in the current situation is that teachers have to develop their own material. We have already explained that this increases the load for the teachers and burdens them with the responsibility. Moreover, this has the additional disadvantage that experiences gained from one teacher's class cannot be transferred to other teachers' classes since they are not necessarily facing similar situations.

In order to address all of the above, in our approach, we design each course in detail, specifying issues such as

- The expected outcome from attending the course;
- The age group of the pupils who can attend them;
- The previous knowledge required for pupils to participate;
- The equipment that is required;
- The duration of the course;
- The way the course is organized;
- Etc.

Moreover, we document the outline of the course, detailing what the teacher is expected to do at each step, designing the robotic project that will be implemented, developing the slides and producing the supplementary material that will be provided to the pupils when they enter the class.

As a consequence, any teacher giving one of our courses will find all required material to be already prepared and will not have to develop anything from scratch. Moreover, regardless of who is the teacher offering a course, its content will be the same; any subsequent course can be delivered by any other teacher without a particular need for the two to coordinate on what has taken place already and what was meant to follow later.

4.4. Reach and Satisfaction

The duration of the conventional educational robotics projects is the main barrier to offering them to a wider audience. With each pupil required to devote many hours to a project, the equipment also continuously tied to that project and a teacher required to be there at all times (supporting the pupils but also supervising the proper use of the expensive equipment), it is not possible provide the course to every interested pupil in a school, much less to every interested child in a region.

We tackle this by removing the main barrier, i.e., the duration of the project. In our approach, educational robotics sessions are stand-alone and have a duration between two and four hours. Once the session is over, the project is completed and the equipment is free to be re-used by others, for another session of the same course or even a different course that utilizes the same equipment. This is different to the conventional approach where the robotics project may be broken down into 1 h or 2 h sessions but they are not independent from each other and the equipment cannot be touched by other groups from the start of the first session until the end of the last session, typically at least several days [14] or more often several months later [15].

Clearly, the projects in our approach are much simpler, but this is not the only difference; they are also different in their goals. The target audiences for our approach are the less privileged children who have never before had the opportunity to experiment with educational robotics. Therefore, no previous experience is assumed (or minimal previous experience in some limited cases), and the courses are designed to start from the basics.

In a short two-hour session that also includes the teacher and the pupils getting to know each other, there is only so much that can be covered, and it would not make sense to expect the children to absorb a great deal of content and retain it. Therefore, the main goal cannot be to teach robot programming; in fact, that is not the goal at all—it is just the means.

One of the two main goals of the courses is to introduce the pupils to the concept of robotics so that with that short course, the children will see and touch robotics equipment for the first time, and they will gain an idea of what is possible. They will also have the opportunity to see and apply the process of constructing a simple robotic structure and programming it to achieve some simple task.

The second, and perhaps more important goal, is to empower pupils to engage with the topic of educational robotics, and science in general, by affording them the sense of accomplishment. To this end, the courses are designed to include short projects in which the pupils do not just copy what the teacher does but also have the opportunity to think and improvise. More importantly, the projects are designed so that before the end of the session, they will have reached completion and will have a result that the children will feel proud about.

The overall desired outcome is for pupils to leave the session having an idea of what educational robotics is about and also the confidence that this is a topic in which they could excel should they choose to engage with it further.

5. Implementation

Our group operates an innovation hub titled Innovation ΓΑΒ LAB, which it uses for its activities that are designed for the community. In the hub, in order to apply what we described in the previous section, in early 2019, we established our own private robotics education school (see Figure 4) that provides free courses to any interested pupil between 9 and 16 years of age.

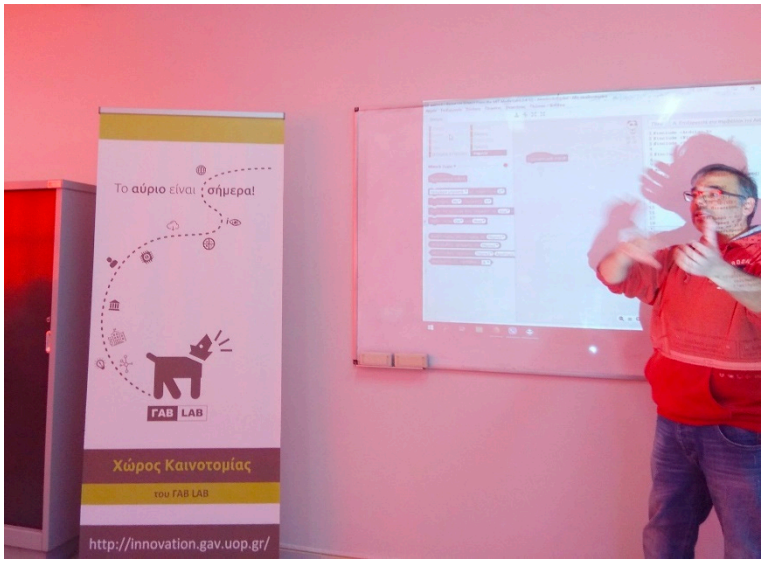


Figure 4. The innovation hub in operation.

The robotics education school that we established should not be confused for a primary school. A primary school is a school where pupils follow the official state curriculum. The robotics school that we refer to in this paper is our own establishment that operates after school hours and offers only robotics programs to children of primary school age. Our establishment does not replace or even resemble a primary school.

In this effort, we received support from the municipality of Nafplio; the support included the purchase of a number of robotics kits of various specifications and two tables for the robotics projects. Most other costs were covered by our group in the context of our service to the community. The greatest contribution of all was clearly that of the teachers. Responding to an open call for volunteers, six computer science teachers signed up and offered their time, effort, passion and inspiration without compensation.

Following a number of initial meetings, during which the concepts presented in the previous section were discussed and agreed upon, the teachers chose (a) the specific kits

they were most comfortable with and (b) the age groups they wanted to focus on, and they started developing their new, short, stand-alone courses. The completed courses were then examined to ensure that all of the specified principles were obeyed. Through this process, six educational programs were developed, as described in Table 3.

Table 3. Innovation ΓΑΒ LAB's educational robotics courses.

Course Title	Robotic Platform	Pupil Age Range
Programming the mBot robot	mBot	9–12
Robotic structures with LegoWeDo 2	LegoWeDo 2	11–12
Robotic structures with LegoWeDo 2—level 2	LegoWeDo 2	11–12
Introduction to LEGO Mindstorms EV3	LEGO Mindstorms EV3	13–15
LEGO Mindstorms EV3, next level	LEGO Mindstorms EV3	13–15
Getting to know ArduinoUno	ArduinoUno	16

The next stage was for the teachers to exchange their content and study each other's work. In this way, all teachers were able to offer any of the innovation hub's courses as needed.

The educational robotics school was ready for its trial operation in April 2019. As a final preparatory step, the teachers specified their availability to offer courses, and a schedule was created with courses being offered in the evenings as well as on weekends. The schedule was announced to the public, and a Google form was used to collect applications for participation, with each pupil limited to applying for only one program so that a maximum number of pupils could be served.

It quickly became evident that the course designed for the age group 9–12 (see Figure 5) was the most popular one, as children aged 9 and 10 (who were only eligible for that course) formed the most populous group of applicants. As a response, we updated the schedule and added more sessions of that course.

Figure 5. Pupils working in pairs on programming the mBot.

In total, 120 pupils attended free educational robotics courses at Innovation ΓΑΒ LAB. The school closed for the summer and entered a redesign phase with the intention to re-open, this time at a larger scale, in the spring of 2020. The start of the pandemic of COVID-19 put this plan on pause, and we have the intention to return to it when the situation permits it.

We should note that whereas the overall methodology presented herein was developed by the authors, the educational content of the individual courses was developed by the cooperating teachers. The authors of this article, not being the developers of the courses, are not at liberty to publish them, and that is the reason the full courses are not provided as part of this paper. Those interested in developing similar programs and wishing to request

access to the educational programs mentioned in Table 3 may contact the authors, who will then forward the request to the corresponding teacher.

6. Scaling Up

No matter how broad our intention is, there is a limit to how many pupils can be served by just one school. Therefore, although we see a clear benefit to the community from continuing to operate our robotics education school as we do at Innovation ΓΑΒ LAB, we also acknowledge that this will never suffice if the intention is to offer courses to every interested pupil.

The four main limitations that need to be addressed are:

1. The number of teachers in the innovation hub and the time they can devote;
2. The number of robotic kits available;
3. The number of classrooms available;
4. The distance to our school from the homes of pupils who do not live nearby.

All of these can be addressed, to some extent, if teachers whose schools have similar equipment can join our efforts and start offering our courses in their schools. This would allow our effort to scale up, having the potential to reach more children.

To make this possible, we have extended our approach, adding training not just for pupils but also for teachers. Although in our program, we focus on educational robotics, which is narrower in scope than STEAM, we still do not feel that it should be limited to teachers with a background in computer science. Quite the contrary, we believe that given the right support, it is a subject that could be taught by almost any teacher at the level required in primary school. In Figure 6, we see one of the first groups of teachers who were trained at Innovation ΓΑΒ LAB on providing the "Programming the mBot robot" course. We chose this course specifically not only because it is the most popular one but also because it is the simplest one; it requires no previous experience with educational robotics and requires the least previous experience with technology in general. The teachers included in this program all come with a pedagogical background and very limited previous experience with technology and computing.

Figure 6. Primary school teachers receiving training on educational robotics together with their instructors.

In addition to being shown how the mBot works and how the specific course can be taught, the teachers were given access to all the educational content that we have developed for the course, as well as an open invitation to contact the staff of the innovation hub whenever they needed support. We also mediate and support the communication between teachers who have received training in the innovation hub, so that experiences gained from one's course can benefit the others.

In this way, we have expanded the pool of educators who can offer our courses while also maintaining the control of what is taught and how. We have also started to establish a network of educators and schools, all supporting each other towards our common goal.

7. Societal Impact

As with any new intervention, designing it to achieve a goal is one thing; confirming that the goal has been achieved in real life is another. In this section, we report on the real-life impact we have observed and discuss the potential for further societal impact when the approach is applied more broadly.

Since the pupils only came to our school for a single session of educational robotics, we do not have access to data concerning their performance in school before and after the educational robotics course. We are therefore not in a position to assess the exact academic impacts the courses may have had on each individual participant. Moreover, when the program was implemented in 2019, our interest was solely the offering of free courses to underprivileged pupils; we did not at the time intend to use the action for research purposes, and hence, we did not make data-gathering provisions such as giving out questionnaires to pupils, teachers and parents. Looking back, it would have been nice to have done so, but we can draw some broader conclusions based on other data that are available to us, as follows.

The interest that our program received has been overwhelming from the start. Within the first hours of the announcement of the courses we offer, we received more than 350 applications for participation; in the end, we were able to serve only 120 of them, and we hope to welcome more pupils when we operate again in the future. More importantly, even after we had closed the form for applications and accepted no new applications, as pupils started to attend courses and then informed their friends about the experience, we started receiving requests via other channels (emails, telephone calls, impromptu visits to our premises) asking for more courses to be organized so that more children can be included. This indicates that in addition to its initial positive reception, our approach, has a cumulative effect, with each implemented session contributing to the generation of further interest.

As far as the broader society is concerned, educational robotics was not a popular topic in our area before the start of our action. There were no private schools offering courses, no local shops selling robotics equipment, no schools participating in competitions and no related events being organized in the region. One could only assume that the local population did not have any interest in the field.

In the one year following the implementation of our program, we witnessed the following:

- A private multi-purpose facility in the area that offers various programs for children started to also offer a robotics course, for a fee;
- Many schools, both primary and secondary, participated in the next year's national robotics competitions. One of the primary schools made it all the way to the finals;
- In a number of schools, parents' associations funded the acquisition of robotics kits similar to the ones in our innovation hub;
- Local shops have started to not only sell robotics kits after order but to also keep them in stock and on display;
- A regional educational robotics competition was organized in our area.

The above indicate a strong societal shift. From a society that was not at all interested in educational robotics, we have moved to a society where educational robotics are interesting enough to command their own segment in the local market, both for services (courses) and for products (equipment). More and more schools are enriching their equipment and developing educational robotics programs. Children are actively seeking opportunities to be involved in robotics, and their families are supportive.

We are humbled to observe the impact the short-lived implementation of our approach has already achieved and are looking forward to applying it more broadly when the

pandemic eases. Moreover, with this publication, we aim to share our approach and urge others to apply it in their own regions, for the benefit of all children everywhere.

8. Conclusions

In this work, we have presented our approach towards making educational robotics an accessible reality for any interested pupil. We started by discussing the issue of intergenerational mobility, identifying the narrowing of inequalities in education as a core goal in the pursuit of social justice. We continued by presenting the way the topic of educational robotics is approached in the Greek educational system today and identified the reasons the current approach leaves so many children behind.

Based on these, we moved on to the presentation of our own proposed approach, which aims to overcome the current difficulties and hopes to make educational robotics accessible to all. Our approach includes implementation in a setting outside of school, shorter courses that build confidence rather than projects, shared equipment, standardized educational content, scaling via the development of a network of teachers and schools and more.

Having applied our approach in our innovation hub in the spring of 2019, we have verified that it is realistic and applicable. More importantly, based on the original reception of the program, but also on the shifts in the local society that we observed over the following year, we have confirmed that our approach has the potential to achieve a broad societal impact.

One issue that cannot be overlooked, and we are grateful to one of the reviewers for pointing it out, is that of sustainability. We have presented our proposal in which robotics courses are taught outside of school hours so that teachers are available, and then we moved on to explain that in our proof-of-concept implementation, all teachers are volunteers. We need to clarify that this—the volunteer nature of teaching—was a happy coincidence, not a part of our proposed methodology. Quite the contrary, we believe that this approach will be difficult to sustain in the long term and suggest that a more viable economic model is pursued. The music school paradigm can again be used for inspiration: either private music school for which reasonable and affordable amounts are charged for access to unreasonably expensive equipment or public music school, for which a public body, most usually a municipality, covers all operational costs and courses are offered for free. In our future work, we will follow the latter, with financial support requested from our local government in order to continue to provide courses free of charge.

Our future plans for this work have three directions. The first and most obvious one is the re-establishment of our in-person educational programs for pupils once the COVID-19 situation permits it. The other directions are about extending the scope and augmenting the impact of our work, in part by integrating it with our other relevant activities. These include building close cooperation with other relevant public entities [16] in order to be able to establish and sustain a wider network of innovation hubs so that more pupils can benefit from them; using data analytics to assess the effectiveness of our activities so that we can re-configure and enhance them where needed [17]; designing educational robotics programs that do not only focus on the subject of robotics itself but rather use it as a means of also developing soft skills [18]; extending our work to include kindergarten pupils [19]; and focusing on pupils from often neglected populations, such as the Roma community, who also typically display high school drop-out rates beginning in primary school [20].

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