Science and Technology Educational Quality Scaling in Spain

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***Abstract*— This Research Full Paper presents a survey about science and technology education scaling. At the end of 2013, the Spanish government released an Organic Law for Educational Quality Improvement (LOMCE). Which this law provides is a guide with the aim of getting information about the changes which this law implies and what is impacted. All of this is based on gender equality opportunities. Education curriculum simplification is also included. This article describes the goals, assumptions, and underlying logic about Spanish legislation change has impacted on science and technology education. The aim of this study is to provide learning technologies to drive science and technology education to students. This study includes an analysis of local scope in the modifications of the Spanish educational legislation and data on the actions of different educational agents in Spain. Several educational centers emerged, and other, which already was present, have been growing. In the last years, educational institutions had the need to prepare their teachers for science and technology knowledge. Several educational centers and robotic educational tools commonly used nowadays are summarized. Additionally, the analysis of different use cases has been included as part of this study. Firstly, cases related to the formal education of Spanish educational centers and how the educators of such centers have perceived the change. On the other hand, a specific analysis of a Non-Official Education Centre is included. Thus, as part of the conclusions included in this article, this paper provides the impact of educational scaling improvement in Spain and a set of robotic educational tools to be addressed for classroom.**

Keywords*— *Education policy, Faculty development, Learning technology, STEM

I. INTRODUCTION

Scientist community is empowering the science education [1], the technology education [2] and the STEM (Science, Technology, Engineering and Mathematics) education [3]. Robotics has become an important tool for the students to be involved in science, technology and STEM educational areas. This occurs due to the presence of robotic educational kits as affordable solutions which can be easily introduced in the classroom. Furthermore, Robotics is being used as the modernization and improvement for most of processes. This occurs as result of robots can be easily integrated within the current industrial processes [4].

Nowadays, two technology phenomena are emerging, the IoT (Internet of Things) and the Big Data. In the context of IoT, Things can exchange information to conduct the making of decisions by themselves [5]. On the other hand, Big Data is the science which analyses a big amount of acquired data with the aim of taking decisions over the environment. The current Industry is being transformed under the name of Industry 4.0, the Fourth Industrial Revolution. The Industry 4.0 is based on digitalization, IoT and Big Data with the aim of providing its manufactured products from the factory to customer's home. This must be done at the same time than if the product is already in the warehouse. Hence, to make real this transformation, companies need to evolve into digital enterprises. Thus, qualified staff on science and technology competences is needed for upcoming years. Furthermore, Spanish education must be aligned with Europe 2020 growth strategy (http://ec.europa.eu/europe2020/index_en.htm) for the coming decade. In the 21st century, however, computer programming is viewed as a critical and necessary skill that everyone should learn [6]. Thus, Europe initiated a trip to use and the implantation of ICT (information Communication Technology) with the endorsement of European Commission in 2010. It was materialized with the Digital Agenda which main objective was developing a single digital market to lead Europe into a smart, sustainable and integrator growing. The actions to be implemented by the European Union were:

- Introduce the target of a single digital market
- Open a legal online access to contents by simplifying authorizations
- Ease payments and billing by electronic way
- Unify telecommunication services
- Reinforce interoperability and standards

- Consolidate the online confidence and security
- Promote a speed internet access
- Invest on research and innovation
- Encourage the culture, competencies and ICT sector
- Take advantage of the resourceful use of technology by society

Robotic educational tools are promising opportunities to be used in STEM (Science, Technology, Engineering and Mathematics) education but a more compensated STEM educational tool is still needed to be included in Formal Education Institutions. Robotic framed in STEM education empowers the creativity when children are using computers. Additionally, a STEM educational tool promotes the following students' competencies: teamwork, problem solving, resilience and communication. Furthermore, creativity can be also strengthened with science fiction prototypes within an educational framework. Some cases of use can be found in [7-15] Hence, disruptive robotic educational constructions can be designed and created with the aim of improving learning sessions. MRP (Multi-Role Project) method helps students to acquire important professional knowledge and skills, experience near-real-world professional realities, and develop their abilities to work both in teams and autonomously [16].

Furthermore, some initiatives have emerged with the aim of providing cost-effective robotic platform for STEM education such as [17]. Additionally, the Thymio project is described in [18] as an open source and free Access robotic educational solution to be used easily by education scientists, teachers and designers. Other example is the Duckietown project, an open, inexpensive and flexible platform for autonomy education and research. The platform comprises small autonomous vehicles ("Duckiebots") built from off-the-shelf components, and cities ("Duckietowns") complete with roads, signage, traffic lights, obstacles, and citizens (duckies) in need of transportation [19]. As identified in [20], engineering design-based science curriculum units may support elementary students' science content knowledge, while helping students learn to design, construct, and test solutions to engineering problems. On the other hand, the arts can contribute to and be an integral part of STEAM education.

Spanish laws are acting on science and technology education from the lower education grade, the Primary Compulsory Education, to provide knowledge to the future generations.

The main goals of this work are to analyze local scope in the modifications of the Spanish educational legislation and data on the actions of different educational agents in Spain. Additionally, it is included a survey of science and technology educational centers and educational robotic tools. Moreover, an analysis of different use cases is included as part of this study. This study covers formal education and non-official education.

II. Spanish Legislation Changes

In Spain, several key indicators show how the level of resources available to the education system has grown substantially over the last five years: the number of students per teacher has been reduced, more technological resources have been incorporated and, consequently, public spending per student has increased (OECD, 2019; Ministry of Education, 2019).

However, the results do not seem to have accompanied the increased provision of material and human resources. On the one hand, learning data such as those offered by the PISA Report on school success and skills development have placed Spanish students at a low-middle level among developed countries since 2000.

LOMCE was released on November 2013 by the Lower House in the Spanish Parliament and was published in the Official State Bulletin (BOE, in Spanish) on December 10th, 2013 (http://www.boe.es/diario_boe/txt.php?id=BOE-A-2013-12886). This new law does not replace but modifies the LOE.

Education, Culture and Sport Ministry provides a guide with the aim of getting information about the changes which this law implies and what is impacted - see http://www.mecd.gob.es/educacion-mecd/mc/lomce/inicio.html. According to this guide, the educational amend implies the following changes:

- A set of measures with the aim of guarantying that students can acquire and express their talents. Additionally, they can reach their personal and professional development. All of this based on gender equality opportunities.
- Education curriculum simplification.
- A set of measures to the get Spain into a better international education position and to converge into educational European objectives focused in the Europe Strategy 2020.

LOMCE sphere covers Primary Education, Secondary Compulsory Education, Baccalaureate Stage and Vocational Education grades. These grades correspond to ISCED (International Standard Classification of Education) levels 1 to 5. Table I depicts the correspondence between the Spanish educational grades and the ISCED levels of education.

TABLE I. SPANISH EDUCATIONAL GRADES CORRESPONDENCE TO ISCED

Spanish educational grades	ISCED level
Primary Education	1
Secondary Compulsory Education	2 and 3
Baccalaureate Stage	4
Vocational Education	5

The implementation of LOMCE has involved many changes. One of them is the modification of the eight basic competences of the curriculum, which become to seven and to denominate key competences. The new law slightly renames some of the previous ones, unites the ones related to the scientific and mathematical world, and eliminates the personal autonomy to replace it with a sense of initiative and entrepreneurial spirit. In this way, it conforms to the European frame of reference. The new seven competencies are the following:

- Competence in linguistic communication: It refers to the ability to use the language, express ideas and interact with other people in an oral or written manner.
- Mathematical competence and basic competences in science and technology: The first one refers to the abilities to apply mathematical reasoning to solve questions of daily life; science competition focuses on the skills to use scientific knowledge and methodology to explain the reality that surrounds us; and technological competence, in how to apply these knowledge and methods to respond to human wants and needs.
- Digital competence: It involves the safe and critical use of ICTs to obtain, analyze, produce and exchange information.
- Learn to learn: It is one of the main competences, since it implies that the student develops his capacity to initiate and persist in learning, organize his tasks and time, and work individually or collaboratively to achieve a goal.
- Social and civic competences: They refer to the capacities to relate to people and participate in an active, participatory and democratic way in social and civic life.
- Sense of initiative and entrepreneurship: It involves the skills needed to turn ideas into action, such as creativity or the ability to take risks and plan and manage projects.
- Conscience and cultural expressions: It refer to the ability to appreciate the importance of expression through music, the visual and performing arts or literature.

These regulations are applied into Formal Education Institutions which must apply the established calendar and subjects in the stated scholar courses.

A specific case to study into this scenario, could be Madrid region technological education development, which can be considered one of the more advanced in terms of technical deepening. Madrid Region technological studies have been transformed into a new subject: Technology, Programming and Robotics, also known as TPR. In the year-course 2015-2016, according to Directorate-General for Quality Improvement of Teaching more than 2.200 teachers have been certified to teach TPR to more than 246.000 students.

The subject is present in the first three years of Secondary School and is taught according a model of two hours a week. The planning of the subject, subjected to three main topics, follows a continuous enlargement of these contents according the course. In this way, the division of the subject could be introduced as follows:

- Block 1: Programming, in which the first data structures, the making of algorithms, the web programming and the use of office applications are included.
- Block 2: Technology, in which contents are focused to materials, resources, relation with Nature and manufacturing processes.
- Block 3: Robotics, which has been created to be taught as the natural consequence of the study of electronics and mechanics, once the students have learnt about programming.
- Block 4: The Internet, by which the student will be able to use the information and communications resources from the Internet, performing a responsible behavior.

Once we have analyzed the content referring to the legislation, next we are going to treat how the different tools of educational robotics are used in the educational centers.

III. Science and Technology Educational Centers and Educational Robotic Tools

Science and technology education are present either in Formal Education Institutions or Non-Official Education Centers before LOMCE was released, some Non-Official Education Centers was already present. Although, once LOMCE was released, several Non-Official Education Centers have been emerging these years.

With the aim of covering the LOMCE release impact into Spanish education and society, a survey has been used. The survey has been answered by representatives of 36 institutions located throughout Spain. Table II summarizes the institutions and their locations. Institutions have been grouped by their location. Additionally, it is included the number of students who are attended to each institution. Students have been grouped by location too. Furthermore, they have been classified into educational grades, mentioned in LOMCE. Most of these institutions are public, the students have not pay for studying and there are about 30 students for each teacher. these institutions are private, the students must pay for studying and there are about 20 students for each teacher.

To provide science and technology education, Formal Education Institutions are using different educational robotic tools such as Arduino, LEGO Education (WeDo and Mindstorms). Other Development Software tools such as Scratch and App Inventor are used too. Furthermore, Software Sketchbook tools such as Processing, SketchUp and QCAD are included. Additionally, Python programming language is included as technology tools. Finally, other robots such as Sphero and Printbot Evolution BQ are used for technology education too. These tools require a computer which is present in most of Formal Education Institutions. Figure 1 depicts the number of institutions which are the mentioned tools to teach science and technology knowledge in classroom. The most used robotic educational tools are Scratch (26), Arduino (26)

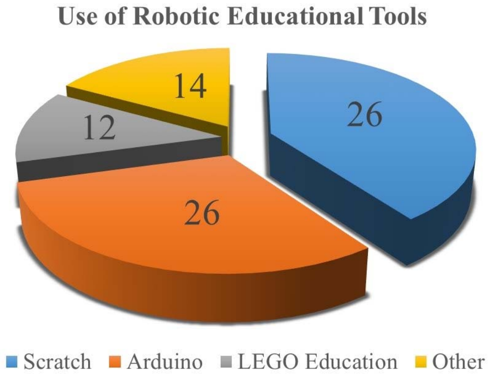

Fig. 1. Robotic tools and the number of institutions which are using them.

TABLE II. INSTITUTIONS LOCATION AND NUMBER OF STUDENTS CLASSIFIED BY GRADE GROUPED BY LOCATION

Institution	Location	Primary Compulsory Education	Secondary Compulsory Education	Baccalaureate	Vocational Training
IES Pino Rueda; IES Ben Gabirol; IES Seritium; IES Virgen del Carmen; IES Trassierra; IES Alhama de Granada; IES Vega de Mijas; IES Ángel Ganivet; IES Torre Atalaya; IES Alfaguara; IES La Laguna	Andalucia	0	4797	1966	1225
IES Rodanas; IES Rodanas	Aragon	0	800	250	650
IES Sánchez Lastra	Asturias	0	320	50	400
IE Juan Ramón Jiménez	Casablanca	480	280	90	0
IES Juan de Lucena; IES Hermogenes Rodriguez	Castilla - La Mancha	0	780	320	150
IES Juan del Enzina	Castilla y León	0	400	400	150
IES Ramiro de Maeztu; IES Ciudad Los Ángeles; Zazuar; Itaca; IES Butarque; Jesús María; IES Pedro de Tolosa	Comunidad de Madrid	300	3290	2180	100
IES Tierrablanca	Extremadura	0	330	40	35
IES Frei Martín Sarmiento; CPI Dr López Suarez; IES Lama das Quendas; IES Pontecaldelas; IES Chano Piñeiro; CPR Plurilingüe Karbo; Martín Códax; Colegio Plurilingüe Montecastelo	Galicia	869	1574	522	744

and LEGO Education (12). Scratch is a project developed by the MIT Media Lab's Lifelong Kindergarten group. It is provided freely. Scratch helps young people to learn by creatively thinking, systematically reasoning, and collaboratively working — essential skills for life in the 21st century.

Scratch is intended to be used by parents, educators and developers. Using Scratch, young students have opportunities for computing education, opportunities that put them into a position not merely as consumers of computational artifacts but as explorers and designers of the world computing offers. Scratch pro-motes that students interact and create their own content related to curricular areas with several advantages, such as motivation, fun, commitment, and enthusiasm, showing improvements related to computational thinking and computational practices. Visual programming environment offering graphical items and states of a computational problem is helpful in supporting programming learning with computational problem-solving [21] and [22]. [23] proposes an integrated curriculum to establish essential abilities of computer programming for the freshmen of a physics department. Furthermore, authors propose the implementation of the graphical-based interfaces from Scratch to LabVIEW then to LabVIEW for Arduino for the curriculum.

Arduino was released by Massimo Banzi in 2005 as a modest tool for Banzi’s students at the Interaction Design Institute Ivrea (IDII). Arduino is an open-source electronics platform based on easy-to-use hardware and software. It is a platform that incorporates a simple microcontroller and an interface development environment to create the applications to be downloaded into the board. The use of Arduino projects includes a wide range of applications from robotics to automatic control irrigation systems. Arduino is widely used in education, e-Textiles Integrate the Arts and STEM in computing education using Arduino as processor [24]. Other example is the development of a professional home automation system based on Arduino platform for the Practical Teaching of Electronics in Vocational Training context [25].

LEGO Education have been working for 35 years with teachers and educational specialists to deliver playful learning experiences. [26] demonstrates that LEGO Mindstorms has become a suitable platform for college students to investigate a broad range of topics within the ACM/IEEE Computing Curriculum 2001. Currently, there are two common tools provided by LEGO Education: LEGO Education WeDo and LEGO Mindstorms Education EV3. LEGO Education WeDo provides an easy way to deploy science, technology, Engineering, Mathematics and coding knowledge to children. Using LEGO Mindstorms Education EV3, students can develop critical thinking and problem-solving skills in middle school. LEGO Mindstorms Education EV3 robotics kit was used to build a DIY (Do It Yourself) braille printer [27]. LEGO Mindstorms can demonstrate easily the concept of mobility by an exercise in which students build a line tracer [28]. Using the LEGO Mindstorms NXT robots as a training platform, reduced significantly the effort of a group of professors when preparing exercises, and encouraged the reuse of their work among several topics and subjects [29]. LEGO NXT Mindstorms kits and standard LabVIEW were combined for laboratory work and student competitions [30]. [31] describes an instructional module that emphasizes integrative design using six simple machines: the lever, the wheel and axle, the pulley, the inclined plane, the screw, and the gear. This simple machine module makes use of an original web-based multimedia learning environment as well as offline, hands-on building activities with the LEGO Technic I set. Combining LEGO EV3 robotics and game design to develop middle school students’ computational thinking strategies is also very useful as [32] demonstrates.

The application was made available through request on July 12, 2010 and released publicly on December 15, 2010. The App Inventor team was led by Hal Abelson and Mark Friedman. MIT App Inventor is an intuitive, visual programming environment that allows everyone – even children – to build fully functional apps for smartphones and tablets. Those new to MIT App Inventor can have a simple first app up and running in less than 30 minutes. App Inventor is a simple programming tool for building Android apps.

Creating an App Inventor app begins in the web browser, where the look of the App is designed. Then, like fitting together puzzle pieces, the behavior of the App is set. All the while, through a live connection between the computer and the phone, your app appears on your phone. Many different types of Apps can be built with App Inventor. Often people begin by building games like MoleMash or games that let them draw funny pictures. The phone's sensors can be also managed. For example, to move a ball through a maze based on tilting the phone. But App building is not limited to simple games. Apps that inform and educate can be also built. A quiz app to help classmates' study for a test can be made. With Android's text-to-speech capabilities, the phone could ask the questions aloud. App Inventor is not intended to be used by professional developers. This is because instead of writing code, the App's looks, and the App's behavior is specified by using blocks. In a case study on a middle-school students game creation course in Beijing App Inventor was used for physics cognitive knowledge involved in the game creation [33].

Python was conceived in the late 1980s and its implementation began in December 1989 by Guido van Rossum at Centrum Wiskunde & Informatica (CWI) in the Netherlands as a successor to the ABC language (itself inspired by SETL) capable of exception handling and interfacing with the operating system Amoeba. Nowadays, Python is a widely used high-level programming language for general-purpose programming. Python features a dynamic type system and automatic memory management and supports multiple programming paradigms, including object-oriented, imperative, functional programming, and procedural styles. It has a large and comprehensive standard library. [34] presents examples of the use of Python in robotics and mechatronics education, including computer vision (OpenCV), 3D dynamics (ODE/VPython), control (python-control), 3D kinematics and robotics (python-robotics) and machine learning (scikit-learn). Python is also used to teach computational physics [35]. Furthermore, [36] shows students' projects resulting from the application of key concepts of image processing and pattern analysis supported by the PBL methodology. Additionally, BlockPy, a web-based, open access Python programming environment, supports introductory programmers in a data-science context through a dual block/text programming view [37].

Printbot Evolution is provided by BQ as a kit and a programming platform. BQ is a Spanish brand dedicated to the design, sale and distribution of electronic readers, tablets, smartphones, 3D printers and robotics kits. Using Printbot Evolution, a student can program robots with ease. This rewarding activity is the perfect opportunity to spend time and share enthusiasm with youngsters. Building a PrintBot Evolution helps to develop creativity, teamwork, critical thinking, as well as motor and 3D design skills. It´s more than just having fun, Evolution is the first step towards learning and understanding technology.

Apart from Formal Education Institutions, Non-Official Education Centers are using that STEM educational tools to provide training courses to institutions' faculty and extracurricular activities for students. Examples of these Non-Official Education Centers are: Robokids located in Andalusia and Science World, El Mundo es Ciencia, placed in Community of Madrid. Robotics is used as a technology in activities designed to enhance teachers' STEM engagement and teaching through improved attitudes toward STEM [38].

Once the Institutions and examples of Non-Official Education Centers are listed, how many students are enrolled in which grade and what robotic educational tools are being used in the institutions, the next step in this investigation is to take a deep sight into how Institutions, faculty, students and society are impacted by LOMCE

IV. Cases of Study

Formal Education Institutions are equipped with ICT (Information and Communication Technologies) materials. The studied Secondary Compulsory School (IES in Spanish) and schools are equipped with personal computers which are used by the students during the classes. They also have internet connection. Although, before LOMCE was released, they had neither robotic educational tool nor knowledge to integrate STEM knowledge using robotic educational tools.

The cases of study have been analyzed using a survey asking to institution directors, faculties and students of the analyzed institutions.

Formal Education Institutions have been dealing with curriculum adaptation. This adaptation has been performed along two angles: the subject content and the needed technologies required with the aim of covering the subject content. Half of the institutions listed in Table II indicates that the institution adaptation to the subject content was complex or very complex. The other half got an easy adaptation. On the other hand, Half of the institutions were obtained for the Technology knowledge adaptation required to provide the subject content complex or very complex. Less than the half of institutions indicated that the Technology knowledge adaptation required to provide the subject content was easy. Figure 2 represents the effort required for the mentioned changes. This effort has been reported by institution directors.

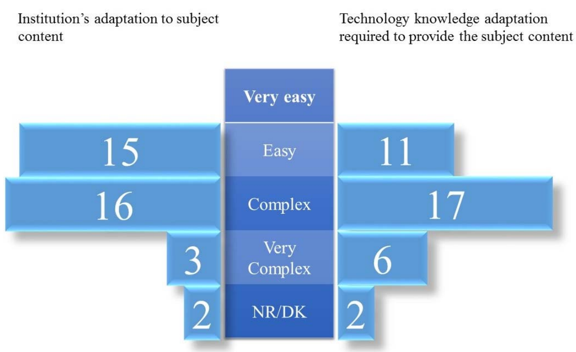

Fig. 2. Formal Education Institutions adaptation effort to LOMCE.

The second pair of questions are focused on faculty. Faculty is also affected because they oversee curriculum implementation and the use of the introduced new technologies. In first place, faculty must apply LOMCE modifications. Furthermore, faculty must include new technologies into the classrooms. Apart from reduced number of institution's faculties, other institution's faculties consider that the adaptation to LOMCE modifications was complex or very complex. For the second question, the answers were similar. Figure 3 shows the effort which has been required for the cited changes.

The third analyzed group are students. They have been also dealing with curriculum adaptation. Students have

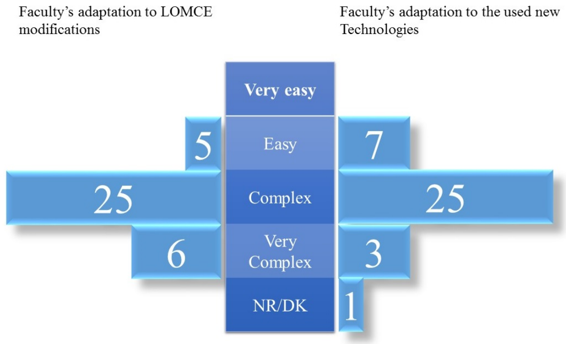

Fig. 3. Faculty´s adaptation effort to LOMCE

experienced two main adaptations: adaptation to LOMCE modifications and adaptation to new technologies which are included in the class. For students, Figure 4 depicts the effort that has been required for the mentioned changes.

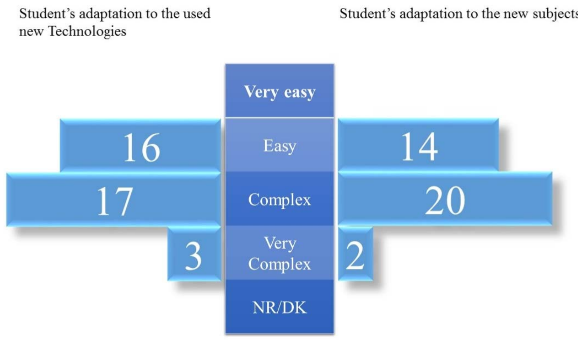

Fig. 4. Students' adaptation effort to LOMCE.

Finally, a question about the assessment for faculty and students was inquired. The opinion of some faculty was an easy change, but more than the half thought the change was complex or very complex. Despite the students' efforts required about the adaptation to LOMCE, the opinion for half of students was an easy change and the other half students thought the adaptation was complex. Figure 5 summarizes the faculty and students' adaptation to LOMCE assessment.

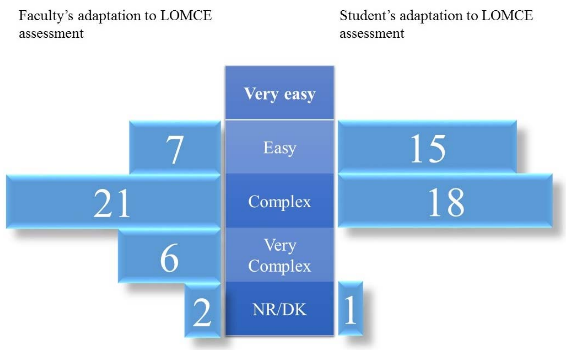

Fig. 5. Faculty´s and student's adaptation to LOMCE assessment.

After the survey results, a Non-Official Education Center analysis was performed. "Science World, El Mundo es Ciencia", (http://www.elmundodelaciencia.com, visited on 23 May 2020) has adhered to this investigation providing more detailed information related to its activities along an interview. Science World was established in March 1st, 2015. It provides extracurricular activities for students aged from 10 to 16 years. It integrates the activities for the following competencies:

- Teamwork: children must work in pairs or groups with the aim to achieve the objective set by the teacher. Students must analyze the proposed challenge, find the solution and distribute the task needed to get the solution.
- Problem solving when students must deal with a challenge, they usually find several solutions which present a complexity grade. Hence, they must divide that problem in other smaller problems than the original one.
- Resilience: capacity of self-improvement or frustration management against failure when a problem is intended to be solved. This is one of the most important competencies to be developed.
- Communication: Group working requires setting a common language and it is also necessary to establish common and suitable communication channels.

Classes are formed into groups of 6 to 14 students gathered by teacher. The used materials are: one personal computer per student, a robotic educational tool, a test table and crafts materials per team. A projector and a screen are used in the classroom too.

The used educational tools are: (1) block programming environments, (2) LEGO Education, (3) Makey-Makey and (4) BQ. The last two tools are electronic kits. The objective about the use of these tools is that they serve as physical vehicle for learning and understanding. These tools have demonstrated that they work properly for Science and Technology teaching. As all the tools, they have limitations but when they are used in the appropriate age range, they allow to students acquiring a large STEM knowledge in a practical and visual way. According to the necessary training time for faculty, to get a minimum knowledge, 10 to 16 training hours could be enough. Although, when a deeper knowledge is intended to be acquired, a training of 40 to 100 hours is required. ICT (Information and Communication Technology) competences are a key element for teacher training in ICT [39].

At the end of the interview, Science World included the following comment: Due to Science World is a Non-Official Education Center with the aim of empowering the STEM knowledge, one of our main goals is that robotics is an excuse to learn Science. We are confident that robotics is one of the best STEM tools.

V. CONCLUSIONS

Since LOMCE was released, four years has passed. Formal Education Institutions and Non-Official Education Centers has been evolving and collaborating to meet legislation requirements. In the next few years, Spanish education must be able to prepare students to achieve competencies, knowledge and abilities with the aim of becoming qualified personnel according to the Europe Strategy 2020. For 21st century education, TEDDICS (Teachers' Emphasis on Developing Students' Digital Information and Communication Skills) is the best way to engage students in STEM education [40]. As stated in [41], K–12 math education is a key policy lever to the engineering pipeline from undergraduate to graduate education.

This can be achieved by using robotic educational tools as STEM enhancer. Tools such the proposed by [42]. Authors also encourage to explore new ways to use robotic tools like Crumble with the aim of deploying STEM knowledges at home joining adults and children [43]. Nowadays, Wireless applications are widely extended in the Scientific, Education and Hobbyist communities. IoT development boards that can be introduced easily in classrooms within a STEM context [44].

According to data provided by 36 Formal Education Institutions and one Non-Official Education Center the following are inferred three kinds of efforts can be inferred from the LOMCE adaptation:

- Economic effort: this effort is held by institutions. They must acquire new educational tools to provide technologies to allow and facilitate STEM integration in the classroom.
- Training effort: institutions need trained enough faculty to deploy STEM in the classrooms using new educational tools with the aim of covering the curricula content related to science and technology.
- Understanding effort: students must face to new knowledge, which is presented in the classroom. Now they must learn programming, electronics, mechatronics, electricity and other fields covered by STEM.

According to survey responses, the included new educational tools have the following tradeoffs:

- Scratch and App Inventor: these tools are very easy to be used either by faculty and by students because students can acquire programming skills in an easy way by Scratch and App Inventor are based on building blocks programming. This different characteristic allows students aged from 10 to 14 years to get into programming without language barriers. On the other hand, neither Scratch or App Inventor allow a physical interaction between what is programmed and the students. Finally, the cost associated to these tools is not a problem because both can be used for free.
- Arduino: this tool is programmable too, but a textual programming language is needed. This is a disadvantage for students aged below 14 years because it is very hard for them. As an advantage against Scratch and App Inventor and Arduino integrates mechatronics and programming at a reduced cost. Additionally, these tools provide a wide range of activities to be carried out. Although, there are not much official, categorized and accessible documentation related to STEM education. A basic Arduino board can be acquired by 20€.
- LEGO Education: this solution is based on building blocks programming. Furthermore, these tools integrate mechatronics and programming. Furthermore, LEGO Education kits include a set of documentation which makes the application of STEM concepts ease in the class. The only disadvantage for these tools is the cost associated to them. A LEGO Education WeDo 2.0 Bluetooth basic kit is about 170€. A LEGO Mindstorms Education EV3 plus Software kit is about 440€.

Finally, to facilitate the adaptation either institutions and faculty, Learning Object recommendations can be used attending to the institutions' resources and the faculty's ICT competence profiles. Hence, LO (Learning Objects) can be used by faculty from LOR (Learning Objects Repositories). We are now developing and studying an open and collaborative development environment which promotes the innovation and the motivation of the students during the learning process within a STEM context. A modular, reconfigurable, flexible, adaptable and cost-effective educational tool. Hence, the results of this study are fully integrated as part as the collaborative scalable development platform.

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