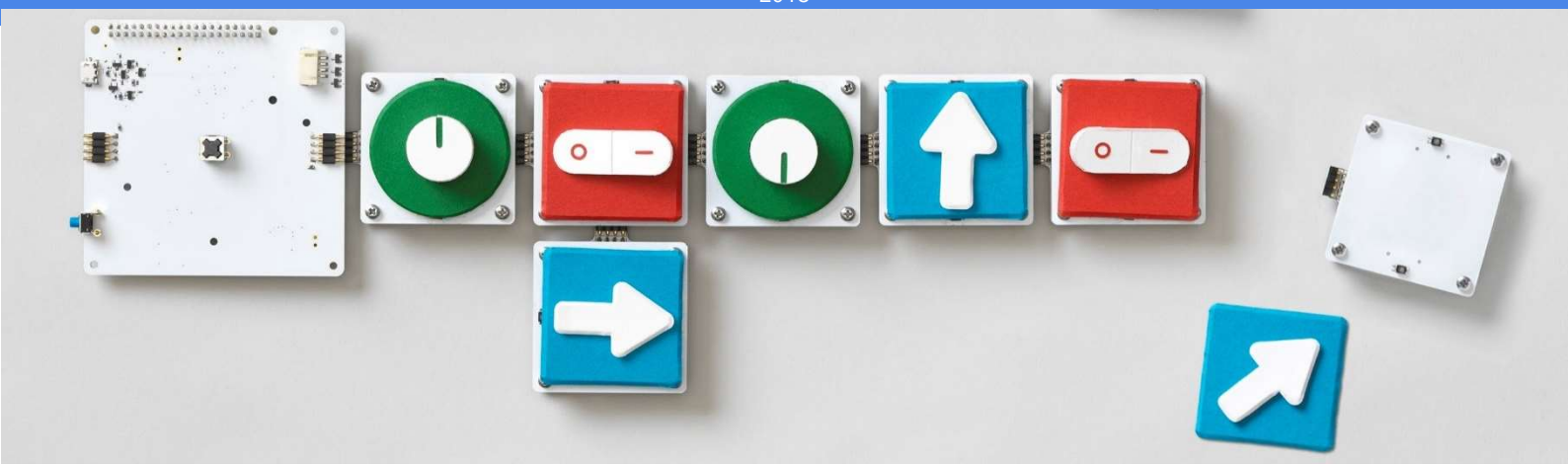
TangIn

Tangible Programming & Inclusion

FRAMEWORK FOR USING TANGIBLE PROGRAMMING CONCEPTS TO STIMULATE LEARNING OF STEM SUBJECTS AT PRIMARY SCHOOL

2018



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Valmieras Pārgaujas sākumskola. Valmierai, Pārgaujai, paSaulei!

Colegio Santa Elena Villarejo de Salvanés

"Know and Can" Association

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1 Executive Summary

Context

STEM subjects, programming, computational thinking, etc. are more than buzzwords. Today's world requires literate citizens that are able to understand and contribute to this increasingly digital world.

The European Union recognizes the importance of digital competence and regards it as one of the eight essential competences and intervention areas identified as priorities by the European Commission for lifelong learning (Recommendation of the European Parliament and of the Council of 18 December 2006).

Although not new there is a clear interest from the academic community in the "tangible programming" concept that has been growing over the past 15 years. It also recognized by several authors that tangible programming has benefits over graphical interfaces such as "resulting in more engagement and providing better opportunities for exploration than graphical interfaces" (*e.g.* Horn, 2009). Additionally, a tangible user interface promotes inclusion for example by narrowing gender differences of interest in computing, which are usually associated to male subjects.

Application

This study presents the research that was performed over the national curriculum of Bulgaria, Latvia, Spain and Portugal and that resulted in the construction of matrixes with topics where tangible programming could be applied. The topics are grouped under three main subjects: Mathematics, Science & Engineering and Technology.

To collect field data and gather relevant information about the application of tangible programming in the classroom a questionnaire was distributed to 157 teachers and researchers of the participating countries. Additionally, a focus groups was conducted in each of these countries.

The collected data shows that teachers recognize the importance of introducing programming and logical thinking concepts to 6 – 10-year-old children but lack the skills and tools to explore these subjects. It was also noted that teachers are eager to use tangible programming resources in the classroom and that this is an approach that will motivate students into STEM related subjects and promote inclusion.

TangIn

TangIn aims to produce and deliver a set of educational resources and materials to promote and support the effective use of tangible programming concepts by teachers in daily classrooms (at primary level schools) while teaching STEM-based subjects.

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2 Introduction

STEM skilled labour force has been in high-demand in Europe. This trend is expected to raise due to current and future consolidation and expansion to the physical world of more automation and digital technologies. By 2020, the European Union (EU) will have up to 825.000 Information and Communications Technology (ICT) job vacancies difficult to fill, due to the shortage of skilled labour force. Basic coding skills are also needed, as more than 90% of today's professional occupations do require digital competences, including programming.

Therefore, even if not everybody is expected to be either an engineer or a programmer, the ability to reason and understand tools and language of this fast-paced information era is critical for self-determination of an individual in the future society. The command of digital tools and programming skills/concepts, as well as critical reasoning skills, should be considered an "universal language", as they will be part of the 21st century literacy skills. The TangIn project strongly believes that education is the cornerstone for addressing these needs while children should have equal opportunities to fulfil their potential in the future society, and school curricula should focus more on this future (current) challenges and tackle them early on.

Tangible programming is a language similar to text or visual programming languages, but instead of using words/pictures on a computer screen, it uses physical objects to represent different programming elements, commands, and flow-of-control structures.

TangIn project intends to conceive and establish a range of resources and materials to address the efficient usage of tangible programming concepts and tools and help teachers in the awareness building of concepts in daily classrooms (at primary level schools). These set of learning tools will be relevant for promoting student's motivation and interest for STEM-based subjects (science, technology, engineering, and mathematics).

The tangible programming, complemented with the development of ICT and STEM skills, will be central in the TangIn project. These intertwined elements will allow young students to attain critical development of precious soft skills, such as teamwork, troubleshooting and critical thinking, through the development of activities that consist on using tangible programming tools to collaboratively solve problems.

This project is a 2-years duration initiative funded by the Erasmus+ programme[1] of the EU. Lead by Carreira & Alegre from Portugal and including partners from Spain, Bulgaria, Latvia and Portugal, representing schools, universities and research organizations, the TangIn aims to produce and deliver a set of educational resources and materials to promote and support the effective use of tangible programming concepts by teachers in daily classrooms (at primary level schools) while teaching STEM-based subjects. These resources will enable teachers to introduce tangible programming concepts and STEM-based subjects, to young students, in a fun, engaging, pedagogical and inclusive

[1] For more information on the Erasmus+ programme, visit: http://ec.europa.eu/programmes/erasmus-plus/node_en

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way. Even teachers with no background in using ICT, neither digital-based tools, will be able to promote and teach tangible programming concepts, with support of physical interfaces (e.g.: blocks commanding a simple robot). More information about the project can be found at www.tangin.eu.

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3 Desk research

In this section, it is discussed and presented the desk research results to establish the state-of-the-art of tangible programming in the context of education and set the theoretical and empirical background to support the project fundamentals, namely, defining scope and relevance and also researching tools and ways to implement in the context of an inclusive classroom.

3.1 Why tangible programming?

Some authors have been presenting several advantages of using tangible programming when compared to the use of graphical languages. It is important to explain that when one speaks of graphical languages, one is talking about code, that is to say, the various languages of programming by graphic objects (Scratch, Kodu, Blockly, etc.) used in computer or mobile devices.

As for the strengths attributed to tangible programming, state-of-the-art highlights the following:

- ⇒ Facilitates collaborative peer-to-peer programming (McNerney, 2000; Price *et al.*, 2003; Zuckerman *et al.*, 2005, Xie *et al.*, 2008; Strawhacker & Bers, 2014);
- ⇒ Facilitates debugging processes (McNerney, 2000), this is, procedures that consist of searching for, detecting and correcting errors;
- ⇒ Helps to narrow gender differences of interest in computing (McNerney, 2000);
- ⇒ Promotes physical involvement, since children learn by increasing the senses used (touch, sight, hearing) (Zuckerman *et al.*, 2005; Falcão & Gomes, 2007). It is well known that, in these age groups, the discovery of the world through touch is of supreme importance in the construction of learning, in the knowledge of the world and in the appropriation that they make of reality.

Having this desk research as a starting point, a literature review about the concept of tangible programming was performed. In Table 1 the information sources used to conduct the desk research are summarized.

Key questions: how are people researching and trying to implement tangible programming in the school context? What policies are decision makers following? How is the success of the implementation? How is it measured (quantitatively *vs* qualitatively)?

Main findings: there is a gap in tangible programming state-of-the-art implementation to be filled by this project innovative approach: designing activities using tangible programming for broader STEM Curricula (methodology) and covering all primary school levels, instead of only elementary (coverage)

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Table 1 – Data sources and literature review in this desk research

Data Sources for Desk Research		
Literature Review		
Academic	Peer-reviewed papers	86
	Book chapters	6
	Congress abstracts and talks	15
Policies	Reports, studies, projects	7
	Directives (EU)	3
	National Curricula	4
Others	Blogs	8
	Websites	11
	Generic journals (media)	4
	Specialized magazines	2

3.1.1 ICT and Digital Thinking context

Digital competences are one of the eight essential competences and intervention areas identified as priorities by the European Commission for lifelong learning[2]. As mentioned before, there is a consensus among all stakeholders (politicians, academics, public, teachers, education officials, students) that the way forward is to try to stimulate competences and implement as early as possible not only specific ICT topics, but also digital thinking in general, across the school curricula at different levels. Logical and algorithmic principles such as sequencing and debugging (Table 2) have been demonstrated to be "teachable" to children as young as 4 years old (Bers, 2008; Cejka, Rogers, & Portsmore,2006; Anderson, & Barnett, 2006). Even from an economic and a developmental standpoint, educational interventions that begin in early childhood are associated with lower costs and more durable effects (Cunha & Heckman, 2006).

[2] Recommendation of the European Parliament and of the Council of 18 December 2006, on key competences for lifelong learning (2006/962/EC), available here https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32006H0962&from=PT

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Table 2 – Digital thinking categories and principles.

Digital Thinking Categories and Principles	
Digital thinking skills	**Definition**
Abstraction	Process of representing/converting a subject/object (tangible or not) in a more understandable form by eliminating unnecessary detail. Prioritizing and choosing the most relevant descriptors by sorting according to the degree of information (100% meaning that one characteristic is enough to describe the subject)
Decomposition	Separating coherently the logical component parts of a subject/object and keep deconstruct them in simpler units/axioms until they can be understood, solved and evaluated separately but without losing crucial information on the original object/subject
Sequencing	Arrange the different parts of a problem in an order allowing to create steps towards a solution
Automation	By recognizing patterns find shortcuts and create repetitive tasks and loops in a way to save labor and time and improve the flow of information
Debugging	Systematic approach to predict and verify outcomes
Generalization	Strategy of exploring and exploiting previous solutions to similar problems by finding connections and similarities

The call for action resulted in different directives, policies and programs at European and national levels (Figure 1) (JRC Science for Policy Report, 2016). Not only there is no unified approach, but also different type of resources and tools are being used to implement these programs. Freedom and diversity of methods isn't necessarily bad, but it seems from this desk research point of view that there is a lack of coherence and vision on the way these programs are trying to be implemented and more often than not, a lack of a continuity strategy to make the transitions from pre-school to primary and secondary school levels.

Another point of divergence is in how to integrate in the curricula, should it be integrated across different subject areas, should it be a specific and independent computing subject or a combination of both. In Wales and Austria for example, there is a specific digital competence curriculum, while in other countries, digital competences are only a topic included in broader subjects (*e.g.* STEM). Whatever strategy is applied, the issue of measuring its impact and success is also a challenge and hindered by the difficulty of defining meaningful and quantifiable metrics. There are not so many examples in the literature (design-oriented studies) and usually with small study groups (n<40) (Sapounidis and Demetriadis, 2011; Schneider and Bilkstein 2018; Jurdi *et al.*, 2018) that may or may not be representative of its implementation in larger scale, and since the national initiatives and programs are recent, it may take some time to really be able to measure its impact. Finally, there is

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also the question of how teachers can be better prepared and motivated for using these new subjects, methods and tools in the classroom. To sum it up, the key questions are:

- ⇒ How to define computational thinking as a 21st century skill for school children?
- ⇒ How can teachers be trained to effectively integrate computational thinking in their teaching practice? Should computational thinking be address within a specific subject? (Computer science, part of STEM, cross curricular topic?)
- ⇒ How to assess computational thinking skills and impact?
- ⇒ What is needed to further the computational thinking agenda in compulsory education settings?

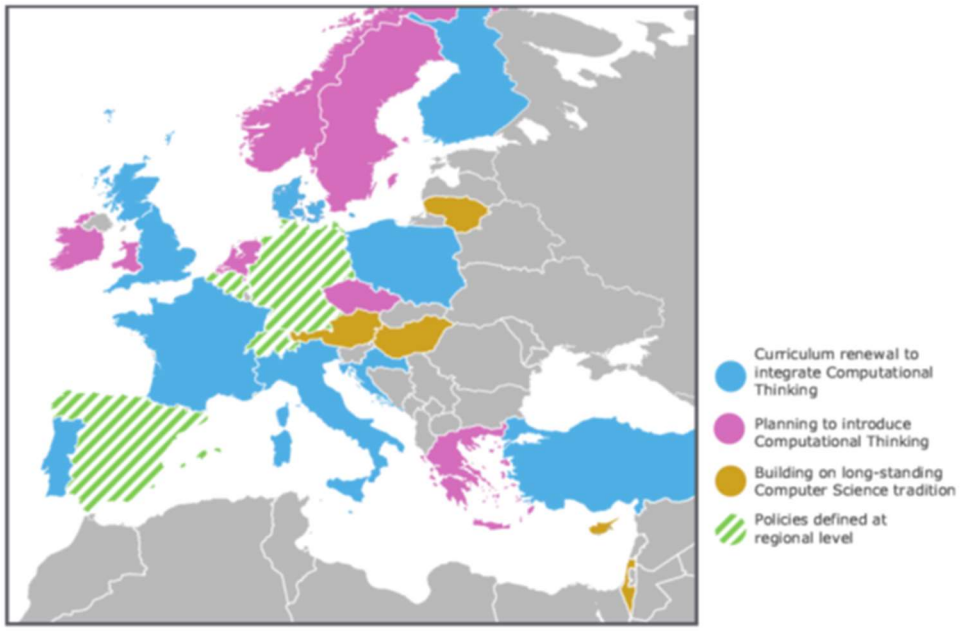

Figure 1 – Approaches to the integration of computational thinking in compulsory education adapted from Developing Computational Thinking in Compulsory Education, JCR report 2016

3.1.2 Tangible *vs* Graphical user interfaces

Different authors have different definitions for digital thinking and coding in particular but, there is the frequent image association to describe it "as solving a puzzle" (Sweigart, 2012; Summit 2015). For the sake of clarity, we will define it as: recognizing patterns and breaking problems in smaller and simpler parts and organizing it in a logical and sequential way.

To stimulate this type of rational thinking and problem-solving skills associated with programming, in younger minds, researchers at Massachusetts Institute of Technology (MIT), with the seminal work of Radia Perlam with TORTIS (Perlam, 1976) and revived two decades later in Japan (Suzuki & Kato 1995), came up with the concept of tangible programming that borrowed insights from the constructionism theory (Papert, 1980) and Piaget development stages findings (Richardson, 1998), and combined with technology to create an entire new field.

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Tangible programming was created having in mind the belief that the syntax rules of text-based computer languages represented a big barrier to learning for young children (Perlman, 1976). Since then multiple researches (Table 3, Figure 2 and Figure 3) have been conducted in the field and different tools were created (mainly robotic setups) (Table 4). According to Wang *et al.* (2014), "*Tangible programming is to make programming an activity that is accessible to the hands and minds of young children by making it more direct and less abstract. It allows children to manipulate "codes" directly, which makes programming more appealing",* which is fairly vague but can be used to differentiate tangible programming from Graphical User Interfaces (GUIs) which serve the same purpose (teaching programming concepts to children) but use visual languages such as scratch, Kodu and Blockly but necessarily resort to digital interfaces (smartphones, computer screens, tablets…) instead of physical objects.

The advantages of using tangible programming tools are many and well described in the literature, exploring the foundational concepts of sequencing, pattern recognition, and cause-and-effect relationships (Kazakoff *et al.*, 2013), making debugging easier and funnier (McNerney, 2000) and according to a few studies, resulting in more engagement and provide better opportunities for exploration than graphical interfaces (Horn, 2009, Wang, 2009; Zuckerman, 2013; Jurdi *et al.*, 2018). For example, Scratch despite valuable is not very easy for beginners and children spend more time learning the interface than programming concepts. With more sensory input (touch, sight, hearing) it is easier to form a mental picture and abstraction (Zuckerman et al., 2005; Falcão & Gomes, 2007)) and the embodied experiences can lead to even more efficient way of learning (Solovey en Jacob, 2009) and facilitates collaborative peer-to-peer programming (McNerney, 2000; Xie *et al.*, 2008).

Table 3 - Results returning from web of knowledge database search for scientific literature with "tangible programming" in its title (search performed on 27 May 2018)

Results returning from web of knowledge database search for scientific literature with "tangible programming" in its title	
Results found	**53**
Citations sum	**247**
Average citations	**4,66**
h-index	**8**

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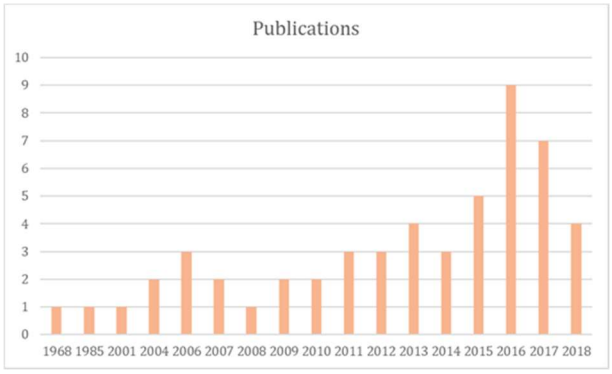

Chart 1 - Publications per year from web of knowledge database search for scientific literature with "tangible programming" in its title (Search performed on 27 May 2018)

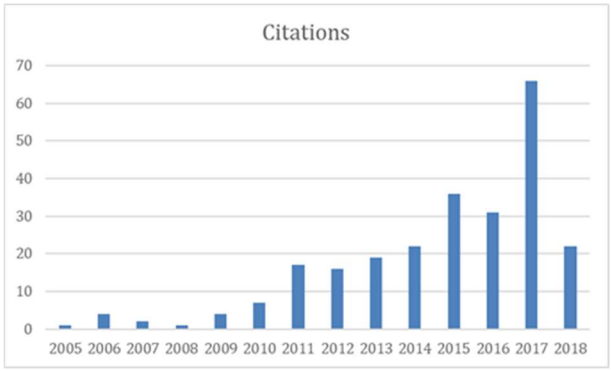

Chart 2 –Citations per year from web of knowledge database search for scientific literature with "tangible programming" in its title (Search performed on 27 May 2018)

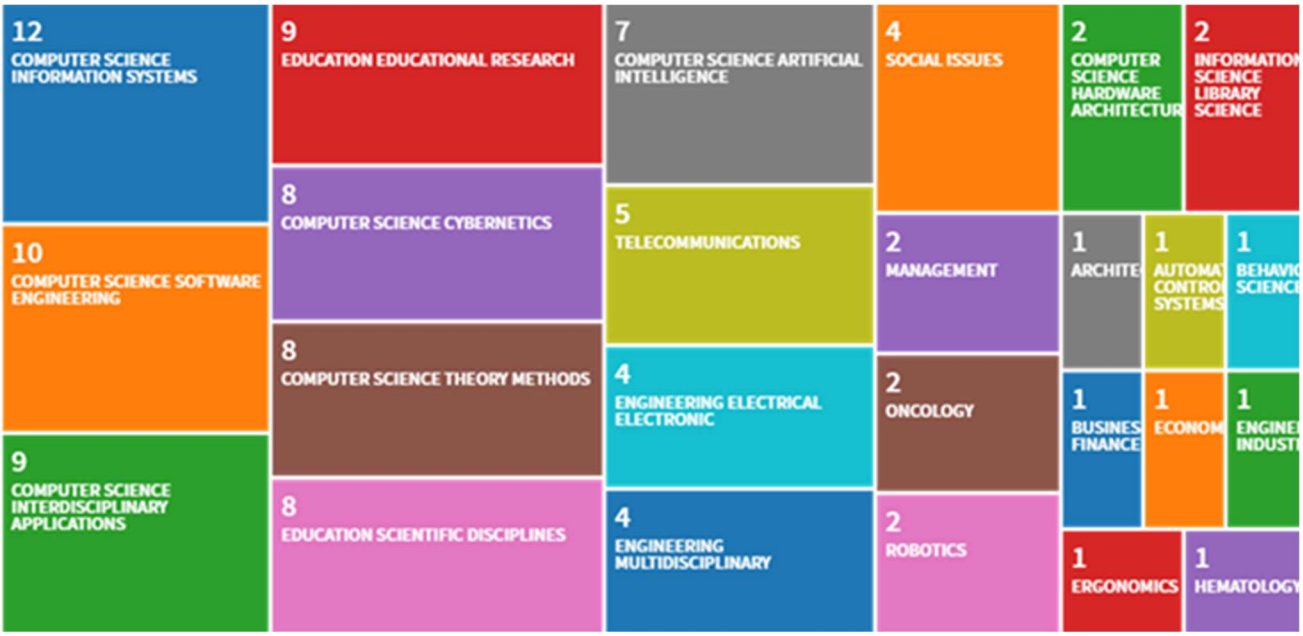

Figure 2 – Distribution of papers by topics of research from web of knowledge database search for scientific literature with "tangible programming" in its title (Search performed on 27 May 2018)

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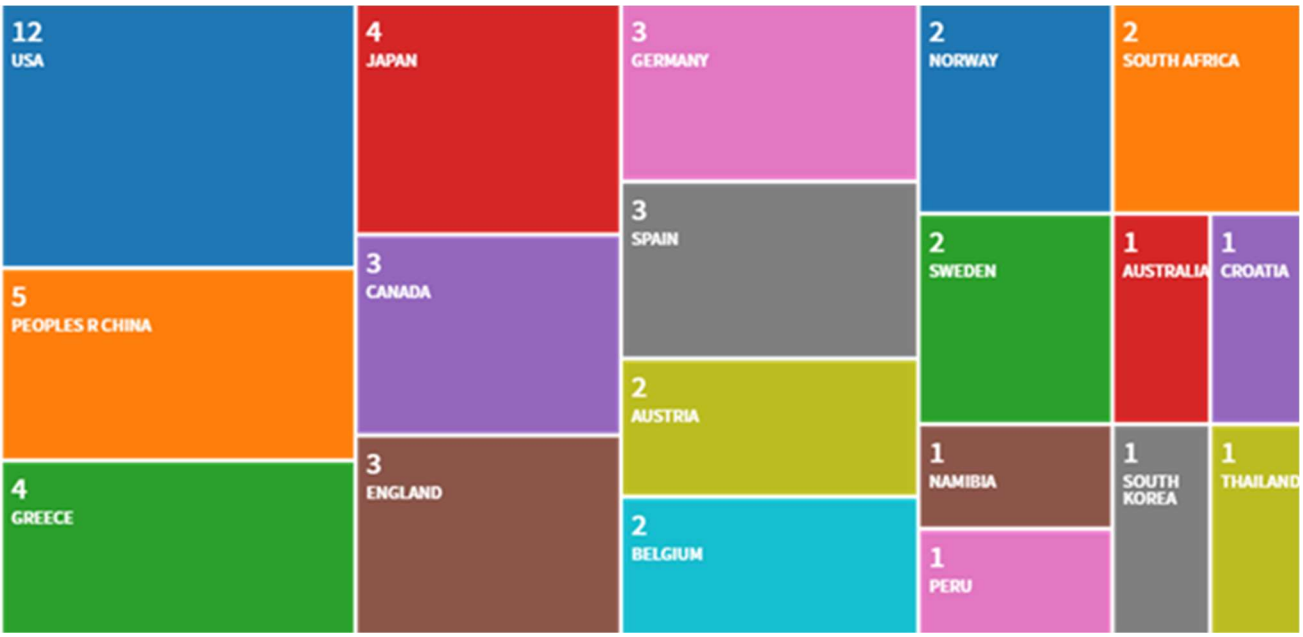

Figure 3 – Distribution of papers by countries from web of knowledge database search for scientific literature with "tangible programming" in its title (Search performed on 27 May 2018)

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Table 4 – Non-exhaustive list and evaluation of tangible programming tools available in the market.

Tangible Programming Resources					
Tangible programming tools & resources	**Website**	**100 % Tangible**	**Activities**	**User friendly**	**Age**
Cubetto	https://www.primotoys.com/	✓	✗	✓	**4-7**
Kibo	http://kinderlabrobotics.com/	✓	✗	✗	**5-8**
Roamer	http://www.roamer-educational-robot.com	✓	✗	✗	**6-10**
Bee Bot	http://www.tts-group.co.uk/beebot	✓	✓	✓	**4-7**
mi-go	http://www.migobot.com	✓	✓	✓	**5-12**
DOC	http://www.clementoni.com/en/61323-doc-interactive-talking-robot/	✓	✓	✓	**4-7**
Pip & Pixie	http://www.swallow.co.uk/pixie/pixie1.htm	✓	✗	✗	**6-8**
Plobot	http://plobot.com/	✓	✓	✓	**5-8**
Robopal	http://www.robopal.cc/index_en.php	✓	✗	✓	**6-10**
Cuboid	http://cubroid.com/	✗	✗	✓	**5-12**
Probot	https://www.bee-bot.us/probot.html	✓	✓	✓	**6-10**
Lego Mindstorms EV3	https://www.lego.com/en-us/mindstorms/learn-to-program	✗	✗	✗	**>12**
OSMO	https://www.playosmo.com/en/coding/	✗	✓	✓	**5-12**
Evolution	http://www.clementoni.com/en/61282-evolution-robot/	✗	✓	✗	**8-12**
Matatalab	https://www.matatalab.com/	✗	✓	✓	**4-9**

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3.1.3 Tangible Programming for inclusion

The goal for this project is not only to create a toolbox for tangible programming to be used in primary school education and in the context of a STEM-based curriculum, but designing and conceiving the activities in a way to promote students inclusion in the classroom. According to one online definition (http://www.inclusionbc.org/), *inclusive education is about how we develop and design our schools, classrooms, programs and activities so that all students learn and participate together despite any kind of diversity with respect to ability, language, culture, gender, age and of other forms of human differences*.

Do to the interactive and physical nature of tangible programming, where groups of children come together to solve problems, there is a great opportunity to shorten differences in terms of previous exposure and motivation between different backgrounds and groups of children. Teamwork and group discussions can take place and, differently of a classical computer interface, more than one student can be in control of the input which foster social negotiation and collaborative behaviors (Marshall, 2007; Horns ,2009; Speelpenning *et al.*, 2011; Resnick, 2013). Tangible manipulatives also provide easy entry-points for novice learners or students with learning disabilities (Vygotsky, 1978) or other special need to create positive experiences as with the proven impact with children with disorders in the (mild) spectrum of autism (Horn, 2008; Farr, 2009; Millen, 2011).

A tangible user interface can be equally attractive for boys and girls (Zuckerman and Gal-oz, 2013) while the stereotype and social stigma for STEM and programming in particular is still heavily associated to male subjects, and thus helping to narrow gender differences of interest in computing (McNerney, 2000). Beyond the tangible nature *per se*, and the learning benefits associated with sensory inputs already discussed, the intuitive nature of tangible programming units or blocks, normally associated with simple commands to be executed and easy to follow output and sequential steps (Figure 4), are crucial in the process of conceptualization and make abstraction simpler. The potential for gamification and goal-oriented activities with storytelling and character play (bees, aliens, cars, friendly robot, etc…) also contributes to foster positive experiences (Resnick, 2013), not only for a heterogeneous classroom but also for teachers from different backgrounds digital/tech exposure and expertise (Beers, 2008). Whatever new methods, models or tools are to be implemented in the public or private education system, teacher's adhesion and motivation will be determinant factor for its success. And to do so, it is essential that any toolbox, guides or activities to be created must have in mind not only the students but also the teachers, and make it simple and intuitive, engaging and fun even to the less technological savvy and the ones with a conservative mindset.

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Figure 4 – Children programming an on-screen submarine using the AlgoBlock system adapted from turtles to Tangible Programming Bricks: explorations in physical language design (McNerney, 2004)

3.1.4 Tangible Programming as a method for other STEM subjects

3.1.4.1 Tangible Programming within STEM or STEM within Tangible Programming?

Training pattern recognition, abstraction and spatial orientation, where we have to transpose an object reality to oneself (robots right or left might be different from ours) are important skills that can be used not only as introductory concepts to programming/coding, but also as a method of thinking and problem-solving to be applied virtually in any subject and level.

There is evidence of cognitive impact of tangible programming tools beyond the scope of programming, including basic number sense, language skills, and visual memory (Clements, 1999). Robotics can also be a gateway for children to learn about applied mathematical concepts, the scientific method of inquiry, and problem solving (Rogers & Portsmore, 2004). Research have also shown that introducing STEM in early childhood might help to avoid stereotypes later (Markert, 1996). Still, our understanding after the literature review is that the main focus on the tangible programming literature and programs is on the pre-school and elementary level and we might be leaving out plenty of uncharted lanes to be explored namely by using tangible programming in a transdisciplinary way especially when teaching STEM-based subjects and in older ages (10-12 years old). To the best of our knowledge and research there is no tangible programming program or activities designed for broader STEM-based subjects (not related with specific programming/coding) beyond some very simple numbers and letters games at the pre-school (elementary) level that could be integrated in the formal curriculum. The concept of loops is very powerful and, in our opinion, insufficiently exploited and combining sensors as logical operators (IFs and WHILEs), angles to smoothly introduce layers of complexity, and the ability to draw, there are plenty of opportunities to explore (Figure 5). The technology exists and it's a matter of creating the content that best suits the needs of both students and teachers (Table 5).

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Figure 5 – Frames from the explanatory TangIn video shown to questionnaire respondents, representing the blocks code for drawing an equilateral triangle connecting the partners countries using MI-GO - https://youtu.be/Blpqy8Ecfos

Table 5 – Capabilities and functions of tangible programming tools available in the market

Capabilities of the Available Tangible Programming Resources					
Tangible programming tools & resources	**Loops**	**Angles**	**Sensors**	**Drawing**	**Mathematical Operators**
Cubetto	✗	✗	✗	✗	✗
Kibo	✗	✗	✓	✗	✗
Roamer	✓	✓	✗	✗	✗
BeeBot	✗	✗	✗	✗	✗
mi-go	✓	✓	✓	✓	✗
DOC	✗	✗	✗	✗	✗
Pip & Pixie	✗	✗	✗	✗	✗
Plobot	✗	✗	✗	✓	✗
Robopal	✓	✗	✓	✗	✗
Cuboid	✓	✓	✗	✗	✓
Probot	✓	✓	✗	✓	✗
Lego Mindstorms EV3	✓	✓	✓	✗	✓
OSMO	✓	✗	✗	✗	✗
Evolution	✓	✓	✓	✗	✓
Matatalab	✓	✓	✗	✗	✗

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3.2 Subjects where Tangible Programming can be used

In this section the results of the research carried out in the school curricula of primary school level in the four countries and the analysis of the STEM contents that can be approached with the use of Tangible Programming are presented.

A lot of specific contents were investigated and evaluated in the different subjects that related to STEM topics, but to effectively build crossovers among the national curriculum and to avoid excessive complexity in the matrix, we present here only a part of them and summarize the content in simple and more generic subjects. For the same reasons that estimated number of hours that teachers shall dedicate to a specific topic (accordingly to the recommendations of the national curricula) are not presented in this analysis, to simplify the approach and also because it is not the aim of the project to focus on the time necessary to teach a given topic neither to harmonize those practices between European countries.

Hence, the following tables present common mathematics, science and engineering content in the curriculum (History itself is not included but historic events and figures relevant for the subject can be used in character play and flow of time activities) that were identified as having the potential to be taught by using tangible programming concepts and tools. In the column of each country a number appears that indicates in which school-year those contents are to be taught to students. It should be noted that some are addressed in more than a school year, although with different degrees of complexity.

Table 6 – Mathematics themes, contents and topics that can be taught using tangible programming

Subject: Mathematics						
Theme	Content	Specific topic	School year			
			Portugal	Spain	Bulgaria	Latvia
Algebra, Numbers and Measures	A series of numbers	Natural numbers	1-4	1-4	1-4	1-4
	Decimals	Decimals and determination and marking of parts.	3-4	3-4	3-4	1-3
	Measurement units	Mass, mass units	3-4	1-2	1-2	1-4
		Capacity, capacity units	3-4	1-2	3-4	1-4
		Length, length units	3-4	1-2	3-4	1-4
		Area, area units	3-4	1-2	3-4	1-4
	Properties of numbers and operations	Associative and distributive properties of multiplication	4-6	3-4	5-6	5-6
		Introduction to Functions	6	5-6	6	6

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Subject: Mathematics						
Theme	Content	Specific topic	School year			
			Portugal	Spain	Bulgaria	Latvia
Elements of geometry	Polygon, Triangle, Square etc.	Drawing, recognition.	1-4	1-2	1-2	1-4
	Lines	Straight, curved, broken, closed open lines – recognition, drawing	1-2	1-2	1-2	1-3
	Line, line segment, point	Drawing	1-2	3-4	1-2	.-4
	Angles	Drawing, recognition	3-4	3-4	3-4	1-4
	Perimeter of polygon	Measurement, calculation	1-2	1-2	3-4	1-4
	Circle	Radius, diameter, calculations	5-6	3-5	5-6	5-6
	Area	Drawing, measurement	3-4	3-4	3-4	4
	Trigonometry	Pythagoras theorem, estimating segments and angles with triangles and other polygons. Interior and external angles. Notion of sines and cosines	5-6	5-6	5-6	5-6
	Symmetry and perspectives	Isometries and planes of symmetry in geometrical 2D and 3D figures	5-6	5-6	5-6	5-6
Calculus	Operation members and result	Counters, sum Reducible, reducer, difference	1-4	1-4	1-4	1-4
		Multipliers, multiplication Divisible, divider, breakdown	2-4	2-4	3-4	1-4
	Sum, subtraction	Operations	1-4	1-4	1-4	1-4
	Multiplication, division	Multiplication table Operations, and division by using visual references	3-4	3-4	2-4	1-4
	Power	Operations with powers of 10	5-6	5-6	5-6	5-6
	Fractions	Operations with fractional numbers	5-6	5-6	5-6	5-6
	Areas	Estimating and solving problems of areas and lengths in regular and irregular shapes, in two dimensions	5-6	5-6	5-6	5-6

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Subject: Mathematics						
Theme	Content	Specific topic	School year			
			Portugal	Spain	Bulgaria	Latvia
	Volume	Estimating and solving problems of volumes in regular shapes in three dimensions	6	6	5-6	6
	Graphical representation	Understanding axis and points of reference. Representation of numbers and vectors (intro)	6	6	6	6

Table 7 – Science and Engineering themes, contents and topics that can be taught using tangible programming

Subject: Sciences and Engineering						
Theme	Content	Specific topic	School year			
			Portugal	Spain	Bulgaria	Latvia
Orientation: Space, Time	Day, night, time flow	Student knows how many days there are in one week and how many months in a year.	1	1	1-2	1-3
		Use calendar in daily tasks.	1	1	1	1-3
	Sky sides	Correct use of concepts: Sky sides, day, night, month, year. Names sky sides.	1-4	1-4	1-4	1-3
	Uniform movement (physics)	Concept of velocity, acceleration and trajectory. Time units and measurements and creating time tables	5-6	5-6	5-6	5-6
	Seasons	Angle and distance of earth to the sun, the notion of poles and the tilted axis of earth	6	6	6	6
	Geography	Maps, scale. Using compass and the cardinal points. Notion of the equator and intro to latitude and longitude	6	6	6	6
Biology	Human nature and physiology	Nutrition, growth, excretion, breathing, reproduction	1-4	1-4	1-4	1-4
		Digestive, Circulatory and respiratory system. Organs and Functions	3-6	3-6	3-6	3-6
	Plants and animals	Separate organisms by class and reign. Identify habitats and relate with food sources	3-6	3-6	3-6	3-6

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Subject: Sciences and Engineering						
Theme	Content	Specific topic	School year			
			Portugal	Spain	Bulgaria	Latvia
		Naming animals and plants	1-2	1-2	1-2	1-2
Nature & Environment	Water cycle	Resources, droughts, stages, sewage treatment, ways to save in consumption	2-5	2-5	3-4	1-6
	Energy and Light	Consumption, renewable energies, fossil fuels, ways to store and units. Concept of Heat and Light	3-6	3-6	3-6	3-6
	Planet Earth in the Solar system.	Movement of Earth Location of Earth in Solar system. Planets. Globe. Map. Land and water distribution on Earth. Continents.	3-4	3-4	3-4	2-3
	Natural Elements	Element States: liquid, gas solid. Periodic Table. Concept of water solution and dilution	3-6	3-6	3-6	3-6
Human Interaction	Living in society	Traffic signs and rules	1-3	1-3	1-3	1-3
		Cities *vs* villages	1-2	1-2	1-2	1-2
		Ways of communication: mail, phones, letters, news, papers… Wireless *vs* wired. Tangible *vs* digital	1-4	1-4	1-4	1-4
	Economy	Notion of commerce and money.	3-4	1-4	2-4	1-4
		Maritime, land and air shipping. Ports and airports. Time schedules and logistics	3-5	4-6	2-4	4-6
		Production from raw materials to manufacturing to distribution	1-4	1-4	1-4	1-4

Regarding **technological education** and considering that technology at primary school level is included in the curricula transversally, several options to create a common framework where tangible programming concepts and tools can be introduced to taught topics of technology, were analysed. It was decided to use as guiding document the Portuguese project for teaching Programming and Robotics in primary education: "Probótica – Programação e Robótica no Ensino Básico – Linhas orientadoras" (Programming and Robotics in Basic Education - Guidelines) (Pedro, Matos, Piedade

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and Dorotea, 2017), published by the Directorate General for Education of the Portuguese government[3]. This document includes different areas such as Digital Literacy, Computational Thinking, Algorithm, Programming and Robotics, which are specified below, and aims to contribute to the development of student's reference skills and competencies for the 21st century, by proposing specific contents to be included across the school curriculum.

The concept of skills of the 21st century is associated with the need and the demands of today's and future society, where problem solving, decision-making, teamwork, ethical sense, project management and use of digital technologies are considered to be core competencies. This is totally aligned with the TangIn project objectives as tangible programming also aims to stimulate the development of such skills, besides generate interest for programming.

The framework proposed is based in learning objectives for students and does not establish a specific school year where such objectives shall be achieved. The table below summarizes the key objectives of the framework.

Table 8 – Technology themes, contents and topics that can be taught using tangible programming

<table>
<tr><th colspan="2">Subject: Technology</th></tr>
<tr><th colspan="2">Digital Literacy</th></tr>
<tr><td colspan="2">• To use technology in a safe, respectful and responsible manner, keeping the private personal information;
• To know how to protect your identity and how to maintain your identity online privacy;
• To understand how changes in technology affect safety;
• To use technology purposefully to create, organize, store, manipulate and retrieve digital information;
• To assess the truthfulness of the information surveyed and the reliability of its sources;
• To understand the opportunities offered by the Internet to communicate, collaborate and share information;
• To demonstrate appropriate behaviours in online collaboration and communication;
• To respect copyright in the use of materials other than your own authorship;
• To identify how digital technologies influence everyday relationship with others.</td></tr>
<tr><th>Topic Computational Thinking</th><th>Algorithm</th></tr>
<tr><td>• To understand the dimensions involved in computational thinking;
• To identify problem-solving strategies (reduction of complexity, decomposition, abstraction, adaptation or adoption of models and known algorithms, data collection and analysis, etc.);
• To problematize everyday situations and formulate problems;
• To symbolically describe and represent sequences of activities different degrees of complexity;
• To solve problems by their decomposition into smaller parts, for similarity or reduction of complexity.</td><td>• To understand what algorithms are, how they work, and their practical application;
• To symbolically describe and represent sequences of activities everyday life;
• To recognize the importance of algorithm design as a method of troubleshooting;
• To solve problems by decomposing them into smaller parts;
• To understand that different algorithms can achieve the same result and that the same algorithm can be reused in different situations;
• To recognize that some algorithms are more appropriate for a context than others;
• To reuse the same algorithm in different situations.</td></tr>
</table>

[3] More information is available here: http://erte.dge.mec.pt/noticias/programacao-e-robotica-no-ensino-basico-probotica

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Subject: Technology	
Programming	**Robotics**
• To understand and apply the fundamental principles and concepts of programming (logic, data types, variables, conditional structures and repetitive, among others); • To analyse programs, identifying their results, errors and their correction; • To optimize the programming of the solution found for a given problem; • To design programs with varying degrees of complexity in specific problems; • To create programs to solve problems, animate stories or games using a textual programming language or programming environment by blocks.	• To understand what Tangible Objects are supposed to do; • To characterize robots, drones, and physical computing; • To distinguish Tangible Objects in its characteristics, functionalities, and applicability; • To adapt actuators and sensors to solve specific situations; • To program Tangible Objects that use actuators and sensors to interact with the environment in which they are integrated; • To manipulate input and output data; • To tailor the Tangible Objects structure to specific contexts; • To create Tangible Objects that interact with the physical world; • To program Tangible Objects to solve simple challenges and complex challenges; • To detect and correct programming errors and inadequate physical structures specific situations

Complementarily with the three key-study areas above (Mathematics, Sciences and Technology), and in order to strengthen the STEM approach by promoting inclusion and promotion of holistic student knowledge, the desk research was also extended to the area of **sustainability**. As such a research was done on the United Nations "Sustainable Development Goals" agenda[4], that includes a set of 17 goals focusing in the sustainable development of individuals, society and our planet. Some of these goals are very related to the horizontal objectives of the TangIn project and so will be included in the framework of the development of the project resources.

[4] United Nations Sustainable Development Goals (Source: https://sustainabledevelopment.un.org/?menu=1300)

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Figure 6 – United Nations Sustainable Development Goals.

From the list of Sustainable Development Goals, the following were considered as very relevant for the project ambitions and objectives, and will be taken into consideration in the upcoming project activities:

Ensure inclusive and quality education for all and promote lifelong learning	Achieve gender equality and empower all women and girls	Reduce inequality within and among countries	Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss

Figure 7 – Sustainable development goals that are most applicable to the TangIn project

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4 Questionnaires

In this section, the results collected through the questionnaires distributed to teachers, educators, and specialists in Portugal, Spain, Bulgaria, and Latvia are presented and interpreted. The objective of the consortium un using this questionnaire was to access the knowledge and perceptions of European teachers on the usage of Tangible Programming concepts and tools to teach STEM related contents at primary school level.

4.1 Sociodemographic characteristics

In this section a brief sociodemographic characterization of the respondents is analysed: geographical distribution, age and teaching experience, gender and subjects thought.

4.1.1 Respondents geographical distribution

The total amount of valid answers to the questionnaire was 157 and were distributed across the countries where the partners of the TangIn consortium are based: Bulgaria, Latvia, Spain and Portugal. Most of the respondents are from Portugal (70) due to the fact that the majority of the partners are based in Portugal.

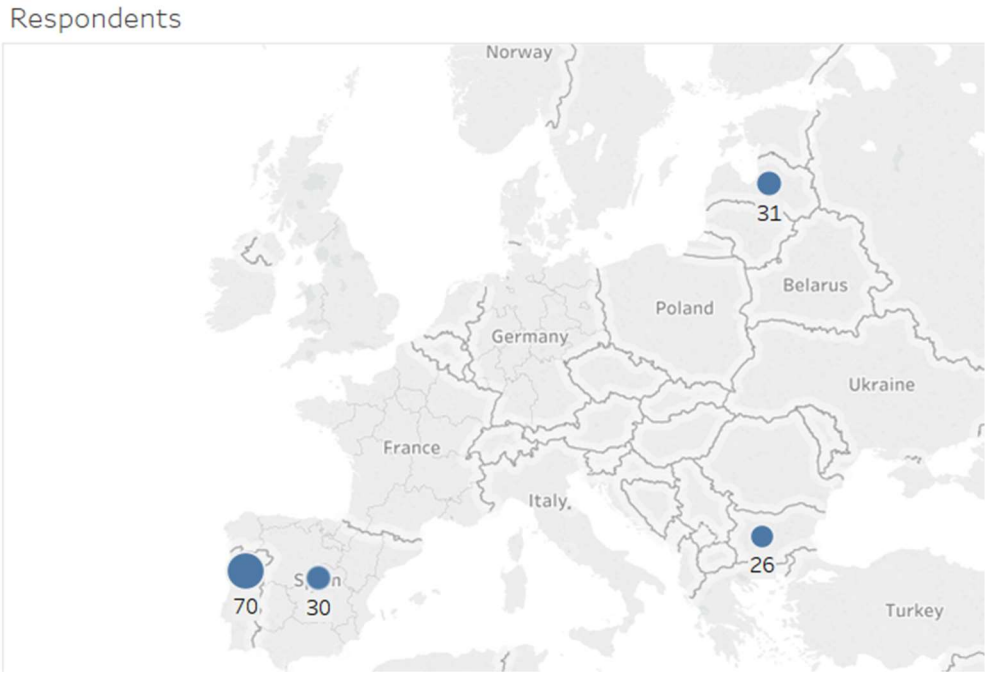

Figure 8 - Number of respondents per country. Bulgaria, Latvia, Portugal and Spain.

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4.1.2 Respondents age and teaching experience

Most of the teachers in Latvia (48%), Portugal (49%) and Spain (60%) are aged between 31 and 45 years old. In Bulgaria, most teachers are aged 45 years old or more. Spain is the country where the average age of teachers is more distributed, accounting with teachers with more than 45 years old (23%) and teachers with less than 30 years old (17%),

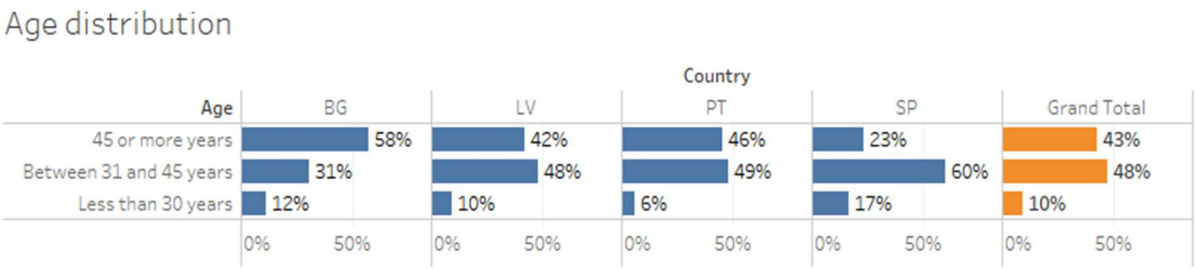

Chart 3 – Age distribution of the teachers per country

Globally the age distribution shows that 48% of teachers are aged between 31 and 45 years old, 43% are older than 45 and only 10% younger than 30 years old.

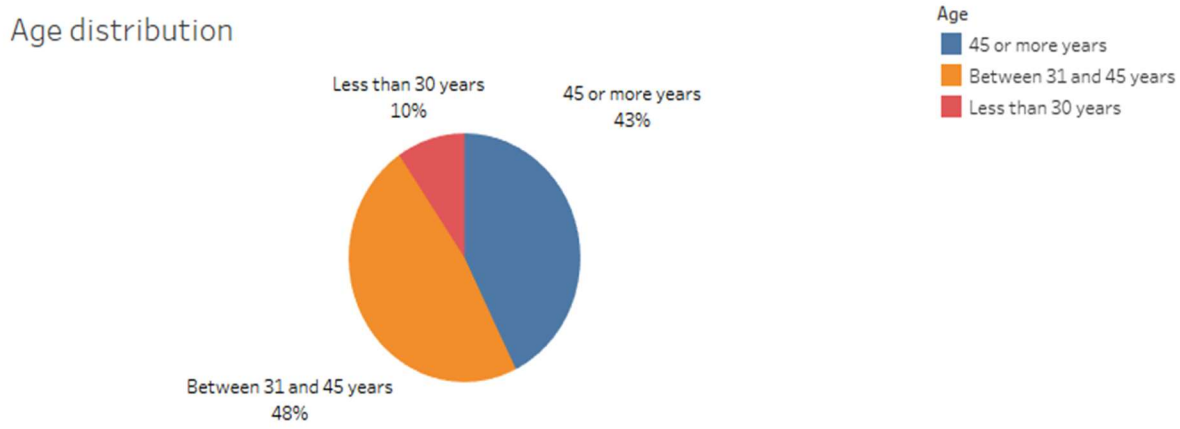

Chart 4 – Global age distribution of the respondents.

As for the teaching experience, apart from Spanish teachers, most teachers that have responded to the questionnaire have more than 15 years of experience. In Spain, many respondents have between 5 and 15 years of experience.

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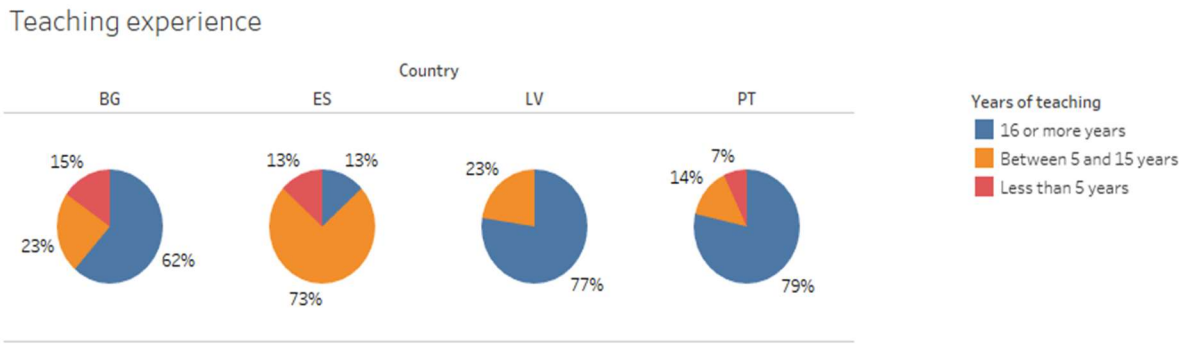

Chart 5 – Teaching experience distribution per country.

Globally, respondents teaching experience across all the four countries shows a clear majority of teachers with a teaching experience higher than 15 years (63%), followed by 29% of teachers with a teaching experience between 5 and 15 years. Only 8% of the teachers have less than 5 years of teaching experience.

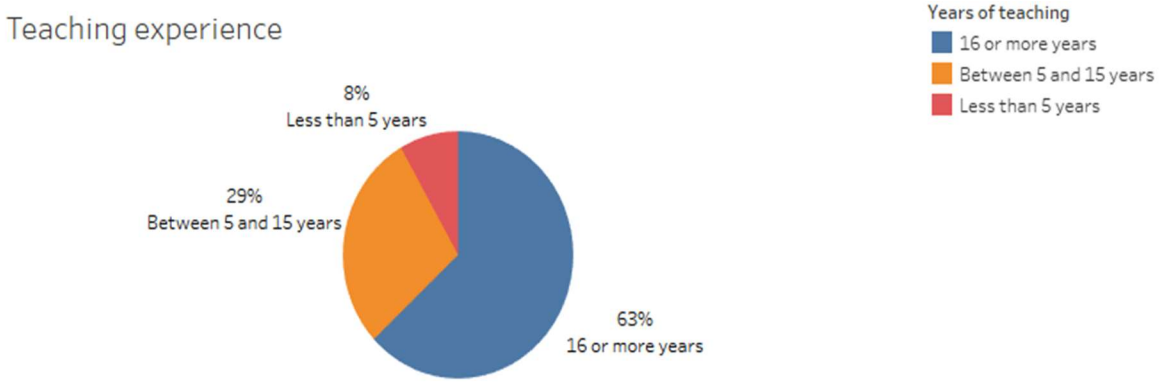

Chart 6 – Overall teaching experience distribution.

4.1.3 Gender distribution

In all the countries of the study, the majority of the teachers are of female gender. The extreme case is Bulgaria, where the totality of respondents was female. On the other end of the spectrum is Spain, with 30% of male teachers among the respondents to the questionnaire. Portugal (27% male teachers) has a gender distribution similar to Spain and Latvia has a distribution similar to Bulgaria, with the male teachers (3% male teachers) being a clear minority.

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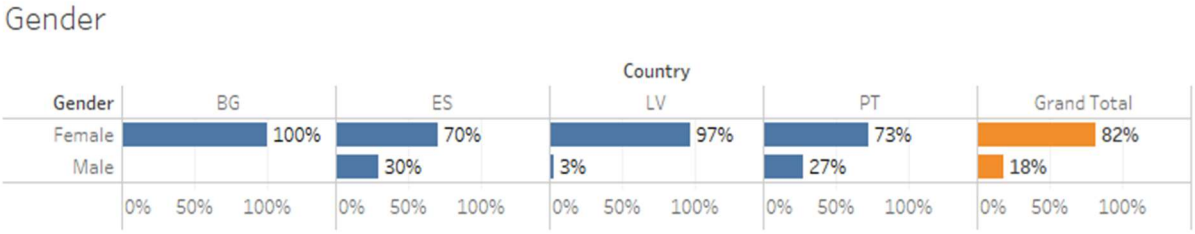

Chart 7 – Gender distribution per country.

4.1.4 Subjects taught

The main subject taught by the respondents is Basic Education (43%). A large percentage of the respondents (27%) answered "Other" as the subject they taught. Mother Tongue (22%) and Mathematics (21%) were the two following subjects that had the most answers by the respondents.

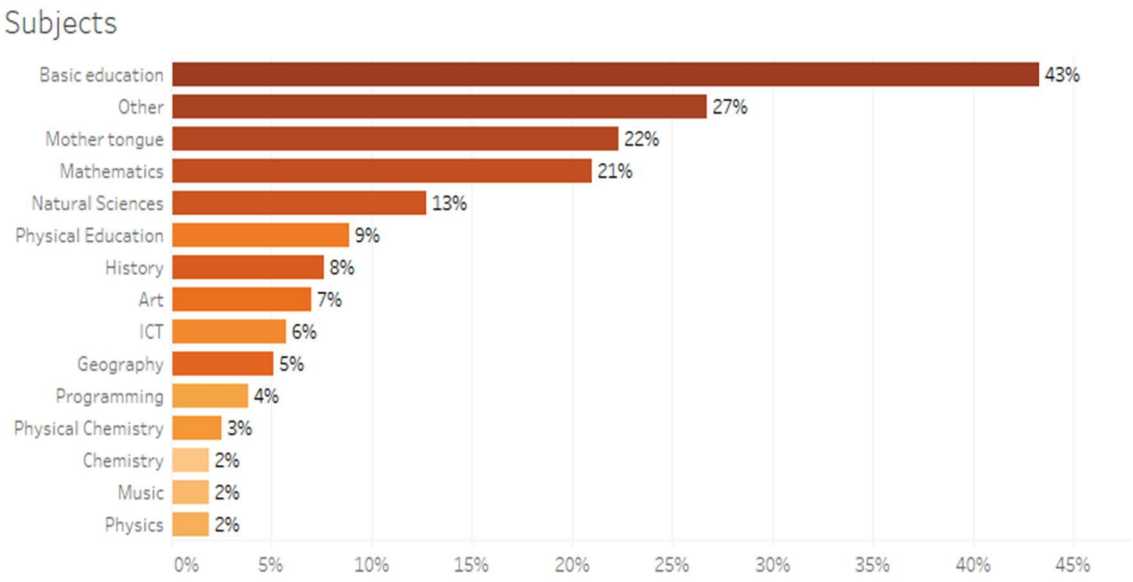

Chart 8 – Distribution of the subjects taught by the respondents.

Since "Basic Education" is a relatively broad concept, a further analysis is shown below. Considering only the teachers that have answered "Basic Education", 35% of them also answered at least one other subject and 65% answered "Basic Education" exclusively. Of the teachers that have answered "Basic Education", 22% also answered "Mathematics followed by 18% that answered also "Mother Tongue".

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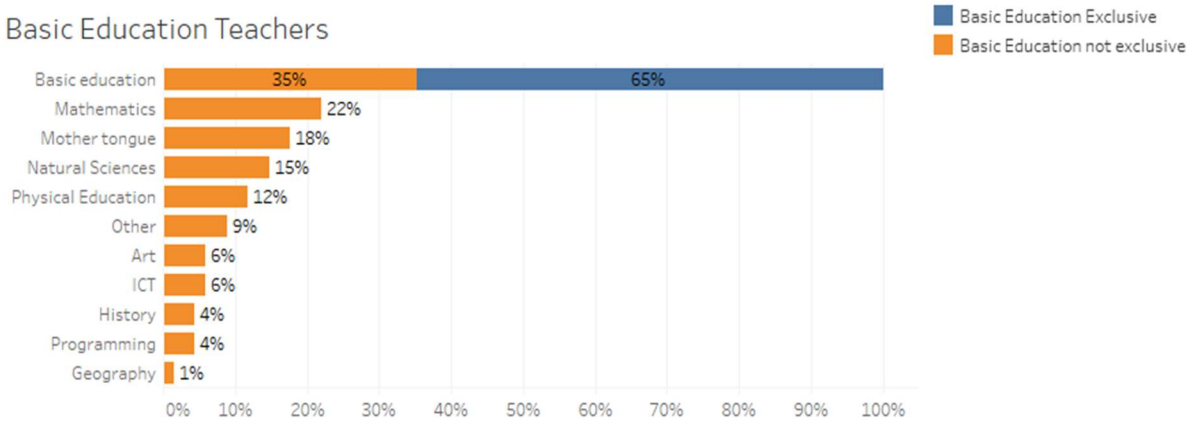

Chart 9 – Subjects taught by the basic education teachers. 35% of the teachers that answered Basic Education" also answered that they taught at least one other subject. 65% of the teachers that answered "Basic Education" selected this option exclusively.

4.2 Use of technology in the Classroom

Practically, all the teachers participating in the questionnaire uses a computer (97%) in their daily life and, although not as popular, other devices as well such as the smartphones (68%) and tablets (50%). E-mail (92%) is the main ICT/technological-based service used by respondents in their daily life, followed by social networks (65%) and Skype (27%). Only 10% use their devices for other purposes.

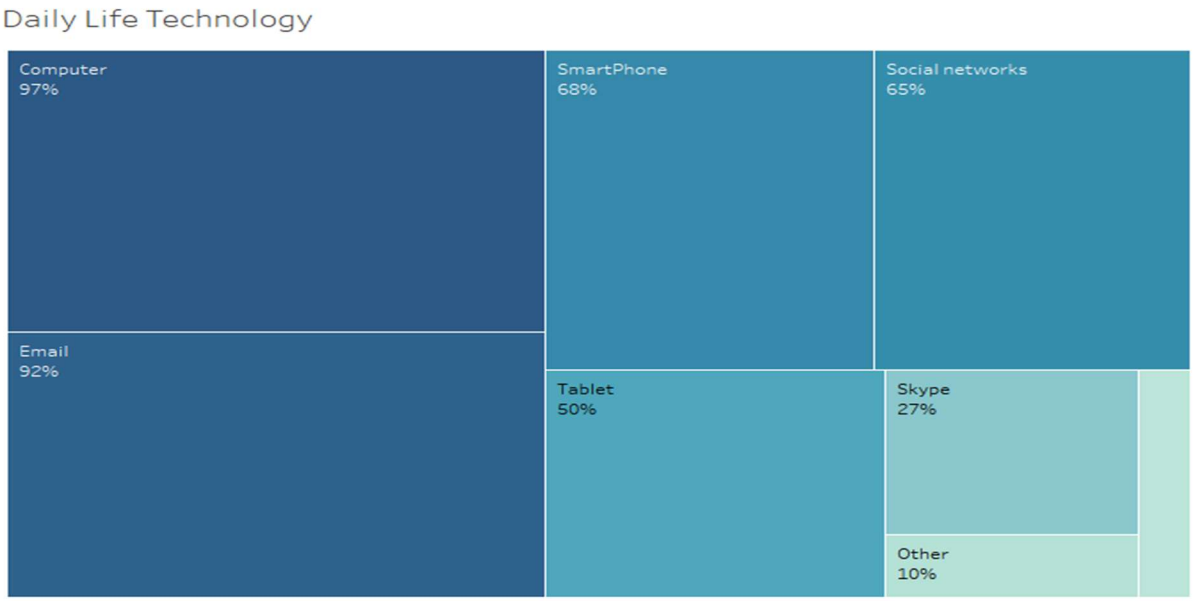

Chart 10 – Technologies used by the teachers in their daily life.

At least one technological-based equipment is available in almost every school of the participating countries in this study. 94% of the teachers answered that a computer was available for their use, however, 26% of the respondents had a computer available for every 2 students. Additionally, 83% of the respondents have a multimedia projector in their classroom and 79% have access to the internet.

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Other technologies are also available in schools such as 3D printers (15%), tablets (10%) and robots (5%).

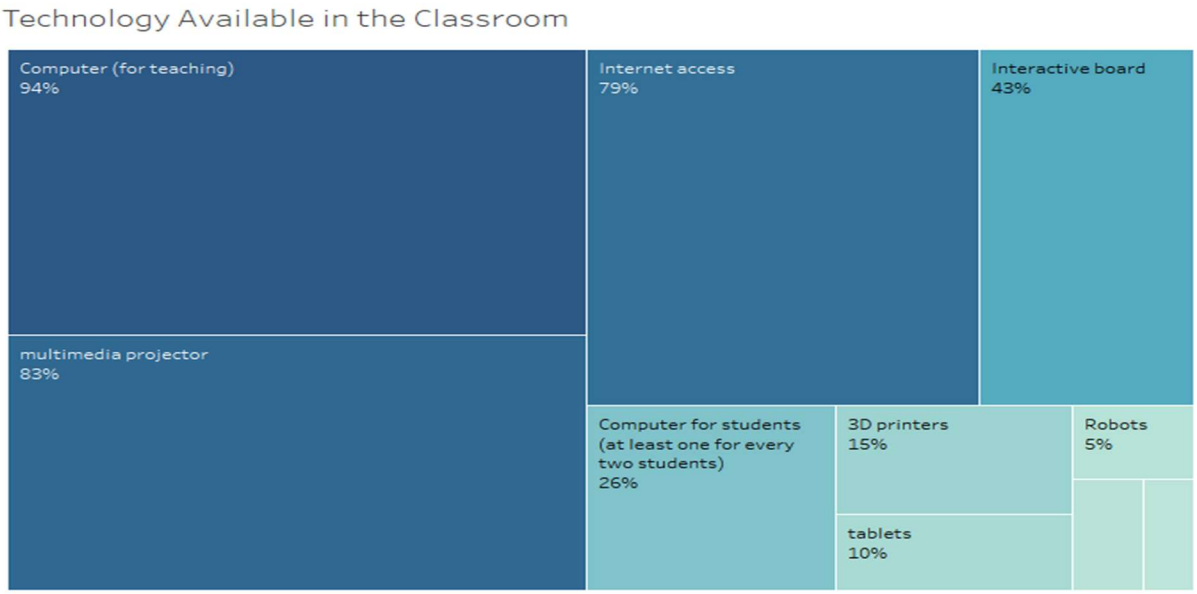

Chart 11 – Technologies available in the classroom.

Considering the relation between technology available in schools and technology effectively used by teachers, most of the responding teachers uses the equipment that is made available for them. The exception seems to be the interactive boards, which are available for 43% of the teachers but only 29% of them effectively uses them and 3D printers, which are available for 15% of the teachers but only a residual percentage uses them.

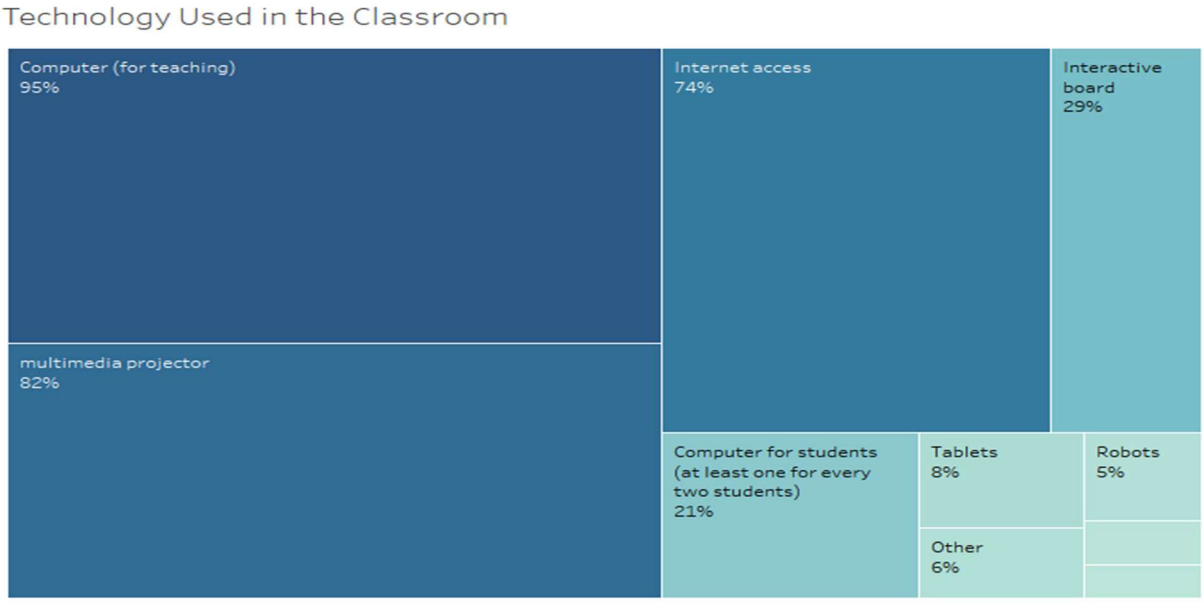

Chart 12 – Technologies used in the classroom.

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4.3 Programming and Logical Thinking Skills in the Classroom

In this section the importance of programming and logical thinking concepts its application in classroom is analysed.

4.3.1 Introducing programming and logical thinking concepts

When the respondents were asked how they felt about the importance of young children developing programming skills, the clear majority answered that it was "Important" (53%), "Very Important" (19%) or "Critical" (25%). Only 3% of the participating teachers have answered that developing students programming skills were "Not Important" for young children.

When it comes to the importance of developing logical thinking skills, the percentage of teachers that have answered that logical thinking skills were "Not Important" dropped to 1%, and the percentage of respondents that believe that logical thinking skills were critical increased to 41% when compared to the importance of developing programming skills. It is thus clear that the teachers involved in this study find relevant to teach programming and logical concepts and skills to young children.

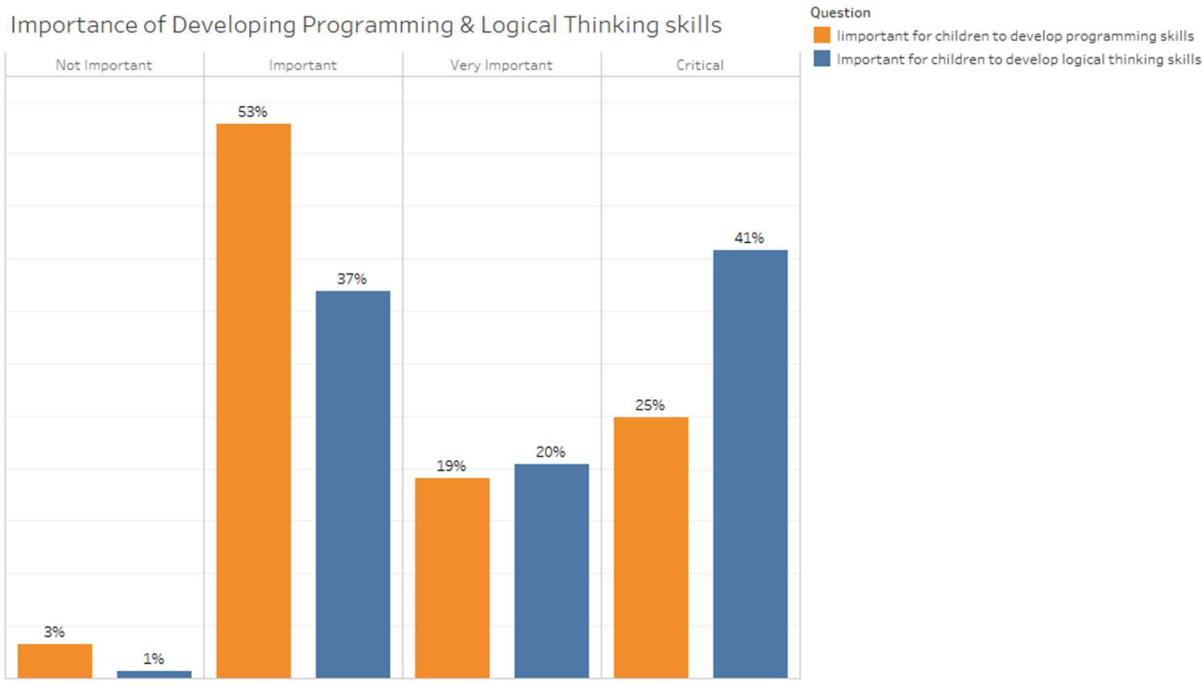

Chart 13 – Importance of children developing programming and logical thinking skills.

According to the teachers responding to the questionnaire, the ideal moment for introducing programming and logical concepts is similar. Approximately half of the respondents believes that the ideal school level for introducing programming and logical thinking concepts is during "Primary School". However, more than a quarter of the respondents believe that it should be included only at elementary school level (lower secondary school level), and between 15% and 21% of the respondents

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in the different countries, have the perception that those concepts could be introduced at pre-school level.

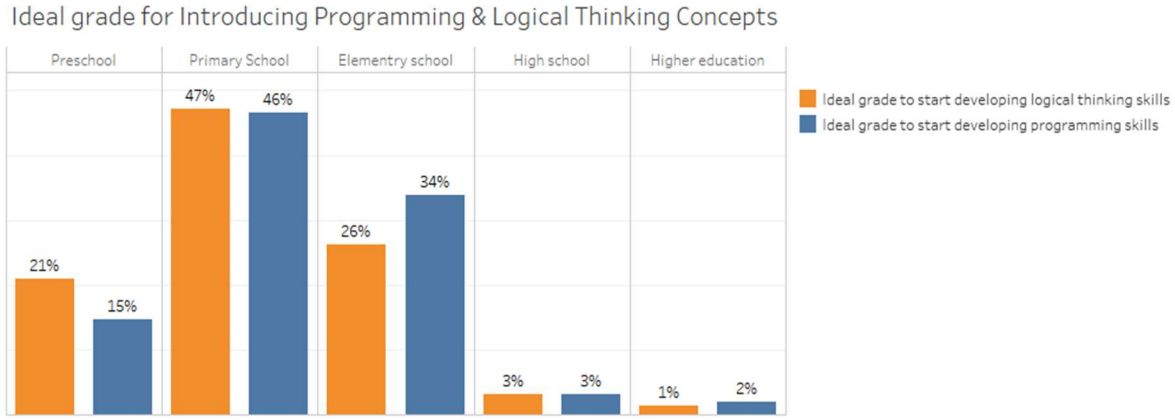

Chart 14 – Ideal grade for introducing programming and logical thinking concepts.

4.3.2 Tools for introducing programming concepts

When asked about theirs and their students' preference between using digital media, such as a PC/Tablet, or tangible programming resources, to introduce tangible programming concepts in the classroom, the respondents answered that 58% of the students would prefer to use tangible programming resources over PC/Tablet and 57% of the teachers showed the same preference.

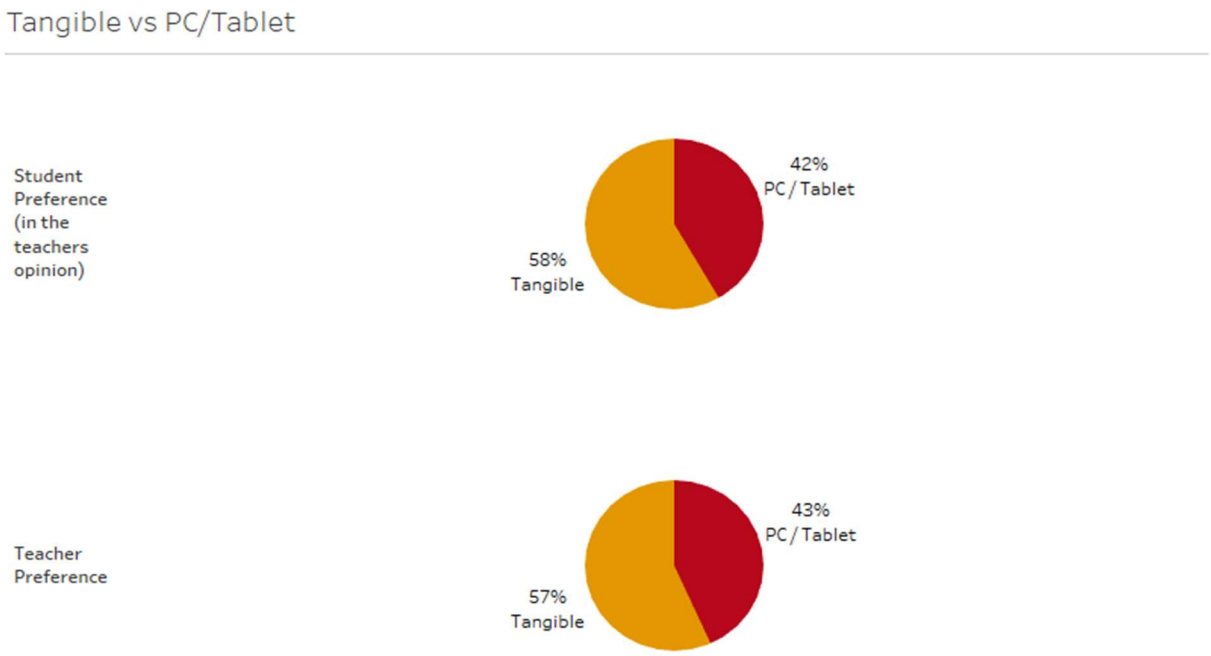

Chart 15 – Preference of the type of resources used for introducing programming concepts. Student preference (in the teachers' opinion) and teacher preference.

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As for the respondents' awareness of tools available for teaching programming, 57% of the responding teachers answered that they are not aware of any of the tool that were presented to them. From the known tools, Scratch and Lego were the ones that gathered the highest awareness level from the respondents, with 25% and 21%, respectively.

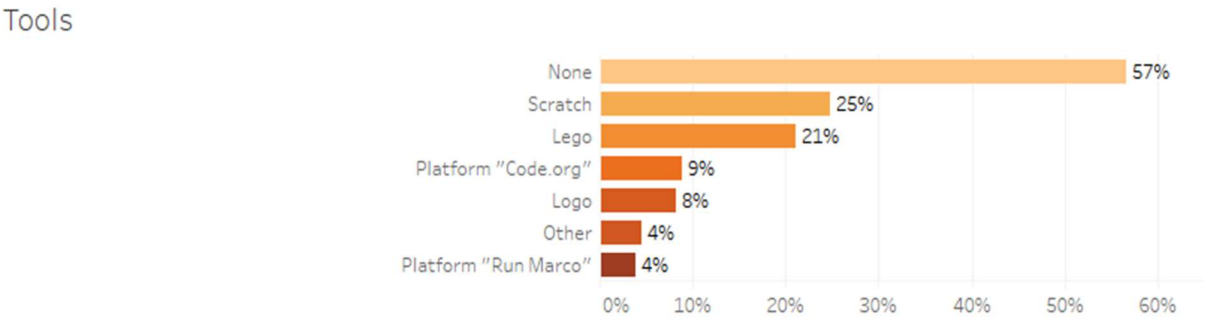

Chart 16 – Tools known by respondents which are used for teaching programming.

4.3.3 Experience in teaching programming

Even if excited and motivated with the idea of using tangible programming tools and concepts, when asked about their experience in teaching programming in the classrooms, 89% of the respondents affirm that they do not have any experience in teaching programming

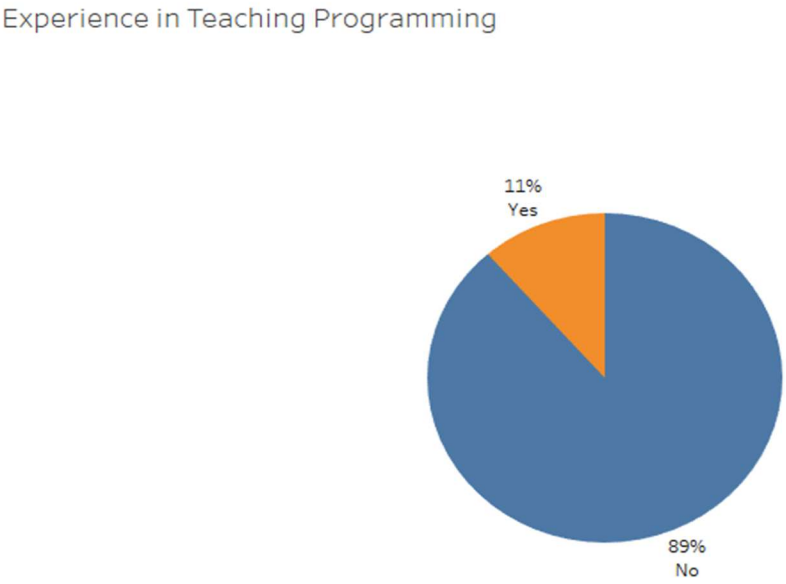

Chart 17 – Teachers that have previous experience in teaching programming.

Among the reasons pointed out by respondents for not teaching programming in their classrooms, the main reason (38%) is because they feel they don't have the necessary skills to teach programming, Interestingly, 28% of the respondents answered that the main reason is because they have never

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thought about teaching programming, while 25% of them stated that they have never had the opportunity.

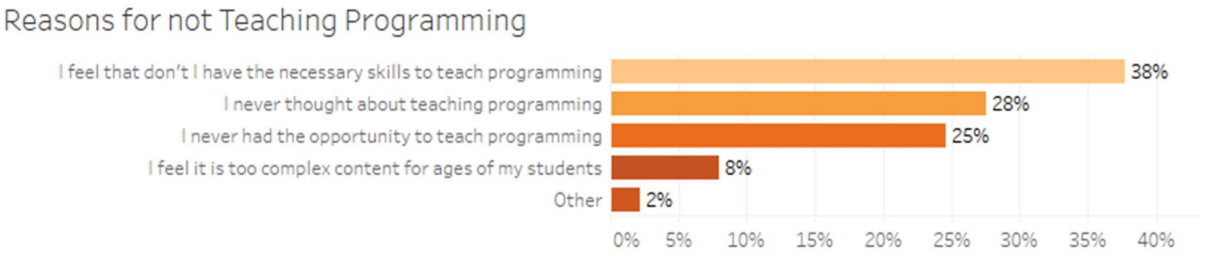

Chart 18 – Reasons for not including programming in their classes.

4.4 Tangible Programming in the Classroom

In this section the aspects related with the application of tangible programming in the classroom are analysed.

4.4.1 Awareness about tangible programming and interest in using the concepts

When asked if the teachers were familiar with the tangible programming concept, 68% of the respondents answered that they weren't.

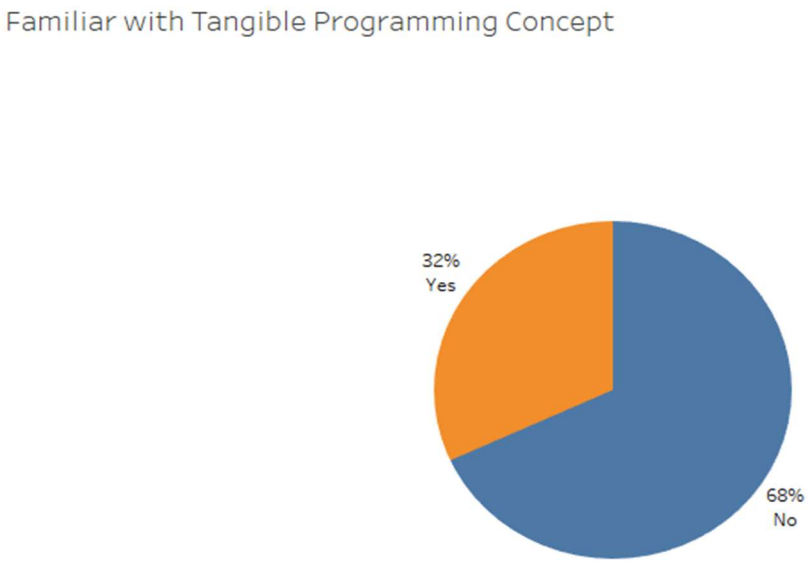

Chart 19 – Teachers that were familiar with the tangible programming concept before answering the questionnaire.

Nonetheless, 84% of the respondents said that if they had the opportunity, they would like to attend a training course about the educational use of Tangible Programming concepts and resources in order to use them in the classroom. Other 16% of the respondents who answered that wouldn't be

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interested in participating in a course justified that it was because they were finishing their careers or that they don't see how tangible programming could be applied to the subject they teach but mostly because they say they have no free time at the moment.

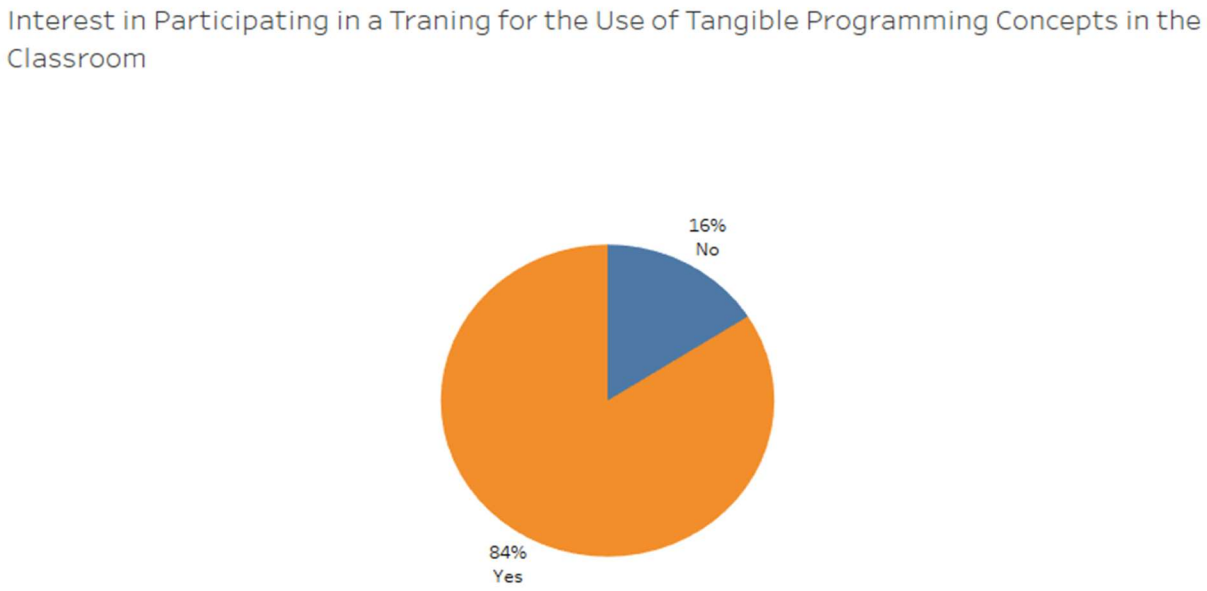

Chart 20 – Teachers with interest in participating in a training course for the use of tangible programming concepts in the classroom.

On top of this, and remarkably, 93% of the teachers answered that if they had a kit (pedagogical guidelines and learning materials and resources) available, they would use it with in classrooms.

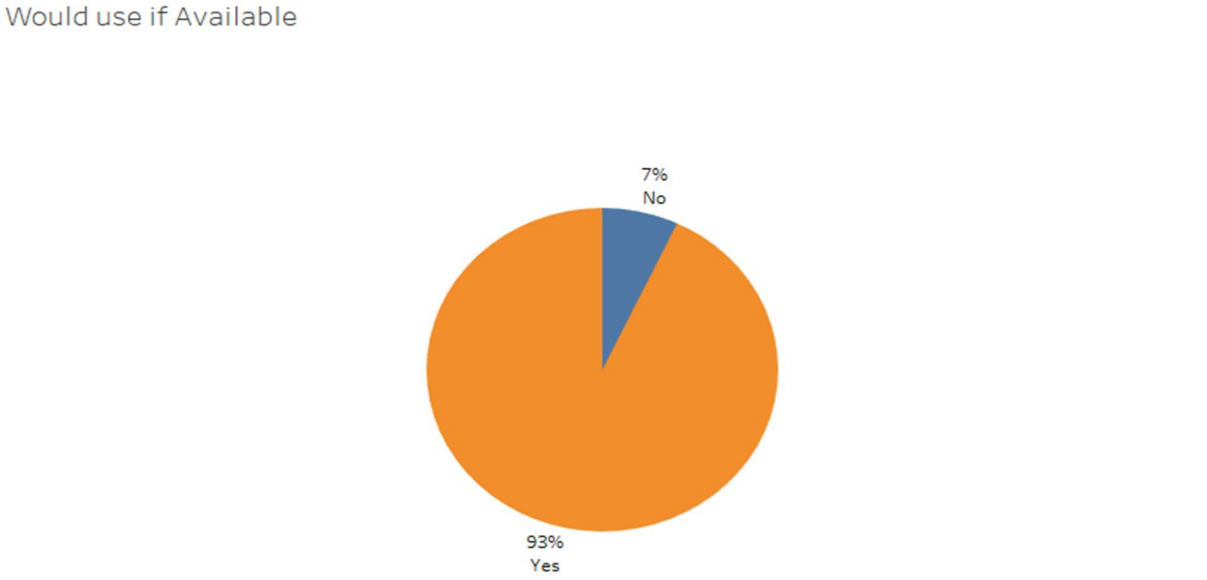

Chart 21 – Teachers that would use tangible programming resources if they were made available for them.

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The interest in the tangible programming concept is also noticeable by the usage that the respondents reported they would give to the resources if they were made available. 13% answered they would use them twice a week in the classroom, 31% would use them once a week and 19% once every two weeks.

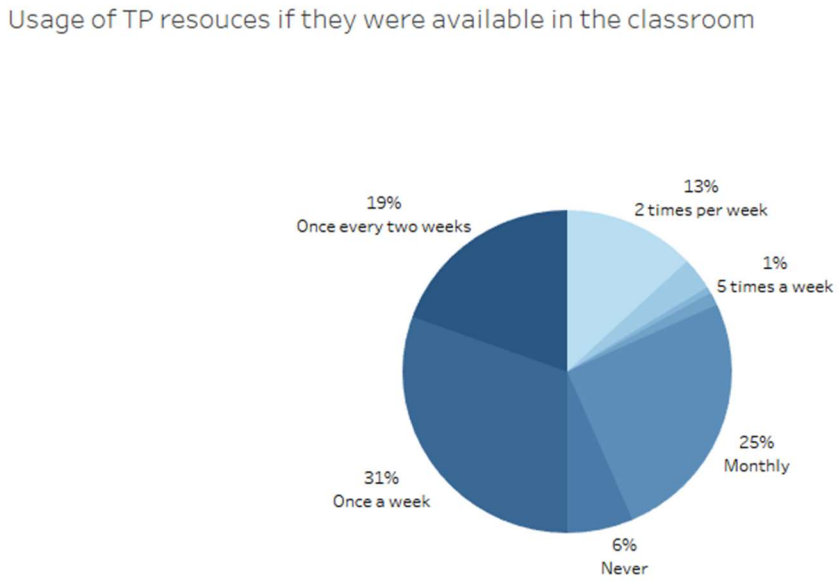

Chart 22 – Frequency of use of tangible programming resources if they were made available to the teachers.

4.4.2 When, where and how to introduce the tangible programming resources

The respondents' perceptions about the ideal students age for introducing tangible programming concepts is relatively scattered between the early years (5 years or before) and 10 years old. It is clear, however, that they should be introduced during the first 10 years of the child's life, as only 18% of the respondents affirm that tangible programming should be introduced only after the 11 years of age.

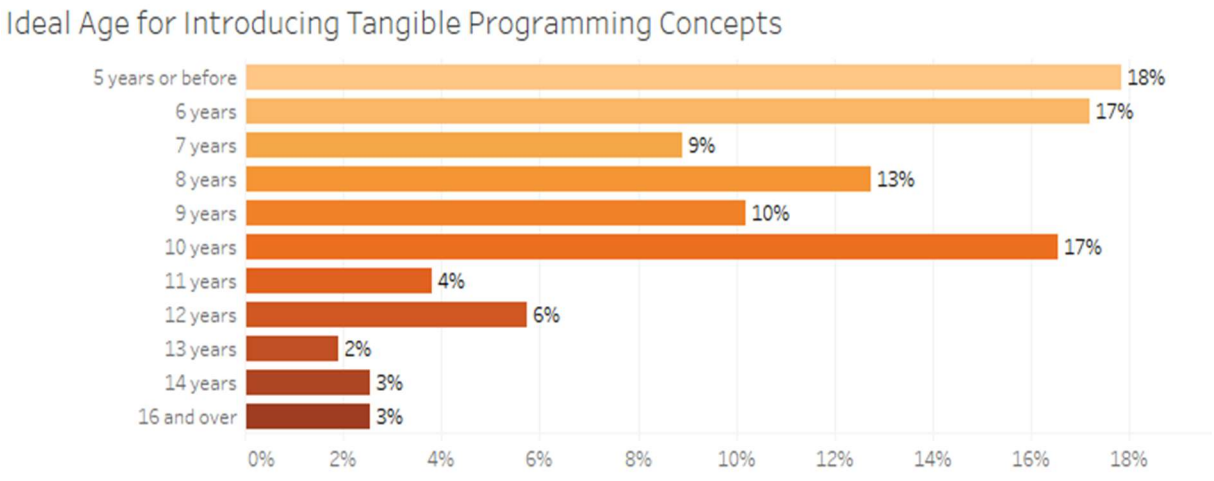

Chart 23 – Ideal age for introducing tangible programming concepts (the when).

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In the respondent's perception, the applicability of tangible programming concepts is strongly related with STEM subjects such as mathematics (72%), ICT (62%), programming (61%), natural sciences (49%), but also with subjects such as mother tongue (21%), music (16%) and arts (15%).

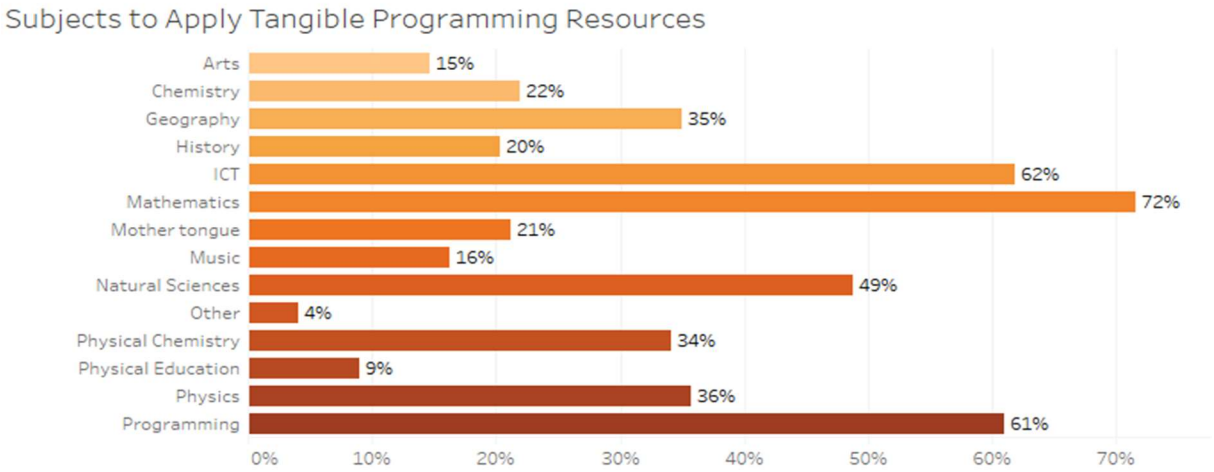

Chart 24 – Subjects where tangible programming concepts could be applied to enhance the learning experience of the students (the where).

As for the context where tangible programming resources would be used, 55% of the respondents answered that the ideal setting would be formal education in the classroom, whereas 42% of the participants answered that it would be best suited for some sort of informal education.

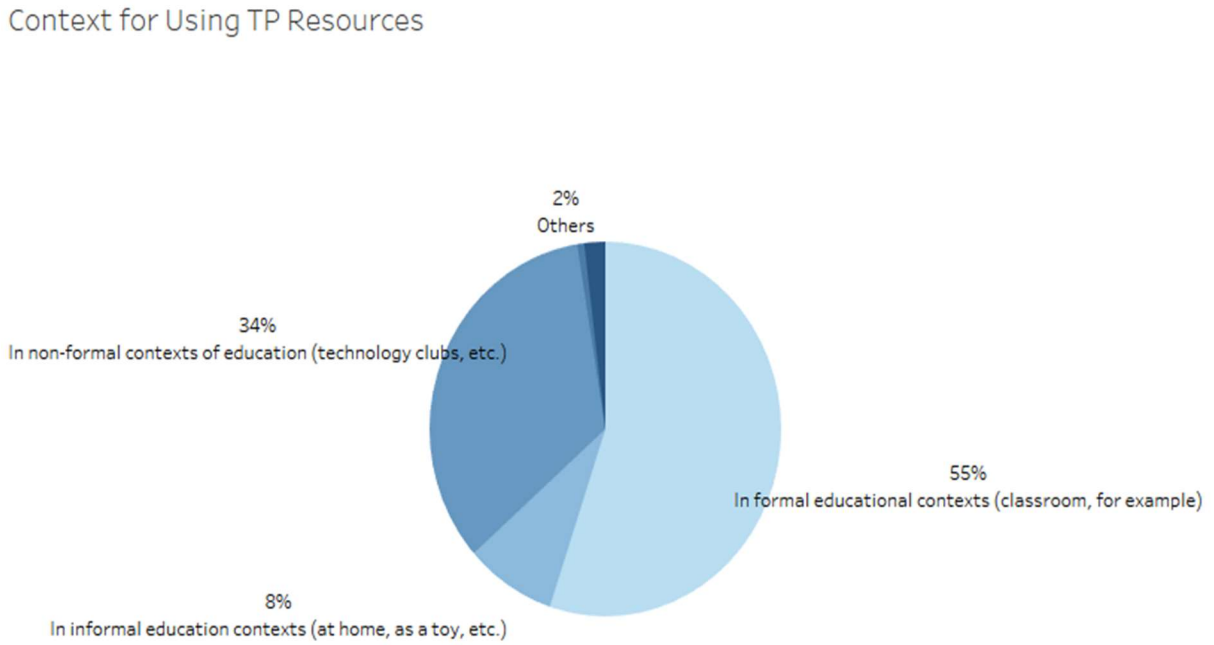

Chart 25 – Context where tangible programming resources would ideally be used.

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5 Focus Group

To have further input from the teachers regarding the use of tangible programming concepts and tools in the classroom to promote inclusion and STEM-based subjects, four Focus Group editions were carried out in each of the participating countries (Portugal, Spain, Latvia and Bulgaria). The key objective was to explore in detail some aspects related to the questionnaire findings, namely the ones related to the effective use of tangible programming concepts and tools to teach STEM-based contents in primary school level while fostering students' motivation and inclusion.

The Focus Group sessions were structured in 3 moments:

- ⇒ Moment 1 - Project and concept presentation
- ⇒ Moment 2 - Discussion about tangible programming in educational contexts
- ⇒ Moment 3 - Discussion about the TangIn outputs

5.1 Moment 1 – Project and concept presentation

The concept of tangible programming and the objectives of the TangIn project were presented to the participants. To help the participants have a clearer understating two short movies were presented (https://www.youtube.com/watch?v=BIpqy8Ecfos; https://www.youtube.com/watch?v=sd_9KiM0cwk).

Like previously observed in the questionnaire, most of participants of the focus group were not aware of what tangible programming was. Additionally, the Bulgarian focus group mentioned that the videos were viewed by 2nd graders and the students' feedback was very positive.

Table 9 – Summary of focus group moment 1 – Project and concept presentation.

Moment 1 - Project and Concept Presentation				
	Bulgaria	**Portugal**	**Spain**	**Latvia**
Comments	The videos were shown to one of the classes 2nd grade and the students' reaction was very positive. None of the teachers were aware about tangible programming and had never used any type of programming as a support in their classes. Only the youngest teacher had a beginner programming course in University. The oldest one was sceptic about her possibilities in using tangible programming in her classes.	Before the focus group session, the teachers involved were not aware of what tangible programming was and had no experience in teaching programming or using programming and robots to teach other curriculum contents.	The project was contextualized, and tangible programming concept is explained through a video and a PowerPoint presentation.	Involved teachers, except one of them, were not aware what tangible programming is and have never been teaching anything related to programming.

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5.2 Moment 2 – Discussion about tangible programming in educational contexts.

Moment 2 was dedicated to discussing about how tangible programming resourced could be used in an educational context. In Table 10 a summary of the focus group discussion on moment 2 is presented.

It was consensual amongst all focus groups participants that the most suitable subjects where tangible programming concepts could be applied were Mathematics and Natural Sciences. This is in agreement with the questionnaire findings where respondents were of the same opinion. Excluding Programming and ICT, Mathematics (72%) and Natural Sciences (49%) were the subjects where most respondents though tangible programming was most suitable.

As for the context where tangible programming concepts and tools could be applied, the participants from Bulgaria and Portugal mentioned that the best option would be in non-formal context such as extracurricular activities. The questionnaire respondents felt that the best context for using the tangible programming would be in the classroom (55%) followed by those who though that the best option would be a non-formal context (34%).

Teachers agreed that using tangible programming resources was an effective way to promote inclusion, motivate the students for STEM-based subjects and foster interdisciplinary, which are the main goals of the TangIn project. However, teachers expressed some concerns as well, including the lack of training (teachers training) and difficulty in adapting some tools to more complex topics. Some of them also mentioned that it's difficult to introduce new methodologies into the classroom due to the excessive workload.

As way to further motivate the students and teachers, the Bulgarian participants suggested that an interclass competition could be organized.

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Table 10 – Summary of focus group moment 2 – Discussion about tangible programming in educational contexts.

Moment 2 - Discussion About Tangible Programming in Educational Contexts				
	Bulgaria	**Portugal**	**Spain**	**Latvia**
Suitable subjects	Maths & Natural Sciences Good way to start programming	STEM, mainly maths. Natural Sciences Difficult for 5th and 6th grade	Math natural science and language	Maths & Natural Sciences.
Context	Extracurricular activity	Non-formal 1st and 2nd cycle	First years of education. Starting at 3 years old	-
Benefits	Inclusion. Motivate students. Improve logical thinking skills.	Motivate students in STEM subjects. Promote storytelling. Inclusion. Interdisciplinary	Creativity. Interdisciplinary	Improve logical thinking and communication skills. Inclusion. Interdisciplinary
Concerns	Lack of knowledge of the teachers. Difficult to adapt to more complex topics	Difficult to introduce new methodologies into the classroom	Students would be bored if used in excess	Lack of knowledge of the teachers. Difficult to adapt to more complex topics of maths
Suggestions	Inter class competitions			

5.3 Moment 3 – Discussion about the TangIn outputs

Moment 3 was dedicated to debating about the TangIn outputs and some general comments about the applicability of tangible programming resources. In Table 11Table 10 a summary of the focus group discussion on moment 3 is presented.

Adding to some of the previously mentioned topics, it was acknowledged that programming skills were essential nowadays and that it's crucial to differentiate the teaching method in order to motivate the students. Interestingly, it was also suggested that tangible programming resources could be used for interdisciplinary subjects such as language and maths using a storytelling methodology.

In accordance with the questionnaire results, where 93% of the respondents answered that they would use tangible programming resources if they were made available to them, the focus group participants said that they would also use the resources in the classroom.

Several concerns were pointed out by the participants Namely: the fact that for example in Bulgaria the majority of teachers belong to an older generation and this might impose some barriers adopting new methodologies; in Portugal the teachers believe that the program is to extensive making it difficult to integrate new methodologies into the classroom; in Spain the concern that the tangible programming resources stop motivating the students or don't have a didactic use; in Latvia that the inertia that some teachers have in changing their teaching methodology is an obstacle to implementing new resources.

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Nonetheless, it's consensual amongst all the participants in the focus groups that the tangible programming resources would motivate the students into STEM subjects.

Table 11 – Summary of focus group moment 3 – Discussion about the TangIn outputs

Moment 3 - Discussion About the TangIn Outputs				
	Bulgaria	**Portugal**	**Spain**	**Latvia**
Comments	Programming skills are essential. Math and Natural sciences are the most suitable but could also be used for interdisciplinary use.	1st cycle is more adequate Maths, technologies and sciences are the most suitable subjects. Language could also be addressed. Storytelling methodology is a good way to teach language and natural sciences. There is a great value of tangible programming tools in mathematics, especially in geometry.	Best use is maths and Natural sciences.	it is crucial to differentiate teaching methods to make children more interested in what they are learning Math and Natural sciences are the most suitable but could also be used for interdisciplinary use.
Would teachers use them?	Yes	Yes. In maths and language	Yes	Definitely yes.
Concerns	High age of primary teachers might be a difficulty to introduce new tangible programming concepts into the classroom.	Program is to extensive and is difficult to integrate new methodologies. Natural sciences teachers said few contents could be approached. Lack of training	Teachers would stop using the resources if they were no longer motivating the students or they would not find a didactic use.	Some teachers would prefer not to change the work style and in some cases it would be difficult for them to change.
Benefits	Motivate students	Motivate students	Motivate students	Motivate students

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6 Conclusions

The world is changing fast and the education methodologies must follow the needs of today/tomorrow's world. Digital literacy is a skill that children must be proficient at if they are to become actors instead of spectators in the increasingly digital world.

Tangible programming is an approach that aims for the exploration of concepts of logic, algorithms and programming but at the same time working on other skills such as creativity, teamwork and troubleshooting.

The data collected during this study shows that teachers acknowledge the importance of introducing programming and logical thinking concepts to young children but lack the skills and tools to explore these subjects. Another conclusion that was drawn from this work is that teachers are very receptive to use tangible programming in the classroom and that this is an approach that will motivate students into STEM related subjects and promote inclusion.

If tangible programming is to be introduced in the classrooms it will be necessary to 1. Develop ready to use resources that integrate curriculum subjects with tangible programming concepts and 2. provide training to the teachers.

TangIn project will tackle these needs by delivering a toolkit with classroom-ready activities aimed to 5 to 10-year-old children, integrating curriculum subjects with tangible programming, and a training package for teachers that will allow them to confidently use the resources.

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8 Annexes

8.1 Annex 1 - Layout to Collect Educational Contents

Discipline: Mathematics						
Thematic	**Contents**	**Specific**	**School Grade**	**Estimated hours (if applicable)**	**Relevance (if applicable)**	**Comments**

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8.2 Annex 2 - Questionnaire

This brief questionnaire is aimed at supporting a research and analysis on the knowledge and opinions that European teachers have about the usage of Tangible Programming to teach STEM related contents at primary school level. The questionnaire was developed within the project TangIn - tangible programming and inclusion a European initiative supported by the ERASMUS+ programme (Project Nº.: 2017-1-PT01-KA201-035975).

In this questionnaire, you are requested to share your opinions, and beliefs in several dimensions considered relevant for the project, especially the ones related to the programming concepts and digital tools. Your answers are anonymous, and we only ask you to provide basic sociodemographic characteristics for statistical data analysis, as well as your email address.

You can get familiar with the concept of tangible programming by assisting this short video, available at https://www.youtube.com/watch?v=sd_9KiM0cwk&t=6s.

Thank you for taking part in this research. Your inputs are important for our future outcomes, which will be designed to address your needs and interests.

A – Sociodemographic characteristics

1. **How old are you?**

   Less than 30 years old

   Between 31 and 44 years old

   45 years old or more

2. **Please state your gender**

   Male

   Female

3. **How large is the school where you currently teach?**

   Less than 300 students

   Between 301 and 750 students

   751 students or more

B – You, as a teacher

4. **For how long are you a teacher?**

   Less than 5 years

   Between 6 and 15 years

   16 years or more

5. **What level/discipline do you teach? (Please select all applicable)**

   Basic education

   Mother tong

   Mathematics

   Sciences (Natural)

   Physics

   Chemistry

   Physics and Chemistry

   History

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Geography
ICT
Arts
Sports
Music
Programming
Other – Please specify

6. **Currently, to what level or levels are you teaching? (Please select all applicable)**

Pre-school
1st Level
2nd Level
3rd Level
4th Level
5th Level
6th Level
7th Level or higher

7. **In your daily life, which of these technologies (software and hardware) do you use? (Please select all you use)**

Computer
Smartphone
Tablets
Email
Skype
Hangouts
Social media (Facebook, Instagram, Twitter, LinkedIn, etc…)
Other:

C. Use of Technology in Educational context

8. **Which technologies are available in your school to use with pupils? (Please select all applicable)**

Computer (for teacher)
Computers for students (at least 1 per 2 students)
Multimedia projector
Internet access
Interactive board
Tablets
Robots
3D prints
Others please specify:

9. **Which technologies do you use in your classes?**

Computer (for teacher)
Computers for students (at least 1 per 2 students)
Multimedia projector
Internet access

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Interactive board

Tablets

Robots

3D prints

Others please specify:

D – Programming competences

10. Are you familiar with the European Code Movement?

YES

NO

11. Do you think it is important to develop children's programming skills?

Not important at all

Not important

Important

Quite important

Very important

12. If you have answered not important at all or not important, please justify?

13. If you agree, in what level should programming skills be introduced?

Pre-school education

Primary school

Lower secondary school

Secondary school

Higher education

14. Do you think it is important to develop children's logic and algorithms skills?

Not important at all

Not important

Important

Quite important

Very important

15. If you agree, in which level should logic and algorithms be introduced?

Pre-school education

Primary school

Lower secondary school

Secondary school

Higher education

16. Do you have specific teacher training (initial training, in-service training, …) in programming?

YES NO

17. In your opinion, do you have the necessary competences to teach programming to your students?

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YES NO

18. Do you have any experience in teaching programming?

YES NO

19. If not, why:

Never had opportunity to teach programming

Never thought about teaching programming

I feel that I have not enough competences

I feel that it is too complex for student's age that I teach

Other

20. Do you know any tool/platform able of supporting the development of programming competences? (Please select all you know)

None

Logo

Scratch

Code.org

Hour of code platform

Run Marco Platform

Lego

Other:

E. Tangible programming skills

21. Before seeing the video, provided, were you familiar with the concept of Tangible Programming?

YES NO

22. If yes, where did you hear about it?

TV

Internet

Press releaser

Academic papers

University (as student)

School colleagues

Education congresses/seminars

Pupils

Other (please specify):

23. As a teacher, if you had to choose, which would you prefer to use in a classroom to control the robot: to play with the blocks or to use a PC/tablet?

PC/Tablet Blocks

24. In your opinion, what would your students prefer to use??

PC/Tablet Blocks

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25. At what age, do you think that using a robot for tangible programming could be more useful?

never
≤5 years old
6 years old
7 years old
8 years old
9 years old
10 years old
11 years old
12 years old
13 years old
14 years old
15 years old
≥16 years old

26. In your opinion, in what context, is the use of Tangible Programming resources more useful?

None
In informal educational contexts (e.g. at home, using it just in a ludic way)
In non-formal educational contexts (e.g. tech clubs)
In formal educational contexts (e.g. classroom)
Other (please specify):

27. Would you like to have Tangible Programming resources to use in your classroom?

YES NO

28. If **you have answered no, please justify**

29. If you have access to Tangible Programming resources to use in your classroom, how frequently would you expect to use them?

Never
Monthly
Once every two weeks
Once a week
2 times a week
3 times a week
4 times a week
5 times a week
More than 5 times a week

30. In your opinion, in what disciplines is it possible to use Tangible Programming resources?

Primary level in general
Mother tong
Mathematics
Sciences (Natural)
Physics
Chemistry

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Physics and Chemistry

History

Geography

ICT

Arts

Sports

Music

Programming

Other – Please specify

31. Would you be interested in attending a training course about the educational use of Tangible Programming concepts and resources in order to use them in your classroom?

YES / NO

32. If you have answered no, please justify

33. If an educational toolkit on using tangible programming concepts (pedagogical guidelines and learning materials and resources) were available would you use it with your students?

YES NO

34. If you have answered no, please justify

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8.3 Annex 3 - Focus Group Guide

This focus group aims to assess the opinions of primary teachers and of STEM areas on the use of tangible programming for the promotion of Inclusion and teaching and learning of contents in the STEM areas; In the constitution of the group will be at least 5 teachers

The maximum duration foreseen for the focus group is 1h30, this time being previously distributed for each of the three moments described below.

There is a need to make an overall assessment of the participants' profile (age, length of service, areas of action, resources at school). It should be noted that the activity will be subject to free registrations by the researcher (possibly audio recording, if possible).

Moment 1 - Introduction (30 min)

In a first phase, the focus group will be carried out -> integrated in the research carried out under the Erasmus + TangIn project.

Subsequently, the project is presented and contextualized, explaining what is the tangible programming, project objectives and activities.

In addition to the presentation, the project video and tangible programming video will be shown.

To finalize the first moment, there will be a moment for clarification of any doubts regarding the project, its objectives and expected results.

Moment 2 - Opinions about tangible programming in educational contexts (30 min)

At this moment, about how the session will be and some rules, in order to each participant has the opportunity to participate and data can be obtained.

Indications:

- Speak one person at a time (so as not to disturb the line of thought and be able to make recordings);
- Avoid parallel discussions;
- All participants should participate expressing their opinion.

Guiding questions for discussion (note that these issues will be introduced in order to generate debate, and their order according to the follow-up of the discussion):

- How can tangible programming promote learning or facilitate teaching in your disciplines / areas / years of schooling?
- What is your opinion regarding tangible programming potential for promoting interdisciplinary approaches between the programming areas and the STEM?
- What impact could tangible programming have on the school environments in which you teach?
- What constraints do they identify for the use of tangible programming in educational contexts?
- What capital gains do they identify for tangible programming use in educational contexts?
- What is your perspective in teaching algorithms and programming? And at what ages should it be introduced?

Moment 3 - Opinions related to the TangIn outputs (30 min)

Guiding questions for discussion (note that these issues will be introduced in order to generate debate, and the order should be according to the follow-up of the discussion):

- If you have access to TangIn resources did you use them?
- In what disciplines / areas do you think TangIn resources might be most useful?
- What impact, at the student level, could be the use of TangIn resources?
- What constraints do they identify so that teachers do not use TangIn resources?

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8.4 Annex 4 - Focus group reports (raw)

Portuguese Focus Group Report

Teachers' involved: 4

A – Primary Teacher (1st to 4th grade), 10 years' experience, female.

B – Primary teacher (1st to 6th grade) 4 years' experience, female.

C – Science Teacher (5th to 6th grade) 11 years' experience, female.

D – Mathematic teacher (5th to 9th grade) 14 years' experience, male.

Moment 1

During this moment the Tangin project was presented and explained with PowerPoint and videos as a support.

It is important to highlight that before this focus groups the teachers' involved didn't knew what tangible programming is and had no experience in teaching programming or using programming and robots to teach other curriculum contents.

Because of this starting point it was necessary to show some videos and contextualize more the subject.

It did not occur any relevant question about the project or the usage of tangible programming to teach STEM (Science, Technology, Engineering and Mathematic) contents after the movies visualization.

Moment 2

Regarding programming teaching, the four participants argued that algorithm teaching should begin in 1st Cycle of Basic Education, while aspects related to computer programming should begin later, around the 2nd or 3rd Cycle. They justified that the concepts of programming may be too abstract for the ages of the 1st CBE (by programming the participants understood programming languages).

Concerning tangible programming, the participants claimed that it is less abstract and easier to understand and handle than programming in computers. Here we highlight the opinions of participants A and B who, having no experience to teach programming, have already attended programming classes with Scratch.

All teachers recognized that the use of tangible programming to teach STEM contents can be motivating, especially in Mathematics. However, professor C pointed out, again, that she sees with difficulty the use of these technologies to address science content in the 5th and 6th years of schooling.

During the debate, teacher A mentioned that one of the possibilities to approach Science with tangible programming would be to promote storytelling and role play situations. That in the 1st Cycle it would be simple to approach some contents like, for example, the routes, of direct form. What other content could be addressed with the use of cards to develop games.

The teacher C mentioned that perhaps in the 1st Cycle it would be simpler and more direct, since the monodocence can also facilitate interdisciplinary approaches. However, in the Natural Sciences discipline, the use of tangible programming will be more efficient in non-formal moments of education. This is because the curriculum is extensive which makes it difficult to introduce innovative methodologies.

Teacher D mentioned that the use of tangible programming in her subject could help the students to visualize more directly some aspects of geometry, such as angles or characteristics of geometric figures. The same could be applied in the 1st Cycle, as well as calculation of perimeters, area, and distances.

Participants A and B agreed, claiming that with creativity it will also be possible to address contents of the Study of the Environment, such as routes, traffic signals, etc.

Participants agreed that tangible programming has a greater potential to promote inclusion, since multiple students may be able to solve a problem at the same time. And that interdisciplinary can also be promoted, as long as "tasks" are

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mobilized that appeal to this mobilization.

All participants agreed that having tangible programming tools at school is a plus because it can be used in different contexts where necessary. However, teachers C and D, despite claiming that if they had these tools they would use them, said that they believe these tools will be more efficient in the 1st Cycle of Basic Education and some Mathematics contents of the 2nd Cycle.

Moment 3

All participants showed an interest in using the resources produced in Tangin in their classes. However, even though the use of robots will be a motivating factor in students, teacher D claimed that if he had an opportunity he would only use it sporadically, because in his opinion the program is too extensive, which makes it difficult to integrate methodologies. The teacher of the natural science (C) discipline stated that few contents could be approached using the tangible programming, which during the year certainly would not use many times.

About the disciplines / areas that TangIn resources might be most useful, the participants emphasized more importance on Mathematics, followed by Technologies and then Sciences. After questioning the moderator, teachers argued that languages could be addressed, but if story telling situations were encouraged, and even the teaching of the natural sciences would have to be centered on this methodology.

On the other hand, in the area of study of the environment (a discipline that encompasses science, geography, history and citizenship), some themes could be approached directly with the help of tangible programming tools, such as pathways, for example.

In the area of mathematics, teachers emphasized the great value of tangible programming tools, the potential for teaching geometry.

As constraints to the use of tangible programming tools, teachers who currently teach in the 5th and 6th grades (C and D) of schooling referred to the size of the programs that hinders the introduction of innovative methodologies. On the other hand, they mentioned that the use of these tools may have a motivational effect on students that may be beneficial for the promotion of learning. However, they pointed out that perhaps in the 1st Cycle the impact would be more effective.

Already participants in the 1st Cycle (A and B) stated that if they had access, they would be interested in using in their classes, noting that they could use both STEM and Portuguese contents (in a story telling perspective). They also emphasized the motivating effect of the use of this type of technology in students. As more constraints to the use of this technology / resources referred the difficulty of access and training in the area.

Spanish Focus Group Report

Teacher´s involved

Primary Teacher: 1st and 2nd of Primary school. Female. 12 years´ experience.

Preschool Teacher: 4 and 5 years. Female 17 years´ experience.

Preschool Teacher: 3,4 and 5 years. Female. 5 years' experience.

Primary Teacher: 4th, 5th and 6th of Primary school. Male. 7 years' experience.

Secondary School: from 12 to 16 years. Male. 12 years 'experience.

Moment 1

First of all, Erasmus + is explained. After that, it said that the project is integrated into it.

After that, the project is contextualized and the tangible programming is presented through a video and a PowerPoint presentation.

Later, the video of the project is presented.

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To conclude this moment, doubts are solved about how the blocks are and how they work. The doubts are solved and an example is shown.

Moment 2

Teachers think that this type of education is crucial for students to adapt to the present and the future. It is a stimulating environment for students. They think that is a very practical in mathematics, natural science and language.

Programming encourages the realization of projects through interdisciplinary, since many contents can be put together and into practice through programming and STEM. The teachers contribute with ideas such as mixing language with mathematics through, lines, numbers ...

The impact would be at first quite remarkable until the normalization of the inclusion of the programming in the classroom. The biggest restriction would be that students would end up bored by the misuse of programming or by its excessive use.

All teachers agree that it should be introduced in the first years of education (3 years) because students would adapt and introduce it into their normal life.

Moment 3

Teachers agree that they would use these resources as long as they were necessary.

They think that the best subjects to practice and in which these resources would be more useful would be Natural Science and Mathematics.

The impact on students would be very motivating and they would have significant learning.

Teachers would not use the resources, if they were no longer motivating for the students or they would not find a practical and didactic use.

Latvian Focus Group Report

Teachers' involved: 4

A – Primary Teacher (1st to 3rd grade), 21 years' experience, female.

B – Primary teacher (1st to 3rd grade) 15 years' experience, female.

C – English Teacher (4th to 6th grade) 17 years' experience, female.

D – Natural sciences and IT teacher (4th to 6th grade) 20 years' experience, female.

Moment 1

TangIn project was presented to teachers and PowerPoint, and video was shown as a supporting material.

Involved teachers, except one of them, were not aware what tangible programming is and have never been teaching anything related to programming.

There were no relevant questions from teachers after showing the video and presenting the project.

Regarding that situation, it was necessary to explain things related to tangible programming and TangIn Project in particular.

Moment 2

Teachers argued on how and in what curricula tangible programming could be most suitable, and all of them agreed that most suitable subjects for it are mathematics and natural sciences.

Although they all agreed that for children it is more suitable, and they are already used to working with blocks and for

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them it will be really easy to adopt and learn programming by using their hands. And it is crucial that children do programming physically in the century where everybody is so used to spend so much time by using their smartphones and computers leaving any physical activity away.

Teachers agreed that it could be difficult to adapt tangible programming in more complex topics of mathematics and Science, but every new challenge is a step forward no matter if it succeeds in the end.

Teachers saw biggest potential in doing simple things using tangible programming, like polygons, lines, angles etc. in mathematics and for example sky sides in combination with some maps when teaching sciences.

Teacher B mentioned that possibly for children it will be easier to visualize things like angles and polygon figures.

The main concern for all teachers was the lack of knowledge and practical skills at the moment and that is what makes them feel unsure if they will be able to handle and integrate tangible programming in their classes.

Regarding benefits of tangible programming, all teachers mentioned children improvement of logical thinking and communication skills. Diversification of learning environment, strengthening of teacher material by doing more practical tasks through tangible programming. And promotion of inclusion is a great benefit, because children will be able to work in groups and Interact with each other in solving given problems.

All teachers agreed that tangible programming tools at school would be positive thing, because it can be used in different contexts.

Moment 3

All teachers agreed that if they will have TangIn resources, they will definitely use them, because in our days it is crucial to differentiate teaching methods to make children more interested in what they are learning.

Speaking about disciplines/areas where TangIn resources would be most useful all teachers agreed that mathematics and natural sciences are the most suitable disciplines for tangible programming and languages could be used as interdisciplinary aspect through all other disciplines.

When talking about what impact could tangible programming give on students' level teachers agreed that Technologies now are crucial part of modern society and children are already using new Technologies even better than teachers themselves and the interest of technology is growing, so it would be very wrong to ignore it and TangIn can give teachers a tool to develop more interest from children to basic disciplines.

Although teachers mentioned that for some colleagues who prefer not to change their work style implementation of tangible programming in their disciplines could make some serious problems.

Bulgarian Focus Group Report

Teachers' involved: 5

A – Primary teacher (1st to 4th grade), 2 years' experience, female.

B – Primary teacher (1st to 4th grade) 11 years' experience, female.

C – Natural sciences (biology and physics) (5 th to 8 th grade) 13 years' experience, female.

D – Natural sciences (geography and chemistry) (4th to 6 8h grade) 15 years' experience, female.

E – Primary teacher (1st to 4th grade) 21 years' experience, female.

Moment 1

TangIn project was presented with the help of videos, some of them with the usage of similar blocks for programming. The videos were also shown to one of the classes 2nd grade and the students reaction was very positive.

None of the teachers were aware about Tangible Programming have never used any type of programming as a support in their classes. Only the youngest one of them in the university has gone beginners programming course. The oldest one

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was sceptic about her possibilities in using Tangible programming in her classes.

The idea of Tangible programming and different possibilities for supporting the lessons were described on different examples – math, geography, astronomy. Some of the teachers shared ideas about possible exercises connected to their subject. Also, some questions about the possibilities of the robot movement were asked – size of the steps (dimensions of the pad for different exercises).

Moment 2

There was a huge discussion haw the Tangible Programming could be implemented in the school curricula. According to the current legislation in Bulgaria the possibilities of implementing could be in extracurricular activities and the most suitable subjects are math related and Natural sciences related ones in the primary classes where it will attract their attention and will have positive effect in the educational process.

In the New school curricula starting 2018/2019 school year different forms of programming will be implemented starting from 4th grade. Starting with Tangible programming earlier will be very helpful for the students. Tangible Programming can add to the subject content the element of competition in a game, which is very important in a multi-ethnic and multicultural environment and can prevent early school leaving. All the classes can be involved and even inter class competitions with bigger pads using even the school corridors.

All the teachers agreed that it could be difficult to adapt tangible programming in more complex topics of mathematics and Science, but every new challenge is a step forward no matter if it succeeds in the end.

Teachers saw biggest potential in doing simple things using tangible programming, like polygons, lines, angles etc. in mathematics and for example sky sides in combination with some maps when teaching sciences.

Teachers agreed that by visualization many problematic issues can be understood and accepted easily – geometric figures, angles, lengths and widths in geography, planet movements in astronomy.

The only concern the teachers shared is lack of knowledge and practical skills at the moment and that is what makes them feel unsure if they will be able to handle and integrate Tangible Programming in their classes. We assure them that the training materials and practical training for some of them will overcome their fears, and the trained teachers afterward will be able to train others.

Regarding benefits of tangible programming, all teachers mentioned children improvement of logical thinking and communication skills. Diversification of learning environment, strengthening of teacher material by doing more practical tasks through tangible programming. And promotion of inclusion is a great benefit, because children will be able to work in groups and Interact with each other in solving common problems sometimes in a different creative way.

Moment 3

Programming skills will be essential in the future. All teachers agreed that if they will have TangIn resources, they will definitely use them, because in our days it is crucial to differentiate teaching methods to make children more interested in what they are learning.

Speaking about subjects where TangIn resources would be most useful all teachers agreed that mathematics and Natural Sciences are the most suitable disciplines for Tangible Programming and languages could be used as interdisciplinary aspect through all other disciplines.

When talking about what impact could Tangible Programming have on students' level teachers agreed that Technologies now are crucial part of modern society and children are already using new Technologies even better than teachers themselves and the interest of technology is growing, so it would be very wrong to ignore it and TangIn can give teachers a tool to develop more interest from children to basic disciplines.

If the presentation exercises after the training are pretty attractive the Tangible Programming idea could be quickly spread across other schools. Again the question of the price of the robots and their service, elaboration of common and new pads was discussed. There is a thread that due to the relevantly high age of the primary teachers many of them will be difficulty involved in the Tangible Programming idea and its implementation.

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