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Costs and Benefits to Implement STEM Programs in Schools: The Stimey Project

REID Alecia Adelaide May (1), GÓMEZ AGUILAR Nieves (2), RIOJA DEL RIO Carlos (3)

University of Cádiz, Spain (1)
University of Cádiz, Spain (2)
University of Cádiz, Spain (3)

Abstract

This paper describes the costs and benefits derived from the implementation of the European Commission Research Programme - Horizon 2020 Project, STIMEY (Science Technology Innovation Mathematics Engineering for the Young), for primary and secondary schools throughout Europe. STEM education provides invaluable benefits to the society when it makes students better problem solvers, innovators, inventors, self-reliant, logical thinkers, technologically literate, increasing their interest and motivation at school [1, 2 and 3]. Some experiences have evidenced that STEM education has to be linked with creative accessible affordable educational materials, available to elementary and secondary schools in a continuous fashion. For example, in the specific case of experiences using robotics, some of the problems come from the lack of teacher's time and training, organization, easy of access to age-suitable academic materials, the lack of ready-to-use tools for lesson and material preparation and the lack of affordable robotic platforms. Moreover, in spite of the slowly growing numbers of robotic platforms and kits on the market, the lack of a range of affordable robotic platforms persists. If we want to reach the whole pre-university students and schools, such materials must truly be inexpensive, as they must be acquired in significant numbers and be replaced regularly due to natural wear-and-tear of hands-on education materials [4].
To motivate the implementation of STEM Education in schools, thus resolving the above disadvantages is exactly what STIMEY will do while bring science and society together in Europe, and consequently increase the continent's international competitiveness. Its socially motivational platform for emotional and educational engagement will combine: social media components and entrepreneurial tools (the present), robotic artefacts (the future) and radio (the past) based on its well-researched pedagogical framework. STIMEY will not only engage and increase the youth's interest in STEM education and careers, but provides the gateway to a viable business investment that shapes the future generation. With all of these possible benefits of STEM education, it is important to ascertain how school headmaster / teachers can effectively include STEM programs in their teaching.

Keywords: *STEM, Schools, Robots, K-12 education;*

1. Introduction

STEM education has become an essential tool for countries to improve their international competitiveness. This type of education makes students not only better problem solvers, innovators, inventors, logical thinkers and technologically literate, but also self-reliant, increasing their interest and motivation at school. That means STEM education have a non-negligible impact on the society [1, 2 and 3] and, because of this, educational authorities have been promoted it as a way to improve the quality of the studies programs in primary and secondary schools.
Assuming this concern, in recent years a whole industry has been developed to supply the materials and tools that are needed to implement STEM education in a society in continuous technological advance. As we will see afterwards, the Global Education Industry (GEI) is considered as an industry sector in expansion. This industry are designing and supplying e-books, software, courseware, learning devices, learning platforms, or dedicated IT solutions to schools. All of them are elements that make it easier for teachers to develop STEM strategies with their students. However, it is known that not all schools have developed the same capacity to adapt to these resources and implement a successful STEM education.
The lack of elements such as teacher's time and training, ready-to-use tools for lesson or affordable platforms is causing many schools to find barriers to promote this type of education in their classrooms. In order to guarantee that the benefits of implementing a STEM education are higher than the costs that have to be faced by schools, an integrated tool must be supplied by the industry. By

integrated tool, we understand that which includes age-suitable and gender sensitive academic materials, training for teachers, communication platform with contents in continuous updating, access to robots, etc. In this line, the STIMEY project (Science Technology Innovation Mathematics Engineering for the Young), an European Commission Research Programme - Horizon 2020 Project, endeavours to become that tool for primary and secondary schools throughout Europe.
The rest of the paper is organized as follows. Firstly, we analyze the industry related to the STEM education to determine if it is an active and growing market which offers products to satisfy its needs. Next section will describe the costs and benefits that schools have to face when decide to implement STEM programs. We argue that the costs generally exceed the benefits and this is the reason why the STEM education is not enough widespread. The fourth section describes our proposal for an inexpensive and integrated STEM tool, the STIMEY project. The main conclusions and the references are placed in the last sections.

2. The global education industry and its future perspectives

For the Organization for Economic Co-operation and Development's (OECD) [5], those companies selling educational resources and services of a technological nature to schools, including e-books, software, courseware, learning devices, learning platforms, or dedicated IT solutions, represent the Global Education Industry (GEI). The GEI field includes a broad range of actors, the more relevant are: chains of private schools; big education corporations and conglomerates providing a broad range of publishing, IT/software and educational services; consultancy firms; philanthropic foundations and advocacy networks. Moreover, we may also find regulators (national and international organizations), public providers, workers (and their organizations), private capital and clients (students and families) [8].
Regarding this industry, Merrill Lynch-Bank of America calculated in 2014 that the value of the education sector, in an international level, is $4.3 trillion (USD) [6]. Moreover, the market size of the for-profit education sector is expected to grow by 17 percent in the last five years of this decade [7]. Given these expectations, the GEI can be considered as an industry in expansion, acquiring its strength and dynamism by the penetration of business actors in new market niches such as on-line education, tutoring or supplemental/ 'shadow education,' edu-marketing, consultancy services for governments and schools, testing preparation services [8]. Traditionally, there have been more market opportunities in those sub-sectors and educational levels, such as pre-kindergarten and post-secondary education, where the state is not so present. Nonetheless, in the last decade, a significant penetration of primary and secondary education levels could be observed by the for-profit sector as well. In fact, this development has been apparent all over the world [8], because the internationalization of this industry lets its actors increase their influence in educational politics, including their capacity to settle education policy agendas and frame education regulation at different scales [9].
However, the implementation of STEM strategies in schools is very heterogeneous up until now. This may be due to the fact that the costs faced by the teaching staff of schools are very diverse, not limited to economic costs, which discourage the implementation of these projects. Knowing in depth not only the benefits but also the costs associated with STEM education will facilitate the development of a tool that can reduce costs globally and make its implementation more attractive.

3. Benefits and costs of STEM education

As it was illustrated above, the educational industry development is guaranteed, because many economic actors are operating in this market and their influence in educational politics and families is growing in recent years. As the intention of providing a proposal which could satisfy the needs of schools, it is of great importance to take into account the two sides of STEM education, benefits and costs. It is an obligation to consider the time and effort invested, mainly by teachers in this emerging industry.

3.1 Benefits

STEM education should contribute to a STEM-literate society, with a general workforce with 21st-century competencies, and an advanced research and development workforce focused on innovation [10]. All of these improvements are crucial for a country's competitiveness in the global marketplace. In doing so, STEM qualifications prepare people for a broad range of occupations, including management. In the OECD's Programme for International Student Assessment (PISA), which compares student achievement in mathematics and science at age 15, the nations/systems with the

largest group of students at the top three proficiency levels are also the systems with the smallest proportion of under-performers in PISA. Interestingly, these nations that are also exceptionally strong in research and development, are rapidly growing their scientific output and have all experienced two decades of exceptional economic performance. This situation shows a strong relationship among science, universal learning, and economic dynamism and prosperity, being a single interdependent system [11].

Then, driven by genuine or perceived current and future shortages in the STEM workforce, many education systems and policy makers around the globe are preoccupied with advancing competencies in STEM domains. The idea is to make students better problem solvers, innovators, inventors, self-reliant, logical thinkers, technologically literate, increasing their interest and motivation at school [1, 2 and 3]. But, what does it really mean STEM education in K-12 settings? Following, for instance, the National Research Council [12], it fosters interdisciplinary knowledge and skills that are relevant to life and prepare students for a knowledge-based economy. STEM education includes the knowledge, skills and beliefs that are collaboratively constructed at the intersection of more than one STEM subject area. In this line, a flexible curriculum enables teachers to teach STEM subjects in their natural contexts, being this curriculum the result of an integration of all the STEM subjects.

3.2 Costs

However, it is clear that the implementation of this integrated STEM curriculum requires a strong effort for schools, in general, and for teachers, in particular. The main costs arise from teacher training and specific materials and tools that are needed. Regarding the first type of costs, STEM education demands knowledge, skills, and teachers acknowledgement. Reducing the gap between current teaching practices in schools and the actual skills needed for STEM education is contingent based upon the expertise of STEM teachers to successfully work with an integrated teaching model [13]. In this model, teachers have the additional responsibility of guiding their students in at least one other STEM subject, which necessitates both an investment in professional development of in-service teachers, and a reorganization of the teacher education programs at universities [14]. In the case of teaching with robotics, teachers are best prepared to innovate when working from a solid foundation prepared by robotics educators [4].

In relation to the resources that are needed, some experiences have evidence that STEM education has to be linked with creative accessible affordable educational materials, available to elementary and secondary schools in a continuous fashion. Moreover, given the current shortage of student interest in STEM topics, increasing attention has been paid to developing innovative tools for improved teaching of STEM, including through robotics [4]. For example, in the specific case of experiences using robotics, some of the problems come from the lack of three resources: age-suitable academic materials, ready-to-use tools for lesson and material preparation and affordable robotic platforms. Moreover, in spite of the slowly growing numbers of robotic platforms and kits on the market, the lack of a range of affordable robotic platforms persists. If the desire is to cover the whole pre-university students and schools, such materials must be inexpensive, as they must be acquired in significant numbers and be replaced regularly due to natural wear-and-tear of hands-on education materials [4].

The above costs make it so difficult for some schools to provide a STEM program in a permanent way. An integrated tool, which provides teacher training and support as well as motivating materials for students with the support of a communication platform, as do STIMEY project, would be an effective way to reduce the costs in order to reach the whole benefits of STEM education.

4. STIMEY Project: A proposal to make STEM education attractive to schools

STIMEY proposes an Educational Environment (EE) with multi-level components, designed and developed on the base of a well-researched pedagogical framework and gender sensitive guidelines, which aims to bring science and society together in Europe while making STEM education more attractive to young people from age 10 to 18 years old. Under STIMEY EE universities, schools, teachers, students, parents, business and media partners come together to complete a circle in which STEM becomes a part of the daily life of youths through an educational portal that also prepares them for future careers.

STIMEY socially motivational platform for emotional and educational engagement combines social media components (the present), robotic artefacts (the future), and radio (the past) to educate, engage and increase the youth's interest in STEM education and careers. The platform, with individual e-portfolios, is designed to tap into young people's curiosity and motivations from an early age while taking into account the specific needs of girls and boys, to not only be attracted to, but also stay with

STEM in a social collaborative environment with serious games and entrepreneurial tools that promote healthy competition among peers.
STIMEY EE will provide teachers with well-researched gender sensitive modern low cost tools to deliver STEM education in an attractive and engaging manner. For example:- The STIMEY Socially Assistive Robotic Artefacts that are designed and developed with the sole purpose to motivate students between 10 and 18 years old, are not only inexpensive, but are also easily upgraded with low maintenance; Radio STIMEY is a 24 hour broadcasting STEM Radio that takes 'The STEM Conversation' to the next level. The Youth STEM Community, STEM Business Organizations, etc. will use Radio STIMEY as a public forum to voice their views.

5. Conclusions

The aim of this article is to highlight the importance of providing useful and inexpensive STEM-orientated tools for schools to reach all pre-university students. We have described the most important barriers that schools must face when they try to implement STEM education. In addition, we have shown the positive aspects of this type of education, which are a growing, profitable global industry and a great impact in society wealth. The international STIMEY team has focused on the above-mentioned costs to design and propose an integrated tool, which helps schools to avoid most of these costs. STIMEY socially motivational platform is a revolutionary tool because combines social media components, robotic artefacts, and radio to educate, engage and increase the youth's interest in STEM education and careers. The usefulness and efficiency of this tool will depend on the number of users (schools, parents, students, teachers, among others) that will join STIMEY community. Follow us on www.stimey.eu.

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