STEM Strategies for Economic Growth

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Abstract

This paper aims to raise awareness of the importance of education in economic growth and not just education in general, but mainly of STEM (Science, Technology, Engineering, Mathematics) education. Such signals are always useful, in order to align ourselves with other countries that have already acquired experience in implementing STEM education and can measure positive effects for the economy.
The present research proposes to approach STEM education through the perspective of the most effective strategies applied so far in various regions of the world and that can be adapted to the Romanian reality. This is also useful for the steps needed to implement the recently adopted project "Educated Romania" (2021), which essentially aims to support education based on STEM competencies.
The micro-research in the second part of the paper is a quantitative one that verifies whether there is, at the population level of parents in general, an awareness of STEM education competencies. It was investigated in what extent people are familiar with STEM education, if they can describe it and how interested would be to encourage their children to learn science, technical subjects, engineering and math skills. Moreover, the respondents' perception regarding the impact that such an approach would have on the economic development of a country was questioned.

Keywords

STEM, education, transformative competencies, economic growth.

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Introduction

STEM education in innovation and economy has numerous benefits mentioned by many specialists in both economy and education "we need (...) more STEM professionals (...) if the country is to retain its historical pre-eminence in science and technology" (PCAST, 2012, p.2). We start from the guidelines, supported by the OECD Learning Compass 2030 and the definition of "transformative competencies" as "the types of knowledge, skills, attitudes and values students need to transform society and shape the future for better lives. These have been identified as creating new value, reconciling tensions and dilemmas, and taking responsibility" (OECD, 2019, p.4). We are trying to create a vision of what is efficient and effective for a country's economy, to analyse a new design in education that can positively influence the economy. Shaping so-called transformative competencies, through activities that generate the competencies needed for future jobs, is of paramount importance. This predictability of transformation in education and learning being also predicted by specialists in the field of economics "because of today's dynamics of economy and living, and also, because of the easy access to the Internet, education and learning are changing" (Pamfilie et al., 2012, p.4029). The U.S. President's Council of Advisors on Science and Technology in 2012 decided to implement public policies on the grounds of "increasing the number of students receiving STEM bachelor's degrees by approximately 34% annually over current rates" (PCAST, 2012, p.2) in order to maintain technology innovation and economic success. The path can also be reversed, i.e. from a strong economy to another type of learning "as Taiwan's economy has progressed, its educational reformation has also undergone major transformation" (Lin, Huang and Lin, 2021).

The content, which relies on science, technology, engineering and mathematics, as well as the ways in which information is conveyed, repeated and acquired, is tremendously important in the reorganisation of the new curricula. The influence of technology and well-paid jobs also has effects on a country's economy, as specialists consider that they "understand the critical importance of reforming the education system as a cornerstone for accelerating Romania's economic growth and development in the medium and long term" (Guda, 2020, p.336). According to a Canadian study (Pagani et al., 2010) it was found that early math skills were stronger predictors of overall academic success than reading skills or social-emotional skills. Findings from such research, along with psychology studies according to which brain architecture develops 80% prenatally, have led to numerous concerns about early math education (Clements and Sarama, 2014; Setyowati, Firda and Kasmita, 2021; Abramovich and Connell, 2021). Other concerns on this topic (CERME11 working group, conferences such as TWG13, POEM4, ICME 13, ERME, etc.) have also been developed in order to support and promote the inclusion of mathematical activities at the youngest ages as a daily and very important task. Nowadays, it goes without saying that the development of mathematical skills and becoming familiar with notions about numbers, geometric shapes, spatial positions are essential for mathematics education and long-term developmental progress, which consequently lead to further significant growth (Duncan et al., 2007; Krajewski and Schneider, 2009; Aunio and Niemivirta, 2010; Aldemir and Kermani, 2017; Björklund, van den Heuvel-Panhuizen and Kullberg, 2020). Equal access to education, namely STEM education, is pursued from the earliest ages to generate visible results and progress in economy.

The acquisition of specific STEM skills/competencies are supported by numerous conferences, books, private schools. They are to be integrated: at primary level: STEM Robotics, Mobile Apps in Early Childhood and Primary Education (Prinsley and Johnston, 2015), middle school (Wyss, Heulskamp and Siebert, 2012; Chiu, Price and Ovrahim, 2015), high school (Means et al., 2018.) even at university level (Bianchi and Giorcelli, 2020).

Numerous recent researches from prestigious publications support the benefits of STEM education (in developing countries) but also the positive effects of STEM education on human resources, implicitly on the economy. "Science, Technology, Engineering, and Mathematics (STEM) education has been viewed as foundational to economic growth by many countries in the world and has thus received continuous attention from ministries of education" (Lee, Chai and Hong, 2019, p.1). The effects of implementing STEM education can also be seen today due to the fact that many countries have adopted supportive policies and experimented with this type of education much faster than in our country.

As early as 2009, the Governor's STEM Advisory Council was set up in the Commonwealth of Massachusetts to develop a STEM plan from pre-K through higher education that would result in workforce with STEM skills (Proudfoot and Kebritchi, 2017, p.3). Since 2018 and 2019 projects that use elements of artificial intelligence and lead to STEM competencies have been implemented in formal schools: AI Singapore, National AI Strategy- Korea, Technology Education from Primary 1 to Secondary 6 - Hong Kong, AI Textbooks - Mainland China (Su, Zhong and Ng, 2022).

At the macro level, the positive impact of STEM education on the economy of various regions is reflected in numerous publications: America (STEAM and American workforce; The impact of STEM on the US Economy); Asia (STEM Education from ASIA, The Asia-Pacific Education Researcher) and Turkey (An overview of STEAM Education and Industry 4. 0; Europe (UNESCO International bureau of Education-Exploring STEM competencies for 21st Century, STEM education and Growth in Europe), UK (Council for Science and Technique); Australia (Office of the Chief Scientist, Australian Business Community Network). For a thorough picture of STEM, we can mention the relevant statistical reports by Hurst et al. (2019). After analysing numerous articles, the authors present, from their point of view, the leading countries in releasing publications related to STEM education: the US, Australia, the Netherlands, Israel, the UK.

1. Effective STEM strategies in the world

In order to best define, transmit, and assess STEM knowledge and to acquire the necessary skills, various strategies have been approached to try to be efficient and effective in STEM education. Thus, one strategy is actually problem-based learning, known in the field by the abbreviation PBL. Problem-based learning as defined by researchers at Indiana University "is perhaps the most widespread and popular approach to problem-cantered instruction". They discuss under the instructional model category "The Problem as a Guide", "The Problem as an Integrator or Test", "The Problem as an Example", "The Problem as a Vehicle for Process", "The Problem as a Stimulus for Authentic Activity" (Duffy and Cunningham, 1996, pp.21-22). All these metamorphoses of the problem have a well-defined purpose, as the name of each subtype of problem indicates, that is to start everything from a debate, to end as a test, to be taken as a model, to develop critical thinking, creativity, to mathematically model STEM problems.

Another contemporary approach which is favoured by Asians is the TPACK (Technological Pedagogical Content Knowledge) strategy. The latter is undergoing a phase of implementation and automatic refinement in several countries. For greater effectiveness Thohir, Jumadi and Warsono (2022) recommend an improved version of this strategy, namely the 4D-TPACK package. According to the authors Qiu, He and Xiong (2022) the TPACK package contains other subcomponents necessary for its implementation namely CK (knowledge from the table of contents = content knowledge), PK (pedagogical knowledge), TK (technical knowledge) and it would be recommended, according to Taiwanese and Hong Kong researchers Wu, Chai and Wang (2022) to combine it with the VFL package.

Robin Fogarty (1991) in "Ten ways to integrate curriculum" ingeniously presents ten ways of connecting information even during the so-called "computer science classes". These strategies are later taken up for STEM education by many education specialists. The strategies involve knowledge from several fields and receive specific names, but it is the graphic representation that I think is eye-catching and memorable, staying in the reader's memory, given all the transformations that are image-based. This has been demonstrated both scientifically (Veen and Vrakking, 2006; Buzan, 2009) as well as through telephones which explore iconic abilities.

The first models, *The Fragmented Model*, *The Connected Model*, *The Nested Model*, refer to a single school subject; *The Sequenced Model*, *The Shared Model*, *The Webbed Model*, *The Threaded Model*, *The Integrated Model* refer to several school subjects and hold our attention and *The Immersed Model*, *The Networked Model* refer to group learning.

Lin, Huang and Lin (2021) presents the ideal trajectory which Taiwan has undergone in order to directly boost economic growth. R. Lin, Professor in the Graduate School of Creative Industry Design, National Taiwan University of Arts, along with his team presents the algorithm they implemented which could be briefly presented as follows: STEM - STEAM (with SAD) - CEER. SAD (science, arts and design) in higher education and CHEER (collaboration, humanity, empathy, ecology and renaissance) in design practice.

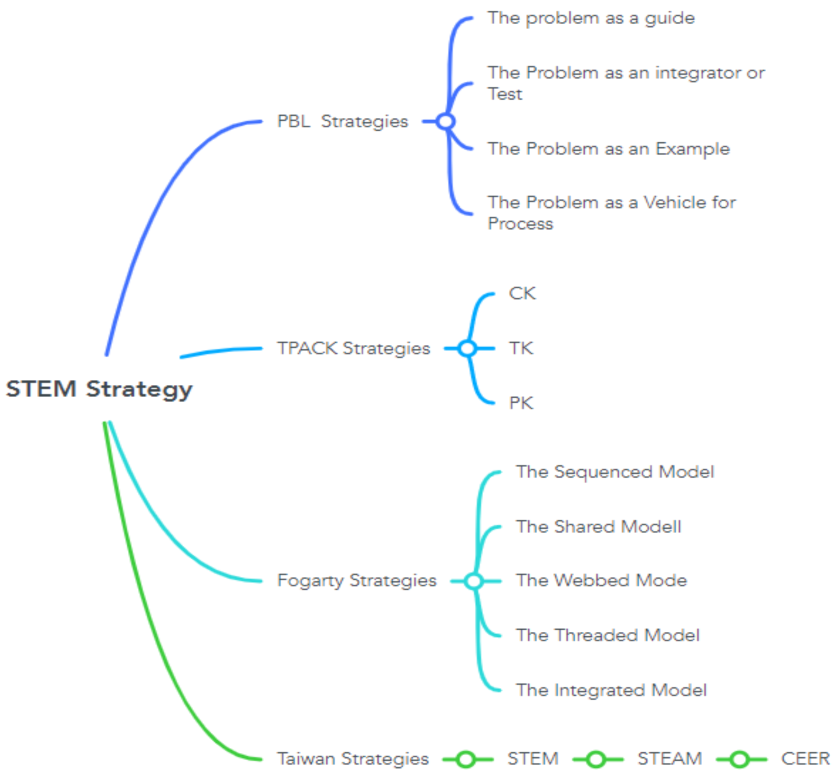

Figure no. 1. Effective STEM strategies in the world
Source: Author own research results

2. STEM strategies in Romania

Theoretical ideas for STEM initially appeared in the Romanian online environment as early as 2017: “unfortunately, from what I know, there is no institutionalized STEM education in Romania, there are no procedures, programs, methodological guidelines or pilot projects” (Bararu, 2017, p.2). Later on, in August 2020, we find out that “the subjects that support STEM education (natural sciences, mathematics, technology, engineering) should be a long-term priority of the development and modernization of education in our country and therefore, their importance should not be diminished by reducing the number of hours allocated” (Center for Educational Assessment and Analysis, 2021).

The advocacy later materialised in non-formal activities but also in activities supported by kindergartens, schools, universities:

- Associations supporting after-school activities: CreSTEM (based on the STEM Association founded in 2016 -crestem.org); “STEM will be a major part of his/her daily activities” 2017 - www.bricks4kidz.ro.; “JA STEM program is supported in Romania by: the European Institute of Innovation & Technology, Honeywell, Johnson & Johnson, ExxonMobil, Waters” - www.jaromania.org; “Robotics on” - 24software.ro, STEM Kids Robotics;

- in articles: Baldea, Garabet and Prisacariu (2017), Tribuna invatamantului (2018), Popovici, Istrate and Mironov (2019);

- STEM educational resources for Romanian teachers: www.esa.int, www.twinkl.ro/resources/romania-teaching-resources;

- partnerships with kindergartens, schools: “a steam to STEAM” - steamwithsteam.eu; “Developing STE(A)M skills of educators through online tools and communities” - eos.ro;

- universities: ASE Bucharest - Garrett Motion continues to invest in STEM education in Romania by launching two new interactive student projects in partnership in the 2021/2022 academic year - garrettmotion.com; Technical University of Cluj - specialization in Robotics;

- the “Educated Romania” project (2021) which supports STEM orientation starting from pre-school level;

- there are also activities that do not mention STEM but they still exist and support the development of specific science and technology skills such as artificial intelligence labs, after-school programming clubs (Scratch, C++, Python), theme camps, robot building and programming clubs, etc.

3. Research methodology

The balance in favour of qualitative or quantitative methods has long been debated by specialists. Here, quantitative research was chosen to collect data using a questionnaire, because it involves an objective measurement of the opinions of the respondent population. The questionnaire consists of questions with a simple, clear syntax in order to obtain the correct answer without interpretation and to avoid taking a long time to complete. The questionnaire follows the scientific structure as the key questions were repeated in a different form to check the veracity of the answer. The simple and to the point design resulted in more relevant and on time responses. The sample chosen was 89 parents (grandparents, legal guardians) who have children in kindergarten or school. The validity of each item in the questionnaire was given by the Cronbach-Alpha coefficient calculated for each item, as follows: 1) To what extent have you heard of STEM education? Cronbach-Alpha coefficient value .8365; 2) To what extent can you describe what it means? Coefficient value .9652; 3) To what extent is your child more attracted to lessons presented in other ways (through projects, computer discussions, etc.)? Coefficient value, .8293; 4) To what extent do you think it will be helpful for your child in the future to learn science, technical subjects, engineering, math skills? coefficient value .9395; 5) To what extent do you consider these fields useful for the economy of a country? coefficient value .8772.

4. Results and discussions

What we observe, after centralising the results from the questionnaires that 69.7% of the parents/legal guardians have heard of the STEM phrase but can describe it in a much lower proportion 14.7%; but they mention that their child is attracted to active ways of learning in a percentage of 89.2%. A percentage of

79.3 of the respondents consider only STEM fields to be useful and 94.5% think they have a positive influence on a country's economy.

It should be noted that the parents who were interviewed are residents in both rural and urban areas. Since all these children attend extracurricular activities such as dance, robotics, languages, it is possible there might be some influence in the answers given, even though they live in rural areas.

Mention should be made that we have noticed that a first step towards STEM education has been taken, thanks to information they had read, changes in technology or other personal experiences. It is also very important to support parents to acquire skills in STEM fields, this is even stated by countries that have implemented STEM education long before us (e.g. Singapore, Massachusetts etc.).

5. Limitation and future research

At the country level there can be multiple limitations when it comes to STEM education, but if there is effective collaboration among specialists in multiple fields, then we can achieve a result with positive outcomes in the economy as well.

We should keep in mind some of the limitations encountered in the past in various past projects so as not to repeat them, namely:

- in some cases, not all the competencies of science, technology, engineering, and mathematics are covered;
- the interdisciplinary implementation of the four areas requires additional technology and pedagogical skills;
- too few training modules specific to STEM implementation;
- other additional activities "required" by the education system (certificates of attendance earned with students, lifelong education courses, appendices and documents required on various occasions, activities demonstrating community involvement, etc.).
- too many changes, adaptations and time needed for self-training with the electronic platforms recommended by ministries to use post-covid as well;
- solid knowledge for designing lessons with the most appealing software tools;
- showing creativity in integrating activities and engaging learners;
- in-depth knowledge of mathematical modelling and beyond;
- thematic labs;
- conditions to explore nature and understand certain phenomena;
- educational policies that support STEM implementation;
- synchronization of activities at micro and macro levels;
- mobilizing companies to train students with STEM skills faster than students, because they are closer to the moment of employment and therefore more interesting than sponsoring and training students, schoolchildren, pre-schoolers;
- there is also a certain time and funding barrier, as the latest STEM education outputs and products do not reach the teacher's desk in time;
- there may also be a reluctance on the part of some students but also on the part of some teachers to work with the latest technologies.

Conclusions

It is interesting to note that, although most of the parents/legal guardians have heard of STEM, a small part of them really understands what it is and know how to describe it. Even if parents are aware that their child is attracted by active ways of learning, they do not match this need with the solution that STEM education represents in this case. A significant majority believe not only that STEM fields to be useful but also it can have a real impact on a country's economic development in the future.

It should be a full recognized statement that education is one of the engines of the economy and that the phrase “you reap what you sow” is a fact.

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