EY-STEAM
Empowering Youths in STEM through the Arts

Review of Literature

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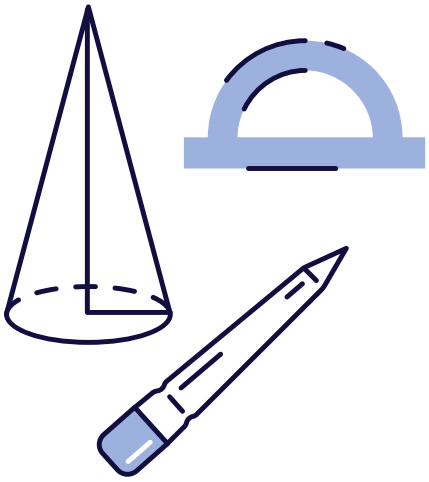


EMPOWERING YOUTHS IN STEM THROUGH THE ARTS REVIEW OF LITERATURE

Introduction

In the last two decades, Malta has experienced a deficit in the number of youths who choose and over-achieved in STEM-related subjects during compulsory schooling. This reflects latest results obtained from the 2018 Programme for International Student Assessment (PISA) and the 2019 Trends in International Mathematics and Science Study (TIMSS). This can be attributed to the fact that both reports shed light on Maltese students' low achievement in mathematics when compared to other countries particularly Finland, Singapore, and Norway (Magri, 2020).

Apart from this, there was also a decrease in the number of youths who take up STEM- subjects during their secondary schooling, particularly when there was the introduction of vocational subjects in state schools with the aim of catering more for students' different learning styles. In fact, from 2004 up to 2017, Malta registered a drastic decline in the number of students who apply for MATSEC exams in biology, physics, and chemistry with the latter being the subject least chosen by youths (Musumeci and Pirotta, 2018). In the face of this worrisome situation, this review of literature aims to improve the current situation and suggest alternative ways that can inspire youths to choose STEM-related subjects.

What is meant by STEM education through the Arts?

STEM is an acronym for science, technology, engineering, and mathematics. Literature defines STEM education as an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world concepts as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new global economy (Tsupros, 2009). As is often mistakenly believed, STEM is not synonymous with STEAM (Science, Technology, Engineering, Art, and Mathematics). The inclusion of the arts introduces new competencies and skills, including active learning; social, emotional, and interpersonal

skills; divergent thinking; and cultural competency. In turn, these offer unique applications to school, work, and life. Hence, the arts provide an opportunity to reinforce learning and cognitive development in meaningful and intentional ways (Dell'Erba, 2019; Huser et al. 2020). This is one of the main reasons why this project is aiming to engage more youths in STEM through the inclusion of arts.

What is the science education set-up like in Malta?

Furthermore, science education is now experiencing another transformational change on both a local and international level. Research is pinpointing the importance of adopting a more inquiry-based approach to science teaching and learning and to give more autonomy to students to be responsible for their own learning. Inquiry-based learning can be defined as a learning method where students are actively involved in their learning process. This is because, during the process of learning, students play an important role in their own learning by gaining the necessary skills that they need to articulate questions, perform scientific investigations and build new knowledge from the previously performed investigations (Branch and Oberg, 2004). Hence, inquiry-based learning gives students a sense of ownership over their own learning and cognitive development (Bache and Hayton, 2012). The inclusion of this approach in the new science national curriculum framework, reviewed as recently as 2018 (see Directorate for Learning and Assessment Programmes, 2018) and the reference to inquiry-based learning in the policy document *A vision to science education in Malta* (Ministry for Education and Employment, 2014), indicate that Malta is moving towards the science education system practised by other countries such as the United Kingdom (National Curriculum in England, 2014) and Finland (Harlen, 2013).

Science education has been part of the Maltese curriculum for over two centuries (Gatt, 2000). However, its importance and relevance to people's lives is quite a recent phenomenon. The latter can be supported by the ongoing changes that are currently taking place in science curricula and modes of science teaching as early as primary schooling. This is because research is shedding more light on the importance of introducing science to students as early as their primary school days (Oppliger, Oppliger, Raber, and Warrington, 2007; Willsher and Penman, 2011) since this makes it more likely for them to continue studying science at later stages of their education system and to pursue careers in science. A related study also shows that STEM engagement in the primary years of schooling determines student's subject choices when they start their secondary schooling (Marginson et al. 2013).

STEM subject uptake in Malta- A Statistical Analysis

According to a local study, the number of students who register for SEC exams in biology, chemistry, and physics has experienced a decline over a period of 10 years (Azzopardi and Musumeci, 2018). This is particularly true for females than for males; this indicates that the stereotypical perception that science is for boys persists in Malta. Such gender bias is true for all fields of STEM, particularly for physics, engineering, and maths and could be attributed to a number of factors.

One such factor is related to the gender role stereotypes which influence the decisions that people take and their aspirations towards science subjects. Women and girls are still expected by society to opt for subjects that are perceived to be softer such as the arts and the languages as opposed to men who are still perceived to be suited for harder occupations, managerial and administrative occupations and as having the responsibility of raising a family (Buhagiar, 2020).

Such a trend is also evident in post-compulsory education and at university level. This could be attributed to the fact that most students hold the perception that STEM subjects at higher education levels are too complex and very difficult to succeed in, attain gain good grades in, and subsequently get a career in the science sector (Magro, 2018).

What are the current projects and initiatives in Malta with regard to the promotion of STEM careers amongst the youth?

After the publication of a vision for science education in Malta, several initiatives have been put into place by the Ministry of Education and Employment, the Chamber of Scienctists, and Esplora Interactive Science Centre, to name a few. Their main aim is that of encouraging more students to take up STEM-related subjects at school and to pursue careers in science. These projects include: Tiny Teen Science Cafés; Science Safari Kids; Fame Lab – Talking Science; and StartSTEM. These projects aim to:

- Combat gender stereotypes regarding STEM-related subjects from an early age of education (Sharklab-Malta, 2019);
- Engage primary school children and their parents with STEM-related subjects in an entertaining and joyful manner (Department of Information, 2020);
- Provide students with an opportunity to interact with STEM professionals, broaden their scientific knowledge, and recognise the value of collaboration within the scientific community (British Council, 2021);
- Encourage more youth to choose science-related subjects and pursue careers in STEM (Office of the Permanent Secretary, 2020).

How can informal learning sectors engage youths with STEM-related subjects?

Informal learning environments can be described as voluntary spaces where participants engage in activities that are not in line with the stringent curricula characteristic of formal learning (Hofstein and Rosenfeld, 1996). Such settings range from community and family activities (e.g., Bricker and Bell 2014; Zimmerman 2012) to more intentionally- designed spaces where trained professionals guide participants in hands-on experiences. Such areas include museums and science centers, summer camps, and community-based science youth programmes (Hofstein and Rosenfeld 1996) such as science clubs and science camps.

Informal learning provides an open-ended experience, and hence, promotes accidental learning (Sefton-Green 2013). Furthermore, such spaces equip learners in skills relating to solving for undefined problems that are complex and ambiguous rather than algorithmic and pre-determined (see Jonassen, 2000; Stewart and Jordan, 2017). Informal learning sectors also promote social interaction between STEM professionals and the general public. As such, this could be regarded as a clear indication that informal learning differs starkly from formal learning settings and might be more likely to engage youth with STEM-related subjects. For this study, focus will be placed on informal learning in science centres. Science learning amongst youth in science centre's demands special considerations since, youths are believed to be a crucial audience in the development of informal education strategies in the fields of STEM (NRC, 2009).

In what ways are science and art related to each other?

Throughout history, the sciences and the arts have been always perceived as two contradictory fields of thought. Some of the main reasons for this could be attributed to the significant number of misconceptions that exist in relation to the link that exists between the arts and the sciences. These include, but are not limited to, the fact that:

- the arts have been regarded as an expression of human feelings and emotions whilst science as that of a pursuit of the ultimate truth; and

- several schools of thought perceive the arts as being aesthetically pleasing but not essential as opposed to the science which are perceived as fundamental for the present and the future.

Despite this, current research is striving to debunk these inaccurate ideas and raise more awareness on the importance of complementing science with the arts and the arts with sciences. Some of the big questions dominating the relevant literature are whether the personal side of science can be utilised to engage in research in the arts and if artistic considerations can be utilised to do science (Eisner and Powell, 2002). Such link is now more important than ever since the predominant trend in contemporary practice is that, when the arts and science are linked together, a new way of exploration occurs, and this often results in a new knowledge invention that can lead to the achievement of industrial revolution 4.0 (Adzaman, Mokhtar and Musa, 2020). Apart from this, the proximity between the fields of science and art brings scientists and artists together and this assists them in enhancing their communication skills with the public. This, in turn, enables the public to better comprehend both fields in a clearer manner (Ede, 2005).

In line with this, science centres and science museums have recognized the importance of including art in their interactive exhibits. For instance, the Exploratorium museum in the United States has long been noted for its artist-in-residence program (Mintz, 2005), whilst Malta's Interactive Science Centre, Esplora, works in direct collaboration with the Arts Council to bridge the gap between the two fields. This strategy brings a wider range of visitors to science centres, particularly those coming from low socio-economic strata that cannot afford to visit art museums, and youths, most of whom are still financially dependent on their parents. On the other side of the coin, however, several issues arise: does this approach assist science museums and science

centres in creating the same level of cachet as art museums? Should science centres focus on deepening their connections throughout their communities, rather than trying to become what some describe as "clubhouses" for the disadvantaged audience? Would this really increase the number of youths who visit science centres and science museums?

Is there local data available establishing what skills sets are currently missing in specific STEM jobs?

ESTABLISHING THE SKILLS SETS WHICH ARE MISSING IN STEM-RELATED JOBS

Even though Malta has experienced an upsurge in the number of citizens in employment, there is still a deficit in the number of citizens that have the skills needed to be competent in the world of work (National Employee Skills Survey, 2017). This, in turn, has led to several initiatives and programmes aimed at increasing the number of citizens that master entrepreneurial skills. This is important especially in STEM-related jobs where the evolution of new technological advances has brought with it the necessity for people to gain completely new skills to be suitable for such jobs. In line with this, Malta has been working in direct collaboration with CEDEFOP and other EU member states to: embrace scientific approaches; forecast prospective emerging sectors and their corresponding required skills; and strategically plan new reforms and education programmes that could assist today's citizens to gain all the required skills needed to enter these new work niches.

Furthermore, recent statistics show that nearly half of the Maltese population of an employment age is deficient in digital skills. This contrasts with the EU average which adds up to 41% of the total number of European citizens. This should be regarded as a worrisome situation since STEM-related jobs entail a workforce that is digitally literate (National Employee Skills Survey, 2017).

This problematic issue is not restricted to Malta. In fact, in a European Commission report entitled "Europe needs more scientists" (Gago et al. 2005), reference is made to the importance of sustaining and increasing the number of STEM experts to drive today's technologically competitive Europe. The report suggests that today's school science education should better reflect real science experience and address the needs and desires of young people in a more effective manner (Osborne, Tytler, Clarke, 2008). Literature identifies four main contributing factors that are further reinforcing such an upsurge in the number of people that are not skilled to enter STEM-related jobs. These are:

- students' negative attitudes towards science as they move from their primary to secondary years of schooling, further reinforcing the issue that awareness on STEM-related careers should start from a very young age as previously mentioned;

- the drastic decline in the number of students, particularly girls (Bøe, Henriksen, Lyons and Schreiner, 2011), who choose science subjects during their post-secondary years of schooling;

- the deficit in the number of teaching professionals who are skilled in STEM-related working sectors; and

- the shortage in the number of qualified science educators (Tytler, 2007).

In addition to this, demand in STEM occupations is directly related to a country's economic status and employment rate. The higher the rate of employment, the higher the demand for employees who are competent to work in STEM- related fields. That being said, there are even some professions where the demand for STEM-competent employees in the labour market is far higher than the supply. The latter is true for engineering, mathematics, the earth sciences, chemistry, and statistics (DEST, 2006a).

As a result of this, there is a dire need for governmental bodies to start setting new reforms within the current education system and which substantiate the introduction of STEM in compulsory schooling. This could eventually result in an increase in the number of scientifically literate students and an innovative STEM workforce being in the pipeline (White House, 2009). In conjunction, science career exhibitions and career awareness informal talks can also play a pivotal role in raising the interest of youths in taking up STEM subjects and pursue scientific careers (Wu-Rorrer, 2017).

As such, non-formal science sectors can also have the potential to facilitate people in gaining the skills that they need to be competent in STEM-related careers. The ability to integrate knowledge and skills to solve problems, make sense of information in a logical manner, and collect and evaluate evidence before taking a final and well-informed decision, can be regarded as among the most important skills needed in today's STEM jobs (Lanthan, n.d.).

Which STEM careers have a difficulty in attracting youths? What affects uptake of certain careers over others? (e.g., gender issues, stereotypes, and so on)

Studies show that the field of engineering is usually the one that attracts the least number of youths for the simple reason that many young adults perceive mathematics and science as not enjoyable subjects to study despite being a prerequisite to excel in engineering (The National Academies, 2008; Hasna and Clark, 2009). Contrarily, there was a slight increase in the number of youths who choose a career in technology. This could be attributed to several reasons, namely among the fact that today's youths are raised in a society dominated by technology and there is also research showing how this influences job satisfaction (Chepseba, Kiflemariam, and Nziwa, 2018), even more now that most youth are digitally literate (Anderson, Chen, and Schroeder, 2013).

The most cited factors that influence youth subject choice on both a local and international level include but are not limited to:

- **Gender** – Gender stereotypes (Archer et al., 2013; Cundiff, Vescio, Loken, and Lo, 2013) persist in influencing youth's STEM subject choice, with females choosing subjects that are stereotypically regarded as "girlish" such as health, social, and biological sciences, with males choosing subjects like mathematics, chemical and physical sciences (Fullarton and Ainley, 2000; Sikora, 2014; Sikora and Pokropek, 2012)

- **Socio-economic status (SES)** – Students coming from families that have a high-SES status are more likely to pursue careers in science as opposed to students coming from disadvantaged families (Fullarton & Ainley, 2000)

- **Ethnicity** – Youth whose parents are born in a non-English speaking country are more likely to study mathematics and physical sciences than their counterparts who are born in English-speaking countries (Fullarton and Ainley, 2000)

- **Personal traits** - Students' perceived usefulness (personal value), self-perception of ability (self-concept) and the level of enjoyment in science and mathematics positively influenced their subject choices (Tripney et al. 2010)

- **Peer pressure** - Youth interaction with their peers is likely to leave an influence and can be crucial for the students to determine their subject choice (De Giorgi, 2010; Moldes, Biton, Gonzaga and Moneva, 2019)

- **Familial background** - Family plays a significant role in assisting students in shaping their engagement, aspirations, and achievement/attainment in science (Aschbacher, Li and Roth, 2010; Ferry, Fouad, and Smith, 2000; Gilmartin, Li and Aschbacher, 2006; Stake, 2006; Archer et al., 2012).

- **Teacher-student relationship** - Teacher's pedagogical approaches, sense of humour, and enthusiasm should be directly correlated to an increase in students' interest in science (Palmer, 2007; Logan and Skamp, 2013);

- **School culture** - School sector (government/Catholic/independent), school gender (single sex/co-educational), location (urban/rural), and school size are factors that have been widely reported as influences on STEM participation (Daly & Ainley, 1999). Students attending independent schools are 1.5 times more likely to enrol in physical sciences (Fullarton and Ainley, 2000). A school's decision to offer subjects such as physics, chemistry and biology has a direct influence on participation rates in these subjects (Smyth & Hannan, 2006).

Do other European countries have an issue with STEM and the youths too?

The lack of participation of youths in STEM is not a phenomenon restricted to the Maltese islands. This could be attributed to the fact that the young population aged between 15 and 19 years demands special attention. Being a critical demographic cohort, it is far harder to develop education strategies in both formal and informal science education (NRC, 2009). Literature suggests hindering youth from freely choosing their own learning choices, determined by their own motivations, sustained engagement, and curiosities further results in students' lack of interest in STEM-related subjects (Massarani, et al. 2019). Furthermore, research suggests that, as from 2009, the share of low achievers in science, irrespective of gender, has drastically declined in most European countries, expect for Greece, Hungary, Portugal, Slovakia, Sweden, Norway, and Iceland where the opposite trend is recorded. Despite this, Europe still has a worrying number of

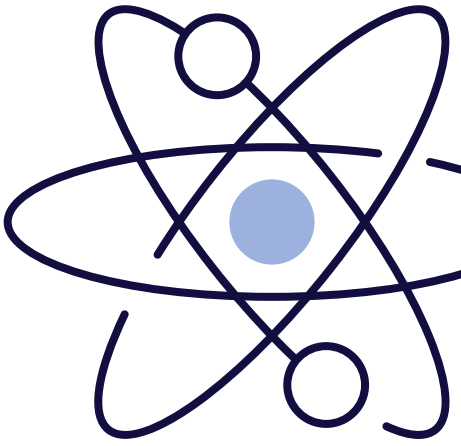
pupils with very low basic skills necessary for the world of work and progress is lacking behind, particularly in mathematics (European Commission, 2015).

That is one main reason why other initiatives are being put forward by the EU Commission to widen the uptake and dissemination of STEM education practices. The Commission is also recognising that informal science institutions and events are inspiring and mobilising young adults more than ever before. For instance, the annual European Union Contest for Young Scientists (EUCYS) (European Commission, n.d.) is one of Europe's leading events for showcasing young scientific talent. It brings together winners of national science competitions where the main protagonists are young people between 14 and 20 years of age who compete together with their European counterparts.

Are there any programmes - courses relating to this topic which are practiced abroad?

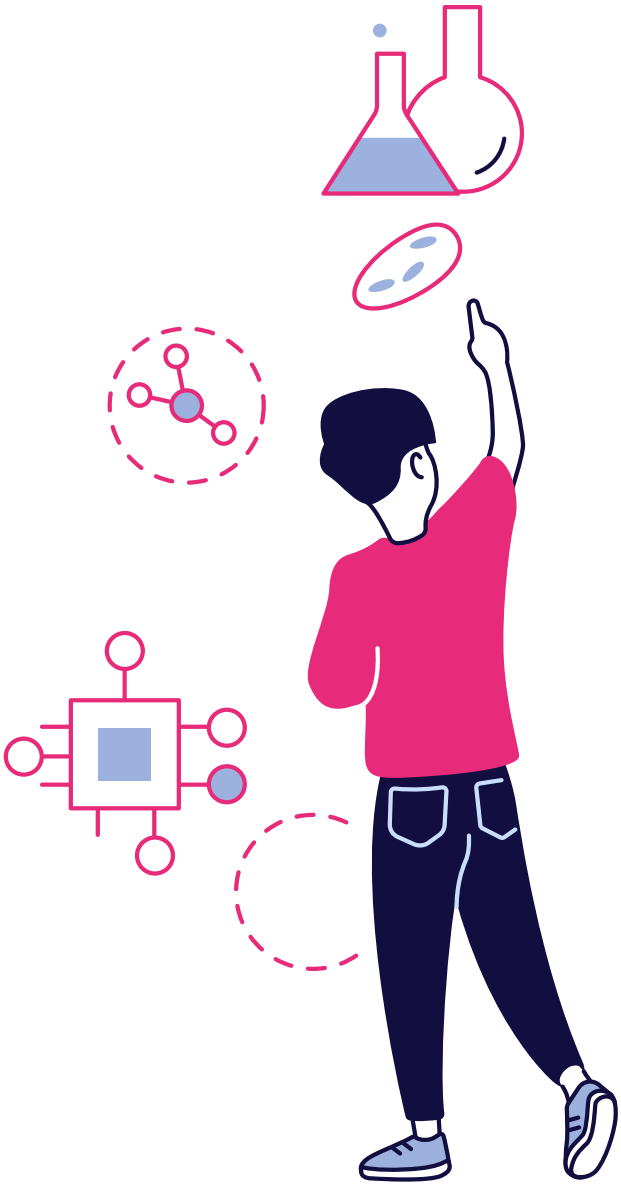
Literature shows that engaging youth in science through the arts in non-formal learning institutions such as science centres and museums is quite challenging. The latter could be attributed to the fact that adolescence is usually a turbulent time due to constant changes on the physical, hormonal, intellectual and social levels. This factor has formed the basis of a decade-long investment by the Wallace Foundation in the development of the YouthALIVE! programmes featuring up to 70 science centres and museums aiming to support and encourage youth from underserved communities to choose STEM subjects and pursue careers in STEM (ASTC, 2014).

Another interesting EU-funded initiative from 2016-2018, called "PERFORM," aims to examine the impact of creative science education approaches focused on performing arts in promoting young people's motivations and involvement with STEM in selected secondary schools in France, Spain, and the United Kingdom. PERFORM does so to bridge the gap between young people and science and to disrupt the unidirectional paradigm of scientific knowledge transfer. PERFORM has also brought together early career researchers (ECRs), performers, teachers, and high school students to create performance-based practices that looked at responsible research and innovation (RRI) and the social element of science (PERFORM, 2018). In turn, secondary school students engage in dialogue with researchers, have an active voice in the process of research and innovation and at the same time, gain a better understanding of the value in aligning science education with the arts and humanities (Eagle and James, n.d.).



CONCLUSION

This literature review has delved deeper into the challenges that Malta and other European countries are facing to engage youths in STEM and how interlinking the natural sciences with the arts can raise the bar and encourage more young adults to choose science subjects at school whilst pursuing careers in STEM. In conclusion, this overview should form the basis of the upcoming project since it gives a clear picture of the existing situation and sheds light on what should be done in the future to assist young people to see the relevance of being scientifically literate. This ties in with the fact that, countries throughout the world, need young people to become the future scientists and technologists so as to remain economically competitive. Technology and innovation are needed for humanity to solve the world's problems and that is why STEM-related employments are expected to increase in the coming years (Lytle and Shin, 2020).



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