STEM IN PRIMARY EDUCATION

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Abstract

There is general agreement among practitioners that the manner by which science is taught at the level of primary schools influences students' perceptions and attitudes towards science, and their uptake of STEM subjects and careers later on. Primary school teachers can play a central role, but they often feel insufficiently prepared to approach STEM subjects in their classes. Their challenges have been discussed between 20 STEM education stakeholders and 22 primary school teachers participating in the 13th Scientix Projects Networking Event. As a result, three key strategies were proposed to tackle the most challenging aspects of delivering effective STEM teaching in primary classrooms: raising the quality of teacher training, increasing easy access to high quality teaching resources and raising the STEM culture in primary education. This observatory presents a set of actionable recommendations for projects/organisations looking to address these challenges.

Key words: Science, Technology, Engineering and Mathematics Education (STEM education), primary education, recommendations, teacher training, resources

Introduction

Scientix, the community for science and mathematics education in Europe, initiated by the European Commission (Research and Innovation DG), set up the Scientix Observatory to help the development and dissemination of different science education projects and document good practices in various aspects of STEM education. The Observatory provides short synthesised articles, focused on one or several related themes or initiatives, or the state-of-play of various topics related to science education.

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The 13th Scientix Projects Networking Event (SPNE13) took place on 27 June 2018 in Brussels. The event focussed on the topic of STEM in primary education and involved discussions between project managers, project representatives and science educators. SPNE13, co-organized by Scientix, GFOSS[1], Cell EXPLORERS[2] and NUI Galway[3], brought together 20 participants from 15 STEM education projects and organisations with the aims of facilitating the exchange between initiatives addressing innovative STEM teaching in primary schools, reflecting on the role of STEM training for primary school generalist teachers, exploring a set of good practices in motivating students to pursue studies and careers in science from early ages, and defining a set of recommendations for follow-up actions in the area of STEM in primary education.

Disambiguation: This article discusses challenges to innovative STEM teaching at the level of primary schools. Definitions of STEM range from separately representing the four discrete fields indicated in the acronym, to various educational approaches situated at the intersections of any number of the four disciplines, to a fully integrated view of STEM as a whole (Sanders 2008, DeCoito 2014; Rosicka 2016). To avoid any confusion between the various definitions of STEM and the various educational approaches that can be implicit in the acronym, for the purpose of this article, STEM is used to refer to the four disciplines included in the acronym, regardless of how they are approached in the classroom. Furthermore, 'innovative STEM teaching' refers to the use of classroom-based pedagogies, which differ from more traditional teaching methods, including (but not limited to) project/problem-based learning (PBL), teaching with inquiry, collaborative learning, student-led learning, integrated learning, etc.

The importance of STEM in primary school teaching

In Europe, various reports recognise the central role played by STEM education in cultivating key competencies (European Commission 2007, Kearney 2015). Focusing on STEM education is seen as an essential step in addressing future shortage of STEM-skilled labour (Businesseurope 2011). However, this focus goes beyond simply addressing the 'STEM labour crisis'. There is a recognised need to address the "STEM knowledge shortage" and to ensure that children are literate enough in science, technology, engineering and mathematics to pursue a successful career, to be prepared for transitioning to new ones (Charette 2013) and to exert a complete and responsible citizenry (EU, 2015). Furthermore, science education is increasingly leaning towards not imparting facts and information, but teaching an objective way of thinking and allowing young learners to be comfortable in admitting ignorance (Brown, 2013)

At the European Union's policy level, boosting interest in mathematics, science and technology is seen as a fundamental objective in order to equip young Europeans with the knowledge, skills and understanding to allow them to engage fully in society, influence and shape the future, and participate in economic activities that increasingly depend on STEM skills (Eur-Lex 2002).

[1] https://gfoss.eu/
[2] https://www.cellexplorers.com/
[3] https://www.nuigalway.ie/

To achieve this scientifically literate Europe, there is a strong case for ensuring effective STEM teaching from early years in order to best target scientific knowledge, competencies and attitudes.

In the literature, we find a general consensus on encouraging pupil's interest in STEM early on to greater facilitates student understanding of the subject matter, reduces barriers to entering jobs related to STEM fields and influences future career choices and attitudes to science (Becker & Park, 2011). Early effective STEM teaching can help lay the foundations for future acquisition of more complex knowledge. In the process of learning, new knowledge is connected to prior knowledge – if the prior foundation is robust, new knowledge meets the necessary conditions to develop (Ambrose 2010).

Attitudes towards science are also fixed from early ages (Turner, 2011) and positive attitudes tend to erode with pupils' advancement in the educational system (Murphy and Beggs, 2003). Identified factors associated with this decline, and relevant to this report, include "the perceived difficulty of school science and ineffective science teaching", and "primary teachers' lack of confidence in teaching science and their insufficient scientific knowledge background". These factors, in concert, also tend to reinforce gender stereotypes in perceptions of science (Narayan et al., 2013; Chambers, 1983; Hillman et al., 2014). Further, family structure has a well-documented effect on science perceptions of children (Archer et al., 2012).

Three obstacles to effective STEM teaching in primary schools

During the SPNE13, 20 participants, representing schools, universities, STEM education and public outreach projects and organisations, met to discuss the main challenges faced by primary school teachers in bringing innovation to their STEM teaching and to produce a set of recommendations for different stakeholders on how to support primary school educators in overcoming these challenges.

The programme of the event included one open discussion of 50 minutes with 22 primary school teachers from eight countries[4] who were invited to participate only in this first part of the programme. Their contributions identified three key issues, which were discussed by the main group of SPNE13 participants during the following two discussions sessions. The main group reflected on the issues highlighted by the group of primary school teachers and proposed a set of recommendations for addressing them.

Foremost, none of the 22 participating teachers felt that their school placed enough emphasis on STEM education at the primary level. Further, only a few teachers felt that they had enough support from their school, regional or national government or any other stakeholders for implementing STEM in their primary-level teaching. The type of support needed was clustered in three groups of interconnected topics, namely:

> [1] The need for **high quality teacher training** to support primary school teachers in bringing innovation to their STEM teaching.

[4] The following countries were represented in the group of primary school teachers: Belgium, Croatia, Cyprus, the Czech Republic, Poland, Portugal, Slovenia and Turkey

[2] The need to offer teachers **access to high quality teaching resources** and materials to guide them through approaching STEM with young pupils.

[3] The need to create a so-called "**STEM culture**" based on a shared understanding among key education stakeholders of the role STEM education can play in preparing pupils for the future.

Obstacles and recommendations

Teacher Training

Primary school teachers' confidence in teaching science has been of general concern throughout recent decades. In the 1990's, Harlen (1997) reported the low levels of United Kingdom primary teachers' confidence and ability in approaching topics such as science, information technology and technology. Ten years on, Murphy, Neil and Beggs (2007) reported that, although progress was achieved in increasing teacher confidence, the problem persists: half of the teachers surveyed in their study have identified the "lack of teacher confidence and ability to teach science as the major issue of concern in primary science." This lack of confidence is rooted in diverse and often interconnected factors. Generalist primary school teachers' lack of science content knowledge (Harlen 1997), or their lack of knowledge in delivering scientific concepts to primary school pupils (Palmer 2015), are some explanations drawn from the literature.

Unsurprisingly, the importance of training programmes for primary school teachers to assist in bringing innovative STEM teaching approaches to their classrooms, was one of the main challenges identified by the SPNE13 participants.

Teacher training can be offered by various actors, and organised either at the level of the schools, by Ministries of Education, through national organisations (such as teacher training institutions) or by international organisations which, while less connected to national curricula or contexts, often situate themselves at the forefront of pedagogical innovation. Flexible models are also explored, with online training having an important role to play in the teachers' continual professional development (CPD), with the added bonus of convenience and cost effectiveness. Massive Open Online Courses, or MOOCs, and webinars specifically targeting teachers are available on various platforms, and often benefit from the support of national or regional education agencies[5]. While this offer is generous for secondary school STEM teachers, teacher training specifically targeting primary school STEM teaching appears limited, an issue corroborated by the group of teachers in attendance at SPNE13.

Another issue is related to maximizing the impact of teacher training. It was recommended that STEM education initiatives find ways of ensuring that teachers exposed to innovative teaching pedagogies share this best practice with colleagues in their schools and that they benefit from appropriate support structures (including the support of key stakeholders) in doing so. There

[5] One such example is the Opening Minds to STEM Careers MOOC launched on the European Schoolnet Academy and supported by Scientix, the community of science education in Europe, STEM Alliance and SYSTEMIC, which received official accreditation from educational authorities from three Spanish regions: Castilla y León, Land of Valencia and Región de Murcia.

is evidence to the positive impact peer coaching strategies have on enhancing staff development efforts and offering support for teachers implementing new strategies (Showers & Joyce 1996).

To tackle the limited availability of STEM training for primary school teachers, partnerships involving universities and research institutions should be developed, to ensure more teacher training of high quality is provided, in both content and pedagogical knowledge.

The conditions for maximizing the impact of training teachers into bringing innovative STEM teaching in their classes should also be created. The primary school educators participating in training sessions should be encouraged to act as ambassadors and peer trainers in their schools/local environments, so good practices can permeate to the level of the less advanced-teachers. Projects could consider organising training sessions involving teachers and their head of schools, to scaffold structures of support at the school level. Moreover, projects should consider developing 'communities of practice' – online participatory spaces where teachers can seek peer support from their more advanced colleagues whenever faced with specific challenges.

Access to STEM teaching resources and materials

Access to good quality resources and materials is of key importance to ensure STEM teaching is carried out effectively at the level of primary schools.

Materials are often costly and unequally distributed among schools. Particularly when it comes to introducing technology in schools (the "T" in STEM), significant differences become visible between schools in rural versus urban environments, with regards to equipment and internet connectivity (Hunter 2017). Initiatives aimed at closing these gaps should reflect on allocating school support based on needs assessment, taking into account existing data on geographical areas of low STEM intervention (c.f. the Discover Programme of Science Foundation Ireland).

Teaching resources focused on STEM teaching in primary education are available online, and published in various national and international repositories, or offered through online platforms of STEM initiatives. However, STEM education projects usually target secondary schools, thus making the offer for younger learners quite restricted. Simply put, STEM delivery at a primary school level appears as a lower priority.

In addition, if resources are developed through the work of international projects, subsequent localisation is often required in terms of language (there is a strong need for resources to be offered in local languages to be used by – and useful to – teachers), curriculum integration (teachers need support in integrating and adapting materials which are not always developed to fit their needs) and cultural relevance. On the same line, thought should be given to the 'openness' of educational resources, to facilitate their adaptation in terms of the format in which they are offered, and of the publication licences.

To support primary school teachers in making use of available STEM resources, projects should consider developing guidelines for their implementation in addition to providing the resources themselves. Initiatives should encourage the collaboration between teachers and scientists to ensure that the resources developed are scientifically accurate and reflect the teachers' pedagogical needs. To encourage

teacher participation, institutions could consider providing small grants for teachers who carry out this type of work.

Moreover, resources should be developed around principles of openness and with consideration for the teachers' need to adapt and localise educational content. Support could also come from peers: teachers who were successful in implementing STEM resources in their school could be encouraged to form communities, share experiences and lessons learnt, and offer advice to their colleagues looking to do the same.

Creating a "STEM culture"

Initiatives focused on improving the quality of primary school STEM teaching need to mobilize the support of all education stakeholders in order to consolidate a "STEM culture" – in other words, to create a general climate favourable to improving STEM education.

Key limitations involving different stakeholders were identified, including lack of awareness, involvement, engagement and allocated funding for early STEM teaching. In primary schools, there is a low level of awareness of primary school generalist teachers of the importance of allocating part of their efforts to improving their STEM teaching. At the level of Ministries of Education, there is little or no allocated funds to either facilitate professional development opportunities in STEM or allow the purchase of materials or small equipment for primary school teachers. At the level of STEM industries, there is little involvement in primary school initiatives, such as campus visits, provision of financial assistance or resource donation. At the level of universities/research institutions, there is a sublevel of engagement in joint partnerships with schools, in supporting practically or financially the flow of content/scientific knowledge (from universities to schools) and of pedagogical knowledge (for example from schools/experienced teachers to universities offering training to pre-service teachers) or in appointing dedicated science educational outreach officers.

Science education outreach initiatives can play an important role in raising awareness of the importance of science in society and in mobilizing the support of different stakeholders. Science events, festivals and national/international competitions which celebrate innovative teaching should be organised and appropriately disseminated. Such initiatives should look to achieve media coverage and make good use of social media channels to attract diverse audiences (including families). Partnerships with highly visible international organisations (such as NASA, ESA, etc.) could be sought to increase the prominence of these events and strengthen the relevance and validity of science outreach in third level institutions.

Initiatives should collaborate closely with teachers to address the challenge of low primary school teachers' awareness of the importance of STEM teaching from early ages and to maximize the usefulness of the materials produced. Similarly, initiatives should look to foster the collaboration between universities / research institutions and schools to facilitate the flow of knowledge between the two.

Conclusions

As is shown from the above findings, further action is required to ensure high quality STEM teaching at the primary school level. The current sporadic support for primary school teachers in implementing innovative teaching in their classes and various limitations linked to resource availability for primary school STEM teaching – all point to a scarcity of motivation towards primary school STEM teaching at the level of education stakeholders. Presuming that generalist primary school teachers can also deliver high quality science, with little additional training, resourcing or support, is naïve.

The 13th Science Projects Networking event brought together specialists in STEM education to discuss the main challenges faced by primary school teachers in bringing innovation to their STEM teaching. Three clusters of issues emerged, and participants produced a set of actionable recommendations for projects/organisations.

- To address the need for high quality STEM training for primary school teachers, partnerships with universities should be developed, with thought given to the impact of training offered and its continuance beyond a single visit.

- To widen access to resources and materials for teaching STEM in primary schools, projects should offer open resources, accompanied by pragmatic implementation guidelines, and encourage practitioners to support each other in bringing these resources to the classroom. Partnerships involving different stakeholders (schools, universities, private companies, etc.) should be pursued to ensure that resources and materials remain relevant.

- Finally, STEM education projects should look to engage all relevant stakeholders and raise awareness of the positive implications of a STEM-literate society in terms of economic benefits and societal dividends.

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