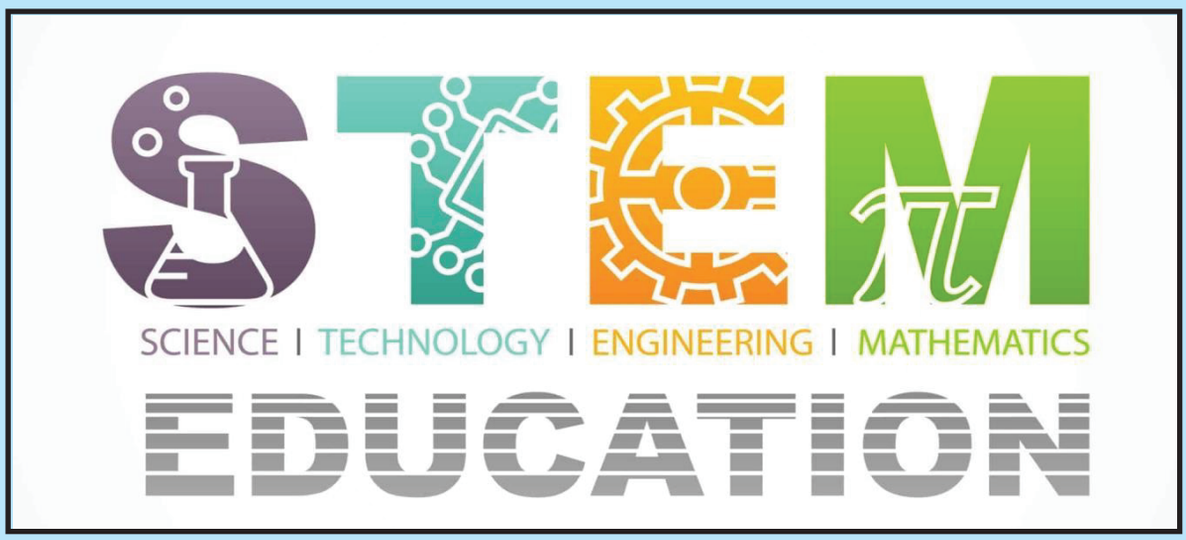
NEC Research Series (2023) – 8

STEM EDUCATION IN SRI LANKAN GENERAL EDUCATION SYSTEM: CURRENT STATUS AND WAY FORWARD



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NEC Research Series (2023) – 8

STEM Education in Sri Lankan General Education System: Current Status and Way Forward

National Education Commission
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Email: chnec@slt.lk; chnec2018@gmail.com Web: www.nec.gov.lk
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Consultants
Prof. Prasad Sethunga
B. A. in Education (Kyoto University of Education, Japan), M. A. in Education (Kyoto University of Education (Educational Administration) Japan), PhD in Education(University of Tsukuba (Educational Administration) Japan)

Prof. Sakunthala Yatigammana Ekanayake
National Diploma in Teaching (National Institute of Education), B. Sc in Bio Sciences (University of Peradeniya) Postgraduate Diploma in Education (University of Peradeniya), M. Sc in Science Education (University of Peradeniya), Postgraduate Diploma in IT Education (University of Peradeniya), Postgraduate Diploma in Research Methods (Graduate School of Education, The University of Bristol, UK), PhD Graduate School of Education, The University of Bristol, UK.

Research Team
Dr. Nirosha Priyadarshani (Former Policy Research Officer)
Mr. K.H. Suranga Lakmal (Policy Research Officer)
Mrs. W.D. Achala Damayanthi (Policy Research Officer - Acting)

Design and Printing
State Printing Corporation, Sri Lanka
Panaluwa, Padukka.

Preface

The National Education Commission (NEC), established by the National Education Commission Act No. 19 of 1991 is a body corporate with the primary mandate to function as the apex policy formulation body of the education sector, and to engage in policy analysis and research, review the ongoing programme and plans with respect to education and undertake research on issues of importance. Going along with the mandate, the NEC has embarked on series of research addressing the some of the current issues faced by the education sector.

This volume deals with the research study gone into examine the extent of diffusion of the concept of STEM education in general education system and the preparedness of key stakeholders in embracing this concept at the classroom teaching and learning. The acronym STEM stands for science, technology, engineering, and mathematics, and STEM education approach is an interdisciplinary approach to learning where academic concepts are coupled with real-world lessons in which students learn by engaging in hands-on, activity-based learning. The STEM education approach was first introduced in 2001 by U.S. National Science Foundation as a way to promote students' interests in studying science, mathematics, technology, and engineering disciplines. Since then, the STEM education approach has been extended beyond the boundaries of the United States. Its recent successor, STEAM incorporates the discipline of arts, which expands the limits of STEM education and application by incorporating ideas of creativity and innovation often seen in arts disciplines into the STEM education approach.

In spite of acknowledging the value of adopting STEM education approach, particularly in K-12 general education system by the educationists, teachers, parents, and policy makers, and despite taking several efforts to promote STEM education in Sri Lanka, it appears that there is still a distinct lack of consensus among the stakeholders including policy makers, administrators, teacher educators, and teachers surrounding how the concept of STEM education approach could be conceptualized and institutionalized. Yet, not much research has gone into assessing the preparedness of schools for the successful adoption of the STEM education approach in general education. Therefore, this study was conducted with the aim of examining the extent of diffusion of STEM Education concept among teachers and the preparedness the schools system to adopt the elements of STEM/STEAM education in the Sri Lankan K-12 general education system, with particular emphasis on identifying the limiting factors that hinder full embracing this universally accepted education technology with the view to propose the way forward.

Prof. Harischandra Abeygunawardena
Chairman
National Education Commission
October 2023

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1. Introduction

The acronym STEM stands for science, technology, engineering, and mathematics, and STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real world lessons 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 economy[1]. Numerous research reports have shown that Science, technology, engineering and mathematics (STEM) education, and economic prosperity and a nation's power are highly correlated in the globalized world [2].

The value of STEM education has been articulated in many literatures. In general, STEM education equips people the competencies or 21st century skills to meet the current skills demands of labor market and make them more employable. Each STEM component brings a valuable contribution both to secondary and tertiary education to produce well-rounded graduates. Science gives learners an in-depth understanding of the world around us. It helps them to become better at research and critical thinking. Technology prepares young people to work in an environment full of high-tech innovations. Engineering allows students to enhance problem-solving skills and apply knowledge in new projects. Mathematics enables people to analyze information, eliminate errors, and make conscious decisions when designing solutions. STEM education links these disciplines into a cohesive system. Thus, it prepares professionals who can transform society with innovation and sustainable solutions. Additionally, it aims to have more students graduating from the STEM fields. Therefore, almost all stakeholders agree that STEM education is about creating more qualified workforce to maintain or to gain a competitive edge within national and across the global labour markets and economies[3,4].

1.1 STEM Education Approach – Global Context

At the turn of the twenty-first century, a consensus emerged in US, that U.S. students' achievements in the science, technology, mathematics, engineering (STEM) disciplines were falling short compared to other industrialized countries. As way to address this, the National Science Foundation (NSF), in 2001 introduced STEM education approach as a way to promote students' interests in studying science, technology, mathematics, engineering (STEM) disciplines in K-12 education system (i.e. kindergarten+12 years of general education) to enhance students' problem-solving, analytical and thinking skills, and science competencies. In the same year, the acronym STEM was

[1]Holmlund, T.D.,Lesseig, K, & Slavit, D. (2018). Making sense of "STEM education" in K-12 contexts. International Journal of STEM Education (2018) 5:32 https://doi.org/10.1186/s40594-018-0127-

[2] Machi, E. (2009). Improving US competitiveness with K-12 STEM education and training. Heritage special report. SR-57. A report on the STEM education and National Security Conference, October 21-23, 2008. Washington, DC:Heritage Foundation. Retrieved from https://files.eric.ed.gov/fulltext/ED505842.pdf

[3] Breiner, JM, Harkness, SS, Johnson, CC, Koehler, CM. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. School Science and Mathematics, 112(1), 3–11.

[4] Holmlund, T.D.,Lesseig, K, & Slavit, D. (2018). Making sense of "STEM education" in K-12 contexts. International Journal of STEM Education (2018) 5:32 https://doi.org/10.1186/s40594-018-0127-

changed to STEM to reflect the standards in science, mathematics, engineering, and technology. Further impetus towards this push was emerged since the early 2000s in the United States following the publication of several key reports. In particular, Rising Above the Gathering Storm (2005), a report of the U.S. National Academies of Science, Engineering, and Medicine, highlighted the links between prosperity, knowledge-intensive jobs dependent on science and technology, and continued innovation to address societal problems. U.S. students were not achieving in the STEM disciplines at the same rate as students in other countries. The report predicted dire consequences if the country could not compete in the global economy as the result of a poorly prepared workforce. As a result, the disciplines of science, technology, engineering, and mathematics became increasingly integrated into K-12 curricula and beyond. Further, greater attention was focused on science, mathematics, and technology research; on economic policy; and on education as these areas were seen as being crucial to maintaining U.S. prosperity[5].

Since then, the STEM education approach has been extended beyond the boundaries of the United States. Over the past few decades, general education systems in many countries across the world have witnessed an increased focus on teaching science, technology, engineering, and mathematics (STEM subjects) using the STEM education approach to prepare students to meet the needs of the 21st century[6]. In the 21st century, individuals are required to possess skills such as critical thinking, entrepreneurship, communication and ICT literacy, collaboration, decision-making, leadership, problem-solving, responsibility, and creativity[7]. Further, this kind of interdisciplinary integration increases the motivation and interest of students in learning STEM subjects and thus will help them to pursue tertiary education in STEM disciplines and position themselves in STEM careers. With these initiatives, the STEM education approach has become an international agenda driven by the changing global economy and workforce needs in both developed and developing countries[8,9,10,11] .

Many countries both high and middle-income countries have realized the need to invest in STEM education-related fields and implemented many programmes to promote the adoption of the STEM approach at all levels of education[12] . Its recent successor, STEAM incorporates the discipline of arts,

[5]HALLINEN, J. 2022. *STEM education curriculum* [Online]. Encyclopedia Britannica. Available: https://www.britannica.com/topic/STEM-education [Accessed].

[6] DARE, E. A., KERATITHAMKUL, K., HIWATIG, B. M. & LI, F. 2021. Beyond Content: The Role of STEM Disciplines, Real-World Problems, 21st Century Skills, and STEM Careers within Science Teachers' Conceptions of Integrated STEM Education. *Education Sciences,* 11**,** 737.

[7] TUNC, C. & BAGCECI, B. 2020. Teachers' Views of the Implementation of STEM Approach in Secondary Schools and The Effects on Students. *Pedagogical Research,* 6**,** em0085.

[8] KENNEDY, T. J. & ODELL, M. R. L. 2014. Engaging students in STEM education. *Science Education International,* 25**,** 246-258.

[9] SIREGAR, N. C., ROSLI, R., MAAT, S. M. & CAPRARO, M. M. 2019. The effect of Science, Technology, Engineering and Mathematics (STEM) Program on Students' Achievement in Mathematics: A Meta-Analysis. International Electronic Journal of Mathematics Education, 1, 1-10.

[10] KURUP, P. M., LI, X., POWELL, G. & BROWN, M. 2019. Building future primary teachers' capacity in STEM: based on a platform of beliefs, understandings and intentions. *International Journal of STEM Education,* 6.

[11] MADANI, R. A. 2020. Teaching challenges and perceptions on STEM implementation for schools in Saudi Arabia. European Journal of STEM Education, 5, 03.

[12] TUNC, C. & BAGCECI, B. 2020. Teachers' Views of the Implementation of STEM Approach in Secondary Schools and The Effects on Students. *Pedagogical Research,* 6**,** em0085.

which expands the limits of STEM education and application by incorporating ideas of creativity and innovation often seen in arts disciplines into the STEM education approach[13].

1.2 STEM Education Approach – Sri Lankan Context

Despite the availability of overwhelming evidence of the benefits of the STEM education approach in general education (or the K-12 system of education), Sri Lanka is yet to embrace it formally to internalize it at the school level. Nonetheless, there have been several initiatives taken, mostly in an incoherent manner to promote the adoption of STEM education approach in the general education system in Sri Lanka.

One of the notable attempts was the initiative taken by the National Science Foundation (NSF) in 2017[14]. The report, titled "Interim Report of the Working Committee on Stem Education 2017; Transforming Knowledge Silos to STEM Experience, stated "*STEM Education in Schools is the only way we foresee to bring up a future ready workforce in the face of severe challenges for sustainable economic growth. STEM Education would provide the integrated mindset for the new generation to tackle real life problems with real solutions*". This report, highlighting the findings of World Economic Forum Human Capital Report 2016, stated that *"though Sri Lanka, has earned a bright spot in the region in terms of educational achievements, because of high educational enrolment and basic education completion rates as well as on the basis of positive perceptions of the quality of its primary schools and education system, it underperforms when it comes to translating the potential of its young people to the workforce, with one in four young people not active in employment, education or training, thus giving an indication of our gaps in education"*. It further stated that "*since 2001, STEM letters have been a part of educational vocabulary but it did not translate into an active process. Our learning process is dependent on silo based curricula of individual subjects. These are taught in the classroom and students cram up what is taught. Teachers specialize in individual subjects and do not necessarily have the insights of multidisciplinary work".*

Having done a comprehensive review of all aspects from K-12 curriculum, teaching and learning and assessments, and human resources, the Report of the Working Committee On Stem Education 2017; Transforming Knowledge Silos to STEM Experience, proceeded to make 27 recommendations for promoting STEM education. The main focuses of those recommendations were primarily focused on advocating the teaching of STEM subjects by adopting an integrated approach thus getting away from Silo-based teaching approach. This report also suggested that STEM subjects have to be taught in conjunction with other chosen subjects such as English, Aesthetics, and Economics.

Subsequent, to the NSF report, the approval of the Cabinet of Ministers was granted in 2017 (Cabinet Paper No. 16/1389/716/035) to prepare a strategic plan to reform the education system including the integration of STEM education approach and to strategize this initiative, the 2018 budget had allocated a reasonable amount of funds for promoting STEM education. In support of this initiative, the Science Education Branch of the Ministry of Education in liaison with a pool of resource persons

[13] YAKMAN, G. 2008. *STEAM Education: an overview of creating a model of integrative education.* Virginia Polytechnic and State University.

[14] NATIONAL SCIENCE FOUNDATION, S. L. 2017. INTERIM REPORT OF THE WORKING COMMITTEE ON STEM EDUCATION 2017: http://www.nsf.ac.lk/images/2022/STEM_Committee_Interim_Report_2017.pdf

conducted several workshops to achieve multiple objectives such as defining STEM education approach according to the Sri Lankan context, developing concept papers on integration of STEM education approach in primary, junior secondary, senior secondary curricula coupled with a proper evaluation system, and identifying capacity development in 2020.

Further, the Sectoral Oversight Committee on Education and Human Resources Development of the Parliament published a report in 2020 which specified nine strategic pillars to achieve the implementation of STEM education approach and SDG 4 targets[15]. In addition, more recently, the National Education Commission through its National Education Policy Framework (2020-2030) prescribed in June 2022 has strongly advocated the adoption of the STEM education approach in the Sri Lankan Education System[16].

Despite the above efforts to promote STEM education in Sri Lanka, it appears that there is still a distinct lack of consensus among the stakeholders including the education administrators, curriculum developers, administrators, teacher educators, and teachers on how the concept of STEM education approach could be conceptualized and institutionalized. This has been the case with many other countries too[17]. It is very conceivable, if Sri Lankan General Education System to adopt and internalize the STEM education approach - that is to embrace experiential learning pedagogy in which the application of knowledge and skills are integrated through in-context projects or problems focused on learning outcomes tied to the development of important college and career readiness proficiencies, the base level implementers, the teachers must have correct perceptions and preparedness to adopt such pedagogy and be provided with the required physical and learning resources. At the same time, administrative level officials' involvement and their readiness to facilitate the teachers to embrace and adopt this approach also affect the successful implementation of the STEM education approach at the school level.

1.3 Importance of the Study

Despite many initiatives taken by a multitude of institutions to promote the internalization of the concept of the STEM education approach in Sri Lanka, not much research has gone into assessing the preparedness of schools for the successful adoption of the STEM education approach in general education. Therefore, this study was conducted to explore the extent of adoption of elements of STEM/STEAM education in the Sri Lankan General Education System and the limiting factors that hinder the adoption of this universally accepted education technology with the view to propose the way forward.

[15] THE SECTORAL OVERSIGHT COMMITTEE ON EDUCATION AND HUMAN RESOURCES DEVELOPMENT, S. L. 2020. 2020 - 2030 National Policy and Strategic Plan on STEM Education. In: MARASINGHE, A. (ed.).

[16] National Education Commission. (2022). National Education Policy Framework (2020-2030). In National Education Commission. Department of Government Printing. https://nec.gov.lk/national-education-policy-framework-2020-2030/

[17] STEHLE, S. M. & PETERS-BURTON, E. E. 2019. Developing student 21st Century skills in selected exemplary inclusive STEM high schools. International Journal of STEM Education, 6.

2. Research Approach

2.1. Objectives of the Study

2.1.1 Main Objective

To assess the extent of adoption of elements of STEM / STEAM education in the Sri Lankan General Education System and recommend ways of further promoting STEAM education approach.

2.1.2 Specific objectives

i) To assess the degree of awareness of key stakeholders on STEM /STEAM education approach
ii) To explore the availability of physical and human resources; teachers, teaching material, and facilities in the schools in terms of STEM/ STEAM education approach
iii) To identify the professional development opportunities for teachers in relation to STEM / STEAM education approach.
iv) To explore ways of further strengthening STEM/STEAM education approach into General Education

2.2. Research Design

According to the objectives, the mixed-method design was utilized for this research as it allows the investigator collects and analyses data, integrates the findings and draws inferences using both qualitative and quantitative approaches or methods in a single study[18].

2.3. Sampling Procedure

The selection of the study sample was done using a stratified sampling method. The sample cohort selected was teachers of junior secondary, senior secondary, and collegiate level education from schools in 9 districts representing 1AB, 1C and Type 2 schools. Three Provinces including Western, Central, and Eastern were selected based on the findings of study conducted by the National Education Research and Evaluation Center (NEREC) which reported three levels of performance (i.e. high, medium, and low) at the National Assessment of Achievement of Students Completing Grade 8 in Year 2016 in Sri Lanka[19]. Within a Province from each district, two education zones were selected based on performance level (i.e. high or low) at the G. C. E. (O/L) from Science and Mathematics subjects. Within each selected education zone, all 1AB, 1C, and Type 2 schools were considered, thus making the total sample size as 1051 schools. This number represents 10% of the total schools in the country.

[18]Creswell, J.W., & Tashakkori, A. (2007). Developing publishable mixed methods manuscripts . *Journal of Mixed Methods Research*, 1, 107-111

[19] NEREC, S. L. 2017. National Assessment of Achievement of Students Completing Grade 8 in Year 2016 in Sri Lanka.

2.4 Data Collection Tool

The questionnaire consisted of 4 parts including i) demographic information of teachers, ii) teachers' awareness on STEM education approach, iii) availability of learning aids and physical resources, and iv) availability of professional development opportunities on STEM education approach for teachers. The response format of the questionnaire included forced choices coupled with Likert Scale of rating and open-ended questions. The questionnaire was pretested with six (6) teachers and updated based on the feedback from the respondents.

The questionnaire was randomly distributed to three teachers from each selected school (a total of 3,153 teachers) representing all levels of junior secondary, senior secondary, and collegiate level education. The questionnaire was administered to the teachers through the channel of Provincial Directors, Zonal Directors and School Principals.

2.5 Data Analysis

The survey data were fed directly to the SPSS and analysis was done using SPSS 22.0 for percentages, descriptive statistics and correlations. The correlation between awareness of STEM education with selected variables were measured using Spearman Rank-order Correlation. The reliability test of the instrument was tested using Cronbach alpha value and the results of the test were valued at 0.976 which is considered as an acceptable level based on the common threshold values.

3. Results

From the target sample of 3,153 teachers, responses from 1310 teachers (42% response rate) were used in this analysis. The responses of the teachers were analyzed and the pertinent results are presented under the following headings: a) Demographic information of respondents, b) Qualification profile of respondents, c) Respondents' awareness of the STEM education approach, d) Respondents' perception of STEM education approach, e) Respondents' perception on availability of learning aids and physical resources to adopt STEM education at the classroom, and f) Respondents' perception on opportunities available for continuing professional development of teachers on STEM education approach.

3.1 Demographic Information of Respondents

The demographic profiles of 1310 teachers were analyzed using frequency and percentages and the results are given in Table 1. Of the 1310 teachers who participated in this survey, 1046 (79.8%) were females. A majority of the respondents (94.8%) were in the age group 30 to 60 years and belong to Class 1 (33.8%) or Class 2 category (53.9%). Similarly, in terms of experience in teaching, 64.7% of respondents had more than 10 years of teaching experience.

Table 1: Demographic Information of Respondents

	Respondent	Frequency	Percentage %
Gender	Male	264	20.2
	Female	1046	79.8
Age	Less than 30	68	5.2
	30-39	441	33.7
	40-49	476	36.3
	50 or above	325	24.8
		1310	100
Grade of teacher service	Class 1	443	33.8
	Class 2 – Grade I	276	21.1
	Class 2 – Grade II	430	32.8
	Class 3 – Grade I	147	11.2
	Class 3 – Grade II	14	1.1
		1310	100

Years of teaching experience	01 - 05 years	194	14.8
	6 -10 years	268	20.5
	11 -15 years	251	19.2
	16 -20 years	222	16.9
	21 – 25 years	186	14.2
	Over 26 years	189	14.4
		1310	100

Source: Sample Survey

3.2 Qualification Profile of Respondents

Educational and professional qualifications of the respondents are depicted in Fig.1 As depicted,59% of respondents had graduate-level qualifications (BA, BSc, B.Ed. B. Com, etc.) and 5 % had postgraduate level qualifications (MA, MSC, PhD, etc.). Among the graduate-level qualified teachers, 35.6% were with BA degree qualifications while 12.4 % were with BSc degrees. The percentage of teachers with B.Ed. qualifications were 4%. Still, a sizable population of respondents either had Diploma in Education (5.4%)or National Diploma in Teaching (18.0%). A sizable number of respondents (15.2%) were with G.C.E. (A/L) or G.C.E. (O/L) qualifications.

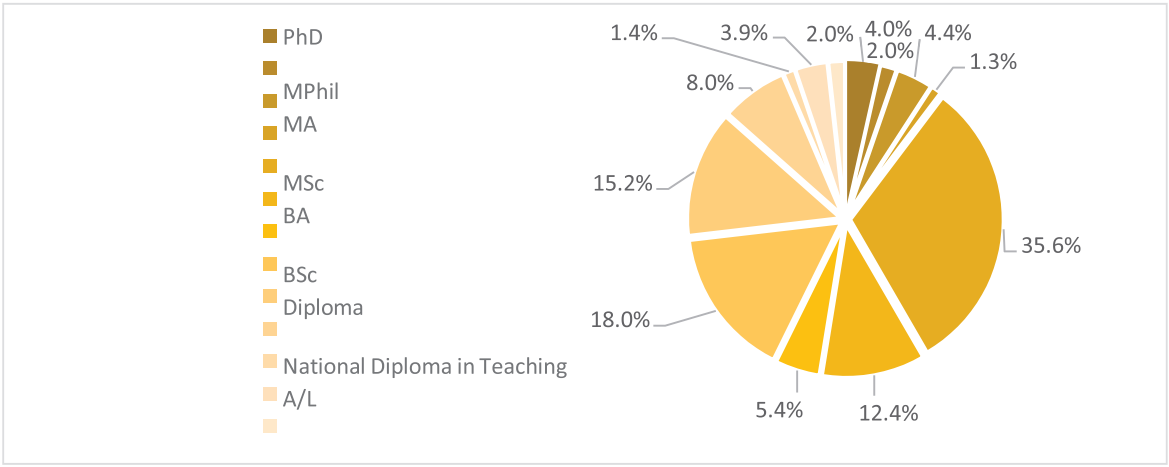

Figure 1: Educational and Professional Qualifications of Teachers

As shown in Fig. 2, 48.0% of teachers had received post-recruitment training; 35.8% had PG Diploma level training either in Education (34.7%) or in Science Education (1.1%) or other disciplines (3.0%), and 6.9% had Master's level or higher-level qualification (2.0%).

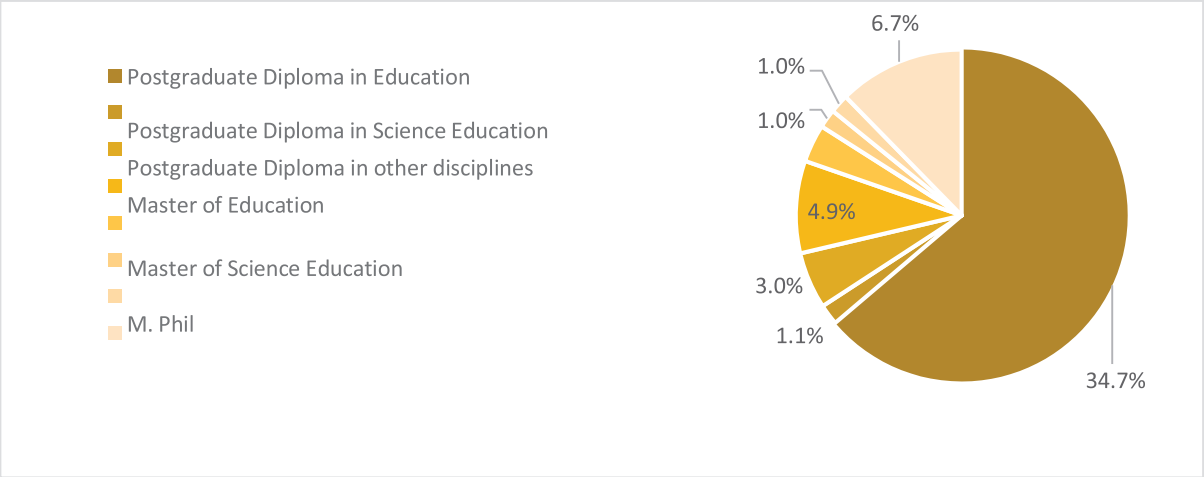

Figure 2: Post-recruitment Training Received by Respondents

3.3 Teachers' Awareness of the STEM Education Approach

As shown in Fig. 3A, among 1310 respondents, only 549 (42%) were aware of the STEM education concept while only 472 (36%) were aware of both the STEM and STEAM concepts. Surprisingly a majority of teachers were unaware of the STEM (58%) or STEAM concept (64%). Out of the respondents who were aware of the STEM concept, very few respondents (1.3%) had gained awareness during pre-service teacher training, and only (20.3%) of them had become aware of STEM/STEAM concept through in-service teacher training programmes, while the majority of respondents who were aware of the STEM concept came to know about it from informal sources such as media (40.8%), through friends (9.0%), other sources (5.4%).

Correlation analysis of teacher awareness of the STEM education approach showed a significant correlation (0.084, $P<0.01$) with age indicating that the awareness of STEM/STEAM is greater among younger teachers compared to senior (older) teachers. As shown in Fig. 4, 47.8% of respondents of the age group below 30 -39 years were aware of the STEM concept while only 37.5% of the respondents of the age group of 50 years or above were aware of the STEM education concept.

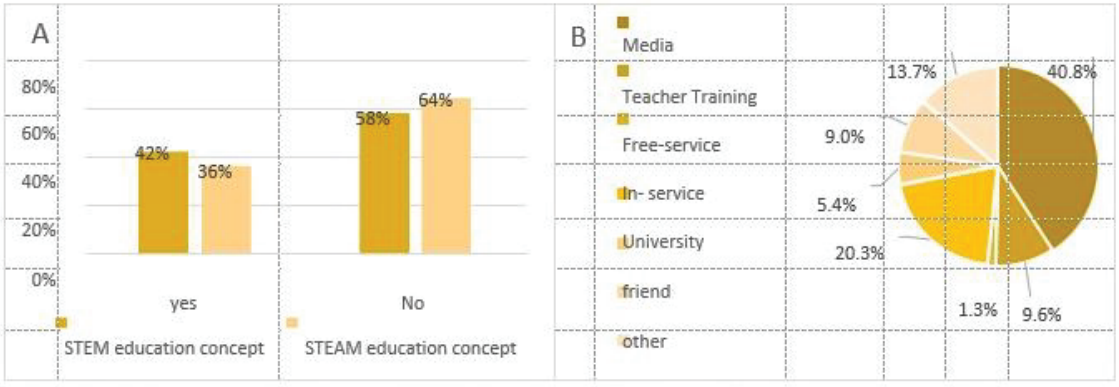

Figure 3-A: Awareness of Teachers on STEM Education

Figure 3-B: Mode of Awareness Received

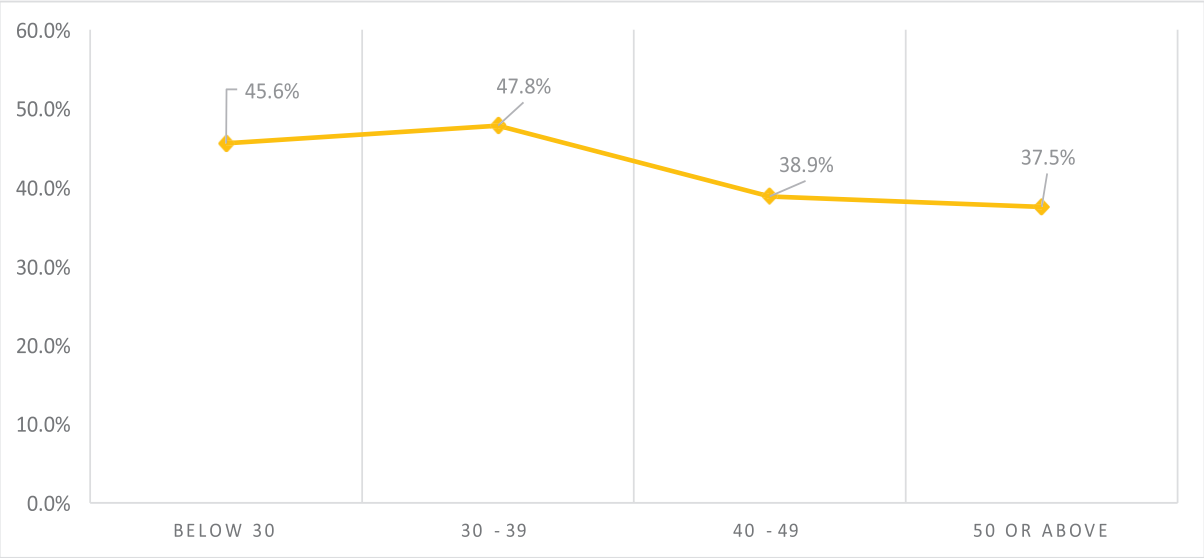

Figure 4: Relationship between Teacher Awareness of STEM Education and the Age of the Teacher

3.4 Teachers' Perception of the STEM Education Approach

As shown in Table 2, only 45% had either agreed (36%) or moderately agreed (9%) with the statement that *"STEM is an inter-disciplinary approach of teaching that provides real-world experience to students"*. About 53% of respondents did not know (39%) or had no clear idea (14%) about the statement indicating their total ignorance of the STEM education concept. Out of 1310 respondents, only 39% of respondents either fully agreed (28%) or moderately agreed (11%) with the statement *"STEM approach could also be adopted under the currently taught mathematics and science subjects"* while 57% of respondents did not know (42%) or had no idea (15%) about the statement. Further, 37% of the respondents mentioned that they require technical and laboratory facilities while only 28% either agreed (15%) or moderately agreed (13%) with the statement *"STEM can be implemented without technical and laboratory facilities"*. Out of 1310 respondents, only 40% disagreed with the statement *"STEM can be efficiently implemented only in developed countries",* while 51% of respondents either did not know (40%) or had no idea (11%). Out of 1310 respondents, 11% of the respondents agreed (4%) or moderately agreed (7%)with the statement *"STEM approach does not suit our country"* while 51% either don't know (41%) or had no idea (10%) on the statement. These results suggest that the majority of teachers lack a clear understanding of the concept of STEM education approach.

Table 2: Teachers' Perceptions of STEM approach-related Matters

Statement	Agree %	Moderate %	Disagree %	No clear idea %	Don't know %
STEM is an inter-disciplinary approach to teaching that provides real-world experience to students	36	9	2	14	39
STEM approach could also be adopted under the currently taught mathematics and science subjects	28	11	4	15	42
Technical and laboratory facilities are required to implement STEM education	37	9	5	9	40
STEM education can be implemented without technical and laboratory facilities	15	13	18	13	41
STEM can be efficiently implemented only in developed countries	7	8	34	11	40
STEM approach does not suit our country	4	7	38	10	41

Source: Sample Survey

3.5 Teachers' Perceptions of the Availability of Physical Resources and Learning Aids

As shown in Table 3, according to the responses 34% of schools were having laboratory facilities and only 16% of them were having adequate learning aids. Similarly, only 8% of schools were having adequate learning aids in mathematics laboratories (10%). However, only 11% of them were having adequate space for collaborative STEM-related activities. The Internet was only available in a few schools (30%). Laboratory assistance service was adequate only in 7% of schools.

Table 3 :Availability of Physical Resources for the Implementation of STEM Education Approach

	Yes	No	Not responded
School has laboratories	34%	11%	55.2%
Laboratories have adequate learning aids	16%	29%	55.6%
The school has mathematics laboratory facilities	10%	34%	56.0%
Mathematics laboratories have adequate learning aids	8%	36%	56.2%

Availability of adequate space in science and mathematics laboratories for collaborative STEM-related activities	11%	32%	56.5%
Availability of Internet facilities for laboratories	30%	14%	55.6%
Adequate help from laboratory assistance	7%	37%	56.0%

Source: Sample Survey

As depicted in Fig. 5, 69% of the respondents mentioned that electricity was available as a common facility and still, there are few schools (5%) without electricity. Similarly, still only 35% responded that schools had adequate building facilities while 37% mentioned that they did not have the building facilities required for the implementation of STEM education. According to the responses, other common amenities required for the implementation of STEM education such as computer facilities, internet facilities, and information communication facilities were available only in 45%, 39%, and 33%, respectively. A sizable number of respondents (37%) mentioned that schools were not having the required building facilities and Information Communication Facilities required to implement the STEM education approach. Further, a considerable number of respondents (above 28%) did not respondents and that might be due to their unawareness of STEM education approach.

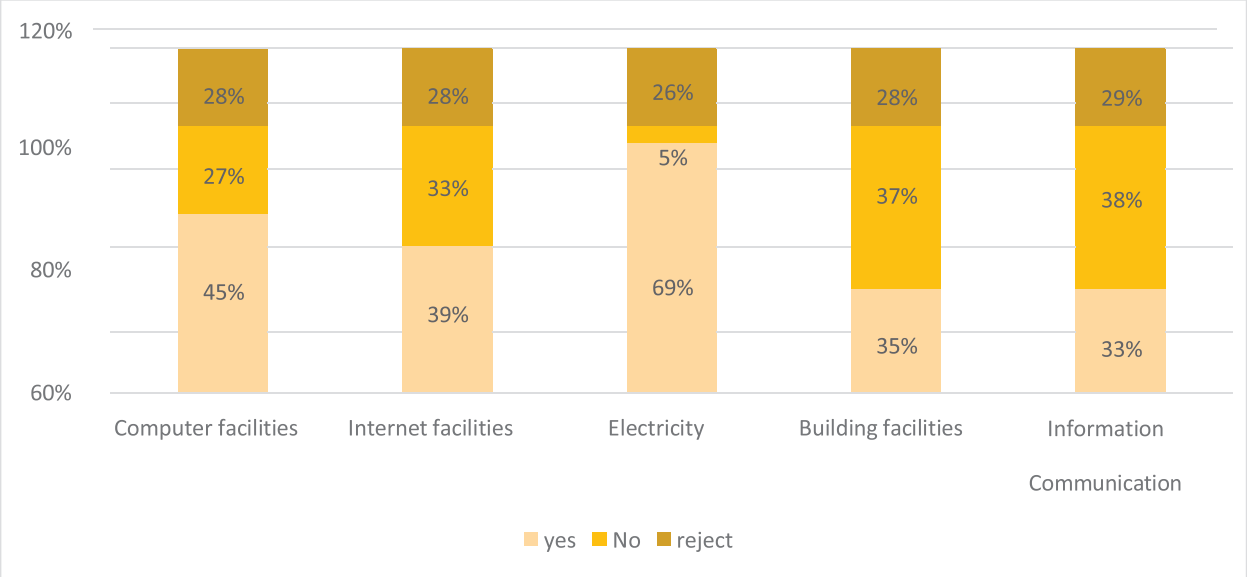

Figure 5: Availability of Common Physical Facilities Required for the Implementation of the STEM Education Approach

3.6 Teachers' Perceptions of Opportunities and support available for continuing professional development in STEM education approach

i) **In-service training**: The current study found that out of 1310 respondents, only 35 respondents (2.7%) received in-service, professional development training opportunities related to the STEM education approach. The opportunities they received were provided by several institutions such as the Ministry of Education, Provincial Ministry of Education, Zonal Education Office, and National Institute of Education.

ii) **Teacher perceptions on the training opportunities provided**: The responses received with respect to the degree of satisfaction with the training received were showed that only 8.2% of the respondents agreed (4.8%) and moderately agreed (3.4%) the with statement *"Satisfied with the STEM-related teacher training received so far".* respondents agreed (3.7%) or moderately agreed (4.8%) with the statement *"Satisfied with the support received from teacher advisors on STEM-related professional development".*

iii) **Teachers' willingness to improve competencies related to the STEM education approach:** As shown in Fig. 6, 51.3% of the respondents were willing to improve their teaching-training skills related to the STEM education approach. Similarly, the majority of the respondents were willing to improve competencies in creative group activities (42.1%), communication skills, both verbal (29.4%) and written (38.9%), and problem-solving and scientific inquiry (35.6%), and 35.6% stated that they want to improve their self-confidence in adopting STEM education approach in teaching-learning.

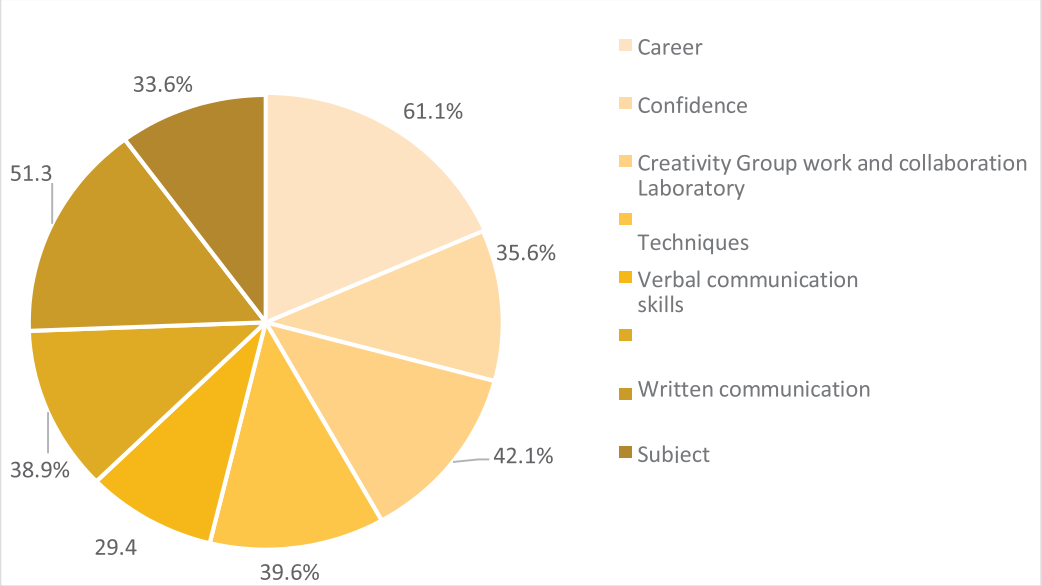

Figure 6: Teachers' Willingness to Improve Competencies Related to the STEM Education Approach

iv) **Learning resources used to acquire knowledge and skill related to the STEM education approach:**

As shown in Table 6, about half of the respondents (52%) respondents did not have any idea about the learning resources through which they could acquire or update knowledge and teaching-learning skills related to the STEM education approach. Similarly the majority of the respondents were not aware that they can get educational resource material through the Internet (47%) and library (50%) to update their knowledge and teaching-learning skills and aids. Only 22% of the respondents always use teachers' guides asa source for updating knowledge while 9% used the library.

Though the internet is a readily available facility for many, only 16% of the respondents used it as an information source to gather or update knowledge on STEM education approach.

Table 4: Resources Used to Acquire or Update Teaching-learning Skills on STEM Education Approach

	Always	**Usually**	**Moderate**	**Somewhat**	**Seldom**	**No Awareness**
Teachers' guide	22%	11%	8%	5%	2%	52%
Internet	16%	15%	10%	7%	5%	47%
Library	9%	17%	11%	6%	7%	50%

Source: Sample Survey

v) **Teachers' perceptions on the support received from the school administration**: Further analysis, of the data collected, showed that only 17.2% of respondents agreed (7.9%) or moderately agreed (9.3%) with the statement *"School provided support to STEM-related professional development"*. Only 12.3% of respondents agreed (4.7%) or moderately agreed (7.6%) with the statement *"Appreciate the support of subject directors on STEM-related activities".* As regards the support extended by the principals of the schools only 17.3% of respondents agreed (8.8%) or moderately agreed (8.5%) with the statement *"Satisfied with the support provided by the principal on STEM-related professional development".*

vi) Teachers' perceptions on the inputs required to promote the wider application of the STEMeducation approach: As shown in Table 5, more than 84% of the respondents have mentioned the need of having awareness programmes on the STEM education approach to promote the wider application of the STEM education approach in schools. In addition, the majority of respondents highlighted the need for guidance for the implementation of the STEM education approach 84%, continuing professional development training opportunities/programmes to update knowledge (83%), physical resources and teaching aids for STEM-related practical activities (83%), etc.

Table 5: Teachers' Perception of Required Professional Development Related to STEM Education

	Required %	Moderate %	Not required %
Awareness programs related to STEM applications	84%	8%	8%
Tips for implementing STEM practices	84%	8%	8%
Update requirements related to STEM applications	83%	8%	9%
Experiential activities related to STEM applications	83%	9%	9%
Observation of schools implementing training related to STEM practices	81%	10%	9%
Good practices related to STEM applications	81%	10%	9%

Source: Sample Survey

Further, respondents mentioned the desire to have study tours or visits to schools implementing STEM education approach (81%) and learn good practices related to the adoption of STEM education approach (81%). Most of them highlighted the need for inputs such as physical resources including laboratory facilities, and ICT facilities to promote the application of the STEM education approach in schools on a wider scale.

4. Discussion

The prime role of education system of any country is to provide human capital equipped with required knowledge and skills to drive its economy. In today's context, where the socio-economic system is designated as 'knowledge economy', the production of goods and services is based principally on knowledge-intensive activities. The key element of value in this system is the greater dependence on human capital equipped with transferable skills together with site-specific knowledge and skills. These competencies are grouped as 21st century skills. One of the key approaches to imparting 21st century skills is the adoption of the STEM education approach[20].

However, the integration of STEM into the education system requires a strong conceptual and professional foundation and therefore, teachers need to have a blend of content knowledge and pedagogical knowledge and skills[21]. Therefore, the current study was conducted to investigate the current status of adoption of STEM education approach in Sri Lankan school system from the perspective of teachers in secondary, senior secondary, and collegiate level education. The results of the current analysis showed that the awareness among teachers of both on STEM and STEAM education approaches is considerably low. Similarly, the study revealed a significant positive correlation between awareness with the age of the teachers showing a slightly higher awareness among younger teachers compared to elderly teachers. Interestingly, those who were aware STEM education approach appears to have gained through informal channels suggesting that the pre-service teacher training, provided by the NCoEs or universities or the in-service training provided by the NIE or universities or any other channel has not given adequate emphasis on the promotion of adoption of STEM educational concepts.

Besides teachers, the physical resources and learning aids are key elements that are required for successful implementation of STEM/STEAM education at the classroom level. Literature from other countries has shown that other than adequate physical resources, ICT-based tools including internet connectivity and learning resources are key to the successful adoption of the STEM education approach in classroom teaching and learning[22]. However, this study reveals that the physical resources available at schools to implement the STEM education approach in Sri Lanka are rather inadequate. Though many schools have at least to a limited extent the common amenities such as teaching laboratories, electricity and computer facilities, the essential elements such as internet connectivity which provide access to ICT-based learning resources and learning aids and tools are available only in a few schools. Therefore, a substantial improvement of physical facilities such as laboratories resourced with adequate learning aids and tools, and computers and internet facilities are required for the successful implementation of STEM education in the general education system in Sri Lanka.

Studies have shown that teachers tend to avoid teaching the topic or teaching subject superficially if they are not comfortable with the content and pedagogical approach, and this is more so with

[20] DARE, E. A., KERATITHAMKUL, K., HIWATIG, B. M. & LI, F. 2021. Beyond Content: The Role of STEM Disciplines, Real-World Problems, 21st Century Skills, and STEM Careers within Science Teachers' Conceptions of Integrated STEM Education. *Education Sciences,* 11**,** 737.

[21] KARUNARATHNE, S. 2020. Implementation of STEM education in schools. Vidurawa. National Science Foundation, Sri Lanka.

[22] DEBRY, M. & GRAS-VELAZQUEZ, A. 2016. ICT Tools for STEM Teaching and Learning - Transformation Framework. STEM Alliance.

teaching conceptually challenging content associated with many STEM themes[23]. Similarly, another study found lack of teacher comfort with STEM content and pedagogy can create deleterious effects on student learning and perceptions of STEM[24]. Similarly a study cited that professional development in scientific inquiry is critical when teachers deal with unfamiliar content such as concepts associated with teaching and learning of STEM[25]. Therefore, teachers must be well equipped with foundation knowledge on STEM education approach which obviously be provided during pre-service training. Thereafter, teachers' knowledge and pedagogical competencies in adopting STEM/STEAM education approaches in the classroom must be continuously upgraded through continuing professional development process. A previous study also suggested that teachers who participated in professional development had increased efficacy, comfort, contentment, and knowledge related to STEM education[26]. All these studies support the idea that improving teacher capacities on STEM education approach through pre-service teacher training and in-service / continuing professional development are vital for the successful implementation it in the classroom. However, according to this study, only 3.4% of the respondents received professional development programmes related to the STEM education approach. Similarly, the satisfaction of the teachers on the training received was very low. However, their willingness to improve competencies related to the STEM education approach is high. Teachers showed their desire and interest to acquire the required professional development indicating their enthusiasm to learn and update their knowledge of STEM education. However, results of the study reveal that the teachers do not receive much encouragement from the school administration, both from the subject directors and from the school principal for adoption of STEM education approach in class room level. This highlights absence of clear policy directives from the central and provincial on the adoption of the STEM education approach in the general education system.

In conclusion, the results of the study show that the school system in general, despite the few attempts made at central level to promote adoption of STEM/STEAM education approach, is not geared to embrace and internalize this approach yet. It appears that there is no coherent and consistent policy and administrative directive coupled proper strategies with activities in this regard. In the absence a policy and administrative directives and programmes, the schools lack the well-informed, enthusiastic school management and trained human resources and required physical resources and teaching and learning aids required to embrace and internalize the STEM education approach at class room level. As such, it is seemingly appropriate to state that, if the Sri Lankan general education system is to adopt the STEM education approach it has to be promoted through appropriate policy instrument that emphasize the adoption of STEM education approach in K-12 education system supported by strategic activity framework including reforms in curriculum, and pedagogical and assessment strategies supported by substantial investment to provide appropriate pre-service and in-service training for building the critical mass of human resources, and for building required physical resources at the school level.

[23]BURSAL, M. & PAZNOKAS, L. 2006. Mathematics anxiety and pre-service elementary teachers' confidence to teach mathematics and science. *School Science and Mathematics,* 106**,** 173-179

[24] BEILOCK, S. L., GUNDERSON, E. A., RAMIREZ, G. & LEVINE, S. C. 2010. Female teachers' math anxiety affects girls' math achievement. Proceedings of National Academies of Science, 107, 1860-1863.

[25] NADELSON, L., SEIFERT, A., MOLL, A. J. & COATS, B. 2012. An integrated approach to teacher professional development in STEM. Journal of STEM education, 13.

[26] NADELSON, L., SEIFERT, A., MOLL, A. J. & COATS, B. 2012. An integrated approach to teacher professional development in STEM. Journal of STEM education, 13.

5. Way Forward

Considering the finding of this study together with the existing reports on STEM education in Sri Lanka, one could conclude that Sri Lanka has not yet formally adopted the STEM education approach into K-12 general education system despite teaching science and mathematics from primary to upper secondary education. It is very clear that this STEM from several key factors, namely the i) lack of consensus among educationists and policy makers, and hence the absence of steadfast policy to adopt STEM education approach in general education system, ii) silo-based, K-12 curriculum and conventional silo-based, teacher-cenetred pedagogical approach at classroom level, iii) inadequate preparedness of teachers and school administrators, and iv) inadequacies of required physical and learning resources.

UNESCO/International Bureau of Education publication, Exploring STEM Competences for the 21st Century (2018)[27] stated that, "*time has come for the education sector to rethink traditional curriculum boundaries, where knowledge and skills are segregated according to subjects*". This document explores the different models that could be adopted to integrate STEM integration into curriculum and teaching practices, and these include;

- STEM through a discipline-specific approach: In this approach, the contents of four STEM disciplines are taught individually but as and where appropriate the integration is practiced. A discipline-specific approach is adopted in the majority of schools, at secondary levels, with perhaps more integration evident at primary level. It tends to be common practice that all students learn the subject areas of science and mathematics. Technology and engineering related subjects such as Design and Technology, ICT, Computer Science and Electrical Engineering tend to be offered as electives, especially at secondary schools. STEM-related vocational courses are sometimes provided in secondary schools.
- STEM through integrated approaches : Interdisciplinary or integrated STEM education is a fusion of the four disciplines of Science, Technology, Mathematics and Engineering, where the focus of learning is not the individual discipline in itself, but on solving real-world problems.
- STEM through pedagogical approaches: A range of inquiry - based / problem - solving pedagogical approaches can be used to integrate STEM into the curriculum. These might be regarded as 'in-between' approaches between discipline-based learning and multi disciplinary/ transdisciplinary approaches, for example: focusing on real world authentic problems in real-world contexts; offering students opportunities to make connections across disciplines; and to develop problem solving, diagnostic and critical thinking skills, including research, hypothesis testing, analysis, synthesis and strong deductive reasoning to realize solutions to real problems

However, Research suggests that an interdisciplinary or integrated curriculum provides opportunities for more relevant, less fragmented, and more stimulating experiences for learners, including improving student motivation to learn; enhancing attitudes and interest in school;

[27]UNESCO/IBE: Exploring STEM competences for the 21st century - UNESCO Digital Library. https://unesdoc.unesco.org/ark:/48223/pf0000368485

making students better problem solvers, innovators, inventors, self-reliant, logical thinkers, and technologically literate.

UNESCO/IBE publication has further stated that "*Although the STEM acronym is in widespread use, yet an agreed definition and approach to STEM remains elusive in practice and policy, programme and practice challenges remain to be addressed at national/regional/state/district and school levels. At policy level there needs to be a commitment to supporting all four disciplines in schools in an integrated way. This requires greater attention being paid to the place of engineering and technology alongside, or within, science and maths. At national/regional/state/district teachers need to be trained to cope with the knowledge, epistemological and pedagogical principles of the contributory disciplines in order to be able embrace integrated approaches. At programme and examination levels there needs to be a commitment to defining and assessing programmes that address holistic global challenges, with adequate access to teacher resources to promote active investigation and creative design of potential solutions. At school level, timetabling and collaborative planning opportunities need to be provided for teachers of contributory disciplines to work together. Above all, if examination and accountability systems do not embrace and assess STEM (and STEAM) in ways which promote STEM competence and literacy (including the kinds of knowledge, skills, values and attitudes outlined in this paper) then integrated multi-disciplinary and transdisciplinary approaches will remain aspirational and elusive"*.

As concluded from this study, if the Sri Lankan general education system is to adopt the STEM education approach it has to be promoted through appropriate policy instrument reached through consensus among educationists and policy makers that emphasize which model to be adopted in embracing STEM education approach in K-12 education system supported by strategic activity framework including reforms in curriculum, and pedagogical and assessment strategies supported by substantial investment to provide appropriate pre-service and in-service training for building the critical mass of human resources, and for building required physical resources at the school level.

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