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**Comparative Analysis of Science, Technology, Engineering and Mathematics (STEM) Education Programs in United Kingdom, United States of America. Japan and Australia**

**\*Tukur Muhammad (Ph.D.)<sup>1</sup> Hano Lawal Jibril <sup>2</sup> Faiza Jibril Isah<sup>3</sup>**

Department of Biological Science, School of Secondary Education Sciences, Zamfara State  
College of Education Maru, Nigeria

Department of Applied Science, Abdu Gusau Polytechnic Talata Mafara, Zamfara State,  
Nigeria

Department of Biology Saadatu Rimi College of Education Kumbotso Kano, Nigeria

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**ABSTRACT:** *STEM education is an important component for global development, many countries have invested a substantial amount of funds in the Program. Many initiatives, Programs, policies, law are formulated to increases the number of students' enrolment and arose their interest to study STEM. In this paper, we present the comparative analysis of successful STEM education Programs in United States of America (USA), United Kingdom (UK), Japan and Australia. We explored different Programs, target groups, objectives and achievement of STEM in UK, USA, Japan and Australia. For USA, the study found that the STEM education Programs are successful but require the involvement of community elites. In UK, the STEM Education Programs are successful and it assisted the country in adding more curriculum materials and trained several personnel. In Australia, experienced a shortage of scientists and engineers and formulated policies and Programs of which some of these Programs were successful and boost the Australian STEM Education. In Japan STEM education Programs has succeeded in increasing the number of enrolment and interest in the areas of science, technology, engineering and mathematics. The stake holders, educators and government of UK, USA, Japan and Australia can use our study to easily identify areas that require improvement. As such, adapt their STEM education Programs in such a way that the STEM education Program can further be boosted.*

**KEYWORDS:** STEM Education; STEM Education Program; United Kingdom (UK); United States of America; Japan and Australia

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## INTRODUCTION

Science, Technology, Engineering and Mathematic (STEM) is a vital component of the global reaction to technological issues confronting contemporary society (Thomas and Watters 2015). It comprises some of the most versatile and important careers in the contemporary world. The STEM is viewed as the newest developments that are making the world a better place to live as a result of STEM contributions (Hossain & Robinson, 2012; Irwanto et al., 2022). Globally,

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research on STEM education is considered as an important tool that can boost the economy of any nation to achieve strong and rapid growth of development. This is because the knowledge attained through the school subject of (STEM) is valuable to countless people in the society in their everyday life (Kitz & Fan, 2014). In other words, STEM has been considered as a serious part if we are to come across the challenges of the future (Panizzon et al., 2014). Subsequently, the global society is alarmed with attaining the demand for vastly skilled workers in the STEM (Knezak, Christensen & Tyler-wood, 2011; Zhan et al., 2022).

Kennedy and Odell (2014) regarded the term “STEM education” as the teaching and learning in the areas of scientific discipline, applied science and engineering, whereas others considered STEM education as an acronym that represent the knowledge of STEM subjects (Lam, et al., 2008; Cormican, 2009; Bybee, 2010; Fan and Ritz, 2014; Jelks et al., 2020). However, STEM education is full of crises arising from deficiency of quality teachers that can improve student inquiry and interest (Thomas & Watters 2015; Kim et al., 2020; Basu, et al., 2021). For instance, Bokov, (2013) noted that, one of the major barriers to economic growth experienced by industries in many developed and developing countries is inadequate professional engineers and technicians in a practical field of STEM. It was disclosed by UNESCO (2014) that, in more developed nations that have the opportunity to possess resources and a more level playing field, evidence shows that students are less inclined to take up science as an interest or career path unlike in the previous decades. This resulted to not having qualified teachers in science and technology, which lead to global concern on shortage of STEM prepared workers and educators (Kennedy Odell, 2014; Global Paradox, 2014). This is despite the continuing increase of research STEM worldwide in this decade (Yu et al., 2006; Zhan et al., 2022).

A call was made by UNESCO (2000) that, there is the need for designing a STEM education program effectively by promoting gender sensitivity, socio-cultural, policies and curriculum UNESCO (2000). This is in view of the fact that the STEM education program comprises of one or more of the following objectives: arose students to pursue classes or course work; draws graduate to pursue STEM careers; draws students to pursue STEM degrees; provide undergraduate or graduate training in STEM and increase the ability of K12 or post-secondary institution to promote education in STEM Fields (Scott, 2013; Cheng Meng.et al., 2013; Takeuchi et al., 2020).

However, policies and programs are emerging around the world that focuses on the STEM education and seek to grow the supply of graduates with the skills and knowledge developed through a quality education in the STEM subjects. The reason is straightforward: the world’s dependence on knowledge and innovation to grow and not diminish. To be ahead in the race, a community needs the skills to anticipate rather than follow (Hackling, 2014; Kim et al., 2020; Irwanto et al., 2022).

Furthermore, many countries have initiated programs to stimulate, enhance and increase the number of student’s enrolment and graduate in the area of STEM. For instance, United States of America (USA) made a call to produce more scientific and technological innovation to maintain its economic growth and development (NAS, 2007) and the need for technologically

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sound workforce in the USA (Thomas & Williams, 2009 Jelks et al., 2020; Basu et al., 2021;  
Zhan et al., 2022).

Very few attempts have been made for comparative studies on STEM education. For example, Freeman (2014) documented a country and regional reports and special interest for of STEM country comparison project of Anglo sphere, Europe, Asia, Latin America, and Middle Est. The study combined policies, strategies and program. The analysis was not in-deep. analysis of the successful STEM education program across the countries, likewise, there was a another study on STEM and technology education: International state-of-the-art in 2014 by Ritz and Fan, the study mainly focuses on the comparison reports of twenty international technology education scholars on their country's involvement in STEM education a survey research method were used and the findings reveals that some countries regarded STEM education to be an advanced teaching of the individual subjects of STEM; others held that an integrative subjects approach should be use in teaching STEM, while many believed that it is an integration of the two approaches.

The major issue with the previous attempts to compare STEM Programs is that, the factors affecting students' performance and motivation, without specifically looking at the fields of STEM education, objectives and achievement recorded for each country were not covered. In addition, an in-depth analysis of successful STEM Programs in USA, UK, Japan and Australia is missing in the literature despite being successful. The in-depth analysis of successful STEM Programs in the countries earlier listed could motivate other countries to emulate their STEM education Programs. This is especially in countries where the STEM education Program is not successfully implemented.

In this study, we propose to conduct an in-depth analysis of comparative study of successful STEM education programs in USA, UK, Japan and Australia.

## **METHODOLOGY**

Generally, a descriptive case study was adopted which relates to available literature, policy documents, and educational initiatives. The literature consists of final report, published journals, and publications of international agencies. The literature and other documents were obtained from different search engines such as Science Direct, ProQuest, Emerald, ERIC, Scopus, Web of Science Web of Science, and Google scholar using keys such as STEM program, STEM comparison, STEM policies, Science, Technology, Engineering and Mathematic STEM Initiatives, successful STEM program of the UK, US, Japan and Australia

### **Perspectives**

This section provides an in-depth analysis of the perspective of STEM education Programs in the UK, USA, Japan and Australia. In each of the selected country for our study, we discussed its STEM education Program, target group and STEM field of Programs, objectives and achievements (Chief Scientist of Australia, 2012; Report Bernard Fitzsimons Churchill Fellow 2011; Elster, 2014; and Focus 2014, Kuenz, Mathews and Mangan 2006; Kennedy and Odell 2014; NSF, 2016; The Institute for Broadening Participation Resource last updated: 2014; The

STEM cohesion Program 2011; Royal Academy of Engineering, 2013; (Freeman, 2014; Mayumi, Shot and Ashlyn 2013; Global education through PIRE, 2015; Global Paradox, 2014 & Siew-Enga, Mahdib, Mohamadin, Abdul Manafd 2015; Jelks et al., 2020; Kim et al., 2020; Takeuchi et al., 2020; Zhan et al., 2022; Irwanto et al., 2022).

### **STEM Education Programs in the UK**

United Kingdom considers experience of an extraordinary increase in the interest of government, industry and others in the successful uptake of STEM disciplines in schools and colleges, which was driven by the demand to increase understanding of STEM-related issues with the general public, and to enhance the skills and aspirations of learners towards a period of input to the scientific and technological infrastructure of the nation STEM (Framework, 2008). The problem of STEM work force in the UK was also documented that the STEM industries reported significant difficulty in recruiting individuals with STEM skills they require. This show there will be failed in the expected STEM qualified personnel in the industries as the older employees retired, therefore, this will be a serious setback to UK's economic growth (Macdonald, 2014). This group noted that UK engineering is experiencing a serious shortage of graduates, unless action is taken, or else this shortage can affect the UK industries, and the number of graduates in STEM Fields which is vital not only for the UK's future but for any nation (Russell Group of Universities, 2009).

### **The STEM Education Programs in UK**

It was documented in a report of Case (2014) that in 2013 David Cameron stated that "if we are going to succeed as a country then we need to train more scientists and more engineers". There are estimates that the UK has an annual shortfall in domestic supply of around 40,000 new STEM skilled workers and we need to double the number of graduates and apprentices in the engineering discipline alone by 2020 to meet demand.

However, various Program were initiated and implemented in order to overcome the challenges, but not all were successful, the successful ones includes: outputs of the engineering engagement Program; teaching tomorrow's designers and technologist's today (TTDTT); AP2 Improving teaching through CPD for mathematics teachers (STEM cohesion Program); Improving teaching and learning through CPD for science teachers (STEM cohesion Program); Improving teaching and learning by engaging teachers with engineering and technology; enhancing and enriching the science curriculum; enhancing and enriching the teaching of engineering and technology across the curriculum (AP6); Program of enhancing and enriching the teaching of mathematics; improving the quality of advice and guidance for students and their teachers and parents about STEM careers, to inform the subject choice and STEM cohesion Program for improving the quality of practical work in science (The STEM cohesion Program 2011 and Royal Academy of Engineering, 2013).

### **The Target Group and STEM Field of the Program in UK**

Form the available Programs which were successful in UK, it has been traced out that the U. K's STEM Education Programs has specific target group which were considered in implanting

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these Programs, means while, most of the targeted groups are the teachers followed by students and STEM directories (The STEM cohesion Program 2011 and Royal Academy of Engineering, 2013).

### **The Objectives of STEM Education Programs**

The Programs has stated objectives to be achieved, To ensure that the new requirements for publicly available evaluation have been successfully been made for entry in the STEM directories; to develop and booster training for STEM ambassadors who are engineers; to coordinate the benchmarking of all the practical resources available; to offer coherent directions for E&E activity across the STEM fields which will bring experts across the AP 5-7; other objectives of the Programme are to increase the commitments in STEM through teaching and learning and to create an avenue that will initiate the committee for mathematics that will trace the national priority (The STEM cohesion Program 2011 and Royal Academy of Engineering, 2013).

### **The Achievement of STEM Education Programs**

The Programs have recorded remarkable achievements like training of over 498 D and T teachers; funding the setting up 87 additional after-school STEM clubs permitting 1,740 students to benefited; supported the RA Engineering workshops on effectively evaluating STEM enrichment and enhancement (E&E) activities; develops and booster the training of ambassadors who are engineers; publication of additional science and mathematics curriculum materials together with technology curriculum under development, above all the Programs trained seven hundred people through the getting practical Program (The STEM cohesion Program 2011 and Royal Academy of Engineering, 2013).

### **The STEM Education Programs in the USA**

Cooney and Battoms (2008) point out the USA experienced inadequate qualified workers as a result of insufficient preparation in the areas of science and mathematics. This created a difference in the USA in the works STEM industry globally. As far back as 2003, the national science board in the USA stated that STEM work force is an instrument that the USA depends on it to uphold its supreme power in the world economy. However, there is declined in the USA innovation-based industries that resulted in jeopardising the rank of the USA as the world's innovation leader (Omayo, 2010). Similarly, Aktikinson and Mayo (2010) argued that the USA is unable to produce enough of its own workers with adequate skills and knowledge in STEM Fields.

The insufficient STEM workforce is due to STEM education pipeline with holes, cracks, and weak points from which students often drop out at predictable points in view of lack of interest, engagement, facilitate, or financial support (Kramer et al., 2014). This problem motivated the USA to call for the producing of more scientific and technological innovation to maintain its economic growth and development NAS (2007) as well as the need for technologically sound workforce in the USA (Thomas & Williams, 2009). However, there is a called for USA in

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expanding its educators and STEM talent pool if the USA wants to maintain its position in the world economy in the new millennium era, where science and technology-based fields are rapidly increasing (Set, 2007). In that respect, it was observed that the number of women graduating in STEM field is decreasing in the USA (Notter, 2010; Irwanto et al., 2022).

### **The STEM Education Program**

Gao and Schwartz (2015) noted that in February 2012, president Obama called for the producing of one million additional STEM graduates by 2020. It was noted by Hira (2010) that the STEM workforce has been a source of USA policy action for more than 50 years. As such, over 90 million US dollars is invested by the American Association of University women (AAUW) and National Science Foundation (NSF) with the aim to find various programs that can increase gender equity in STEM fields (Notter, 2010; Basu et al.,2021). In overcoming the problem of STEM fields and STEM Education, the report of the GAO Fund (2012) revealed that in the year 2010, 13 federal agencies invested over \$3 billion in 209 programs designed to increase knowledge in STEM fields and attainment of STEM degrees. Moreover, the number of programs within agencies ranges from 3 to 46 with the departments of health and human services, energy and the National science foundation administers more than half of these plans. Nearly a third of the programs had obligations of \$1 million or less, beyond programs specifically focused on STEM education, agencies funded other broad efforts that contributed to enhancing STEM education.

However, various Programs which were introduced and succeeded in increase and enhancing STEM education and graduates in the field of STEM includes: Pathways in technology early college high schools (P-Tech) afterschool STEM mentoring program; NSF mathematics and science partnerships; NSF graduate research fellowships; ED mathematics and science partnerships; NSF research experiences for undergraduates; NASA minority university research education program; NIH national research service awards and lastly, Texas STEM (T-STEM) Initiative (Kuenz, Mathews, & Mangan 2006; & NSF, 2016).

Other Programs successfully implemented by the USA includes; graduate research fellowship (GRF) program; NSF research traineeship (NRT) program; scholarships for service (SFS) program; the louis stokes alliance for minority participation – bridge to the doctorate (LSAMP-BD); The NSF scholarships in science, STEM (S-STEM) program; the Robert Noyce teacher scholarship program (NOYCE); NIH Ruth L. Kirschstein national research service awards; NSF research experiences for undergraduates; ED science and mathematics access to retain talent grants; ED mathematics and science partnerships and minorities in marine science undergraduate program (The Institute for Broadening Participation Resource last updated: 2014; Kennedy, & Odell 2014).

### **Target Group and STEM Field of the Programs**

The US STEM Education Programs have a group which meant to benefit from the Program, in other words, target group. Most of the successful STEM programs in US considered the following group as their target: college students, graduates and post-doctors' students k12 students, science teachers, form the results it was indicated that most of these Programs were

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Published by the European Centre for Research Training and Development UK targeted to graduate students in the field of technology, science and mathematics and STEM, while teachers are the least target group see (Kuenz, Mathews & Mangan 2006; Kennedy, & Odell 2014; NSF, 2016 and The Institute for Broadening Participation Resource last updated: 2014)

### **Objectives of the STEM Education Programs**

The STEM education was introduced in USA has objectives required to achieve. the objectives of the Programs consist: To develop or enhance research training opportunities for individuals selected by the institutions; to encourage talented science, technology, engineering and mathematics major and professionals to become K12 maths and science teachers; to provides institutions with students' scholarships to encourage and enable academically talented USA students and increase the academic achievement of students in mathematics and science. This is by enhancing the content knowledge and teaching skills of classroom teachers; transforming STEM education through innovative recruitment and retention strategies; to create and promote new, innovative, effective, and scalable models for STEM graduate students' training in emerging research emphasis areas; to help build the USA STEM human capital necessary to ensure the Nation's leadership in advancing innovations in science and engineering; to provides a context for looking at how STEM can be redefined to move beyond the boundaries the separate disciplines and to increase the size and diversity of the USA workforce in science and engineering (Kuenz, Mathews & Mangan 2006; Kennedy, & Odell 2014; NSF, 2016; & The Institute for Broadening Participation Resource last updated: 2014).

### **Achievement of STEM Education Programs**

The stated objectives of STEM education Programs in USA make a remarkable achievement in financial support, skills and enhancement among the recorded achievements are the following Programs: provides up to \$4,000 for each of the third and fourth years of undergraduate study and is in addition to the student's Pell Grant award; mathematics (as opposed to science) instruction in middle schools, and provide professional development to roughly 46 teachers over a period of about 21 months; introduces underrepresented students to the marine sciences, helps the students to develop greater confidence in their potential, and prepares them for successful careers in field providing professional development and salary supplements for exemplary mathematics and science teachers to become master teachers while they fulfil a 5 years teaching commitment in high-need school districts; the fellowship grant programs supported around 2,500 pre- and postdoctoral students in 2004; assists universities and colleges in diversifying the STEM workforce through their efforts by significantly increasing the number of students successfully completing high quality degree programs in STEM disciplines.

In addition, other recorded achievement by the implemented Programs are as follows: approximately 37 percent of the scholarship track supports graduate program activities; provides professional development to roughly 46 teachers over a period of about 21 months; a total of 2,356 grants were awarded which funded nearly 9,000 pre-doctoral fellowships and nearly 5,500 postdoctoral fellowships; T-STEM academy students outperform students from comparison schools with similar demographics, there were 65 T-STEM academies serving over 35,000 students in Texas; financial supports for graduate students with demonstrated high

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Published by the European Centre for Research Training and Development UK potential for excellence in STEM and in their ultimate chosen career; provides a mechanism for developing a knowledge base about the implementation and impact of innovative graduate traineeship programs and graduate education policies. these Programs provide three years support to approximately 1,000 graduate students annually in STEM disciplines with additional focus on women in engineering and computer and information sciences (Kuenz, Mathews and Mangan 2006; Kennedy and Odell 2014; NSF, 2016 and The Institute for Broadening Participation Resource last updated: 2014).

### **STEM Education Program in Australia**

Hurford (2009) opines that engineers in Australia believe that there is the need to build a new national curriculum for science, technology engineering and mathematics (STEM) literacies of Australia. They also stated that all citizens of Australia require to develop science, technology, engineering and mathematics (STEM) understanding make them to rejoice the importance that technological advances provide, to allow them to know their lives direction and involve intelligently in the knowledge economy. Yet, there is a decline in the enrolment in Australian's Students, which stimulate concern by Australian that its economic will re-laid on production and practical application of science, technology, engineering and mathematics (STEM) experience, this decrease in enrolment is also witnessed at secondary school as stated by Mark et al. (2014) that, there is declining in achievement and negative attitude towards STEM subjects among primary and secondary school students, and also declined participation in academically requiring STEM Subjects at senior secondary school level, however, these problem resulted due to student's negative attitude, lack of curriculum which is relevant to contemporary life and inadequate of science, technology, engineering and mathematics (STEM) qualified teachers Rice (2004), whereas it was noted that STEM skills are critical to the management and success of R&D projects as well as the day-to-day operations of competitive firms in Australia (Chief Scientist, 2014).

### **The STEM Education Program in Japan**

The economic growth and development of Japan has been facing challenges with alert Japan to restructure its curriculum in science and technology, to achieve reasonable success in pointing area like science and technology (Mayumi, Shota, and Ashlyn, 2013). The decline of public enthusiasm for science and technology has led to the decline in the participation to science and mathematics especially physics and reduce the number of perceptions of undergraduate in STEM fields (Freeman 2014). Moreover, STEM Education in Japan is still weak, which was due to the poor performance in literacy (Kudo 2012), Ishikawa and Ashlyn Moehle (2012) observed that, the STEM education in Japan was unable to increase the interest of students in mathematics and science, and nearly half of students do not feel the study science and mathematics is vital to secure the job they are interested in.

In response to this situation, Japanese policy and law makers realised the urgent need for necessary measure for a Japan to be in the clues of the global competitiveness in the 21<sup>st</sup> century (Ishikawa and Ashlyn Moele (2012), generally, the government was committed and convinced that science and technology are the bed rocks of any nation' growth and development, security and quality of life for its citizen (Holroyd, & Coates, 2007).



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### **The STEM Education Program in Japan**

It was indicated in the consultant report that, in the 2010 Japan was able to yield 9.95 researchers per one thousand labour force work, which is considered as the top ratio globally (Ishikawa and Ashlyn Moehle (2012), Japan's education system took series of curriculum reform to overcome the barrier such as: "science for all" which focus on scientific literacy "science for excellent" which is meant for elite education, and teachers are recognised and invited to contribute in the continues professional development and get compensation (Freeman 2014), which has produced more than 650,00 researchers in science and technology were maintained in Japan, it is therefore the third largest number in the world (OECD 2012a). Also, Programs were created and implemented in Japan like support for development of science and mathematics student's projects; Nano Japan IREU; leading graduate school doctoral Program; super science high school Program and training of science elite

### **The Target Group and STEM Feld of the Program in Japan**

The group targeted for the achievement of the Programs are: university students, PhD students, primary and secondary school students as well as senior secondary and higher education, all in the field of science and mathematics, science and engineering, biology (Freeman, 2014; Mayumi, Shot and Ashlyn 2013; Global education through PIRE (2015).

### **The Objectives of STEM Education Programs**

The Programs of STEM Education in Japan has stated objectives to be achieved which include the following: cultivating talent and improving the scientific talent; to create and innovate school; to stimulate and motivate competition among students; to develop research skills; to create science base society and To offer elites science and maths education in collaboration with universities and supports Olympiad participants and to offer elites science and maths education in collaboration with universities and supports Olympiad participants (Freeman, 2014; Mayumi, Shot and Ashlyn 2013; Global education through PIRE (2015).

### **The Achievement of STEM Education Programs**

Freeman (2014) stated that the Basic Law of 1995 in Japan institutes a framework aimed at progressing science and technology for societal and economic development, this law was administered through the council for science and technology Policy led by the Prime Minister. Law was formulated in assisting the STEM education Programs to be successful, and it has yielded some reasonable achievements such as improvement of the ability to design and syntheses as well as problem solving; the Programs were also able to increase the enrolment of students in science courses; provides financial support to universities for undergraduate science and technology courses; motivates and assists students to be active in science and mathematics learning and also provides science and mathematics education to elites (Freeman 2014; Zhan et al., 2022).

### **The STEM Education Programs in Australia**

Often all these problems, Australia make an investment in STEM where 65 percent of its economic growth per capital from 1964 to 2005 indicated the level of capital labour and technological innovation which make it possible in large amount Chief Scientist (2014), He

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also noticed that the value of Australian investment in STEM will disappeared if its practitioners operate without due regards for Australians, and their want, needs aspirations and concerns, with this, Davies (2014) ascertain that, there is alert for the demonstration in term of the need for re-rationalise about national strategies to increase chance to and the improvement of STEM teaching and skills development, and it was examined by Bissaker (2014) that science, technology, engineering and mathematics (STEM) teachers, could excite and engage their students by developing rich socially and culturally relevant and adequate STEM curriculum. In addition, Australia's Chief Scientist Lan (2014) stated that Australian government announced the common wealth science council and 12 million investments in STEM education, He further lamented that as a nation, we need to make sure that, Australians citizen know how to share in the chances produced by STEM in learning environment to the workforce force in daily life.

In addition, In Australia, 65 per cent of economic growth per capita from 1964 to 2005 can be ascribed to improvements in the use of capital, labour and technological innovation—made possible in large part by STEM (Chief Scientist, 2014), Australia's STEM investments and policies have suffered from a lack of coordination, misdirected effort, instability and duplication. We have long presumed that good things will just happen if we wait (Chief Scientist, 2014), and the federal level, policy and Program responsibility is diffused. The science, research and innovation investment reported in 2012-13—amounting to approximately \$8.6 billion—was spread across a suite of Programs in 13 separate portfolios (Office of the Chief Scientist, 2014). Above all various STEM Education Programs were also initiated by the Australians' government, such as STELR Program; project-based learning (PBL); Interest and recruitment in science (IRIS); World integrated learning (WIL); Australian power institute (API); science and technology education, leveraging relevance; Queensland Division's Wonder of science (ATSE) (Chief scientist of Australia, 2012; Report Bernard Fitzsimons Churchill Fellow 2011; Elster, 2014; Focus 2014; Jelks et al., 2020).

### **The Target Group and STEM Field of the Program in Australia**

The STEM Education Programs implemented in Australia targeted on only KSt., K Techers; K12 teachers; Postgraduate students; University students, with specific objectives stated and at last the achievement were recorded, the fields where these Programs fused includes: STEM, ICT, engineering and science (Chief scientist of Australia, 2012; Report Bernard Fitzsimons Churchill Fellow 2011; Elster, 2014; and Focus 2014).

### **The Objectives of the STEM Education Programs in Australia**

It has been recommended that, if Australia needs to achieve in successful implantation of STEM Programs, it most ensure an appropriate breadth and depth in the workforce, government and industry stakeholders must access and communicate appropriate data that are consistent and uniform in the way in which STEM is defined using analyses that provide clarity thereby dispelling the current 'smoke and mirrors' that potentially cloud the area presently (Panizzon et al., 2015).

Furthermore, the objectives of these STEM education Programs in Australia are too many to mention, among which are: To trace the deficiencies in teaching and learning science, technology at

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secondary school in Australia; increase posturing engineering in STEM, employability and enterprise skills and awareness on course and career in emerging industries; to improve the retention and gender equity patterns in higher education; to increase the quality and number of engineering graduates with the skills and motivation for career in the engineering industries and also to address the problem of low participation rates in Australia in mathematics and science subject at the higher secondary school level (Chief scientist of Australia, 2012; Report Bernard Fitzsimons Churchill Fellow 2011; Elster, 2014; Focus 2014; Zhan et al., 2022).

### **Achievement of the STEM Education Programs in Australia**

Over the period from 1998 to 2006 in Australia, the number of graduates from all fields increased from 125 000 to 172 000 and the proportion of science and engineering graduates increased from 25% to 29% (Hackling, 2014), furthermore, the best indicator of Australia's shortcomings in STEM is the pipeline' of future STEM graduates in our primary and secondary schools.

The Programs has recorded remarkable achievements which includes: trained over 1500 science secondary school teachers and about 150, 00 students were touched in Australian schools; provides context and mentor ship for school teachers and their appropriate teams; improved recruitment, retention and gender equality practices in higher education and motivated students to participate and demonstrate higher level of achievement with their projects and conference presentation participate (Chief scientist of Australia, 2012; Report Bernard Fitzsimons Churchill Fellow 2011; Elster, 2014; Focus 2014; Jelks et al., 2020).

### **Paradoxes**

This section explores the main paradoxes that could limit the achievement of STEM education in these five countries. We posed the questions what lessons other countries can that have not implemented or planning to implement STEM Education Programs be learned from STEM education Programs across the five countries that can be a guide and means for other countries to emulate for their economic growth and development.

Constructivism as an idea to construct new knowledge based on the acquired experiences would seem to be applicable to all five countries. Use of various STEM fields, target group and can appear to be a means through which these countries succeeded in implementing their STEM education Programs. Constructivism to some extent in term of Programs designed to succeed theoretical transformation leads the teachers and students to be creative and innovators and apply it in their domain. A pathway forward for U.S, U.K, Japan and Australia is to capitalise on the drawing attention and interest of students to peruse STEM education fields; provision of means that will increase the ability of secondary and post-secondary students to enrol in to STEM fields and STEM related subjects, which gave these five countries opportunities to boosted their economy and increase the number of engineers, technologists and engineers and STEM workforce.

However, it is important to analyse the STEM Education programs of US, UK, Japan and Australia, who skills that their teachers required, will aid in delivering STEM knowledge to the learners who's for their future changes. Tyler et al. (2011) conducted a study which brings out the limitations of how constructivism learning could assist and encourage student's interest in

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STEM education. Their results revealed that, the quality of learning and learning environment appeared to be in an innovative constructivist-based project, however, this study could not yield proof the student's achievement, it has also been established by Kennedy and Odella (2014) and Ikwanto et al. (2022) that, High quality STEM education programs provide teachers with opportunities to collaborate with one another in unified efforts aimed at integrating the four subjects into one cohesive means of teaching and learning. It is when this objective is achieved that students gain access to meaningful curricular opportunities, promoting critical thinking skills that can be applied to their academic as well as everyday lives.

Facer and Sandford (2010) point out that for the past 25 years the demand to reform the present system of education which is relevant to the learners and the basic unit of education in the school and the knowledge economy has been a focal view. In order to achieve the demand of highly skills workers and increase the workforce in the field of STEM to globalised labour market and boost the international economy, US, UK, Australia, Japan and Australia have to strengthen their quality of education and teaching particularly in the areas of science, engineering, technology and mathematics adding all structures of teaching and learning environment and reshaping the school curriculum right from secondary to tertiary level, for instance, The report of the advisory forum in the UK led by Onion(ND) opines that, the major concern of the government is centred on the quality of teaching, and government was contented with the reviews of curriculum, and priority should be given in recruiting individuals into teaching STEM as well as giving opportunities to great excellent constant professional development to all STEM teachers, secondly, enforcing schools to be doing biology, chemistry and physics as isolated subjects at key stage 4, while, Davies (2014) stated that, Australia focused on re-rationalise about national strategies to increase chance to and the improvement of STEM teaching and skills development, however, one of the main concern of the US is increasing the academic success for the entire students' priority at all levels NSF (2006).

It has been pointed out that, the goal of US education is to arouse students to pursue classes or course work; attracts graduate to go for STEM careers; makes students to pursue STEM Degrees; offer undergraduate or graduate training in STEM and rise the capability of K12 or post-secondary institution to additional preparation in STEM Fields, and UK and Australia. However, developing countries have not attempted these approaches.

Besides the ideas practices and objectives of UK and US, strategies on how to boost and stimulates teachers and students to could be in line with Japan and Australian system the practice enable these countries to address issues of meaningful learning and enhance the quality of students achievement in STEM fields and STEM related subjects, in line this, Thomas and Watters, 2015 point out that, efforts to implement reforms combined by professional development Programs meant at training them new approaches of teaching and learning, can cultivate reform based on belief. However, UK developed an interest to take up and increase the STEM disciplines in various universities and colleges, yet, the country experienced serious shortage of graduate in the fields of STEM, which draw the attention of President call for the Australian to maintain and increase more scientists and engineers, this stimulate the UK to initiated and implemented various the Programs such as Program of enhancing and improving teaching and learning of mathematics, and STEM cohesion Program for improving the quality

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of practical work in science, unlike Australia, UK use the STEM directories apart from teachers and students as targeted group. More than 1,740 students benefited from the Programs.

On the other hand, the success of STEM Education Programs depends on the achievement yielded, as can be seen from Table 1, for instance, among other achievements by the STEM education Program in Australia includes an increase in the Number of graduates in STEM fields, increases, motivate and gender equity for the students in higher level. In another hand, Japan STEM education system experience decline of students' interest particularly in the area of science and mathematics and the students recognise the importance of science and mathematics (Ishikawa, Ashlyn Moehle 2012; Basu et al., 2021; Irwanto et al., 2022), the government tried, committed and invested in science and technology which are the key element for nations' growth and development, among other means Japan government use was reforming the science curriculum, "science for all" and "science for excellent" which they consider primary and secondary school students, university and college students, unlike USA, UK and Australia Japan considered elite in the Program. Japan education Programs were succeeded in increasing the number of enrolment and motivating students in science and mathematics as well as educating the elite in the area of science and mathematics.

Despite the fact that US, UK, Australia and Japan considered teachers and students as their target group, they also, involve elite and still there are other issues such as involving elite and parents in the designing of and implementing the STEM education programs, from the results of this paper, it shows that is only Japan used elite and primary school students as one of its target group, however, UK, regarded directorates when implementing its STEM education programs, unlike the rest of the country. Still on the target group US has the highest target groups compared to the UK, Australia Japan.

As regard to the STEM fields reflected in the STEM Education Programs, the results indicated that, US,UK, Japan and Australia recorded an achievement because they gave more priority to STEM fields, while Japan concentrated more on science, mathematics, biology and engineering, other countries too, need to consider STEM related subjects such as biology, chemistry and physics, in addition to STEM fields in implementing STEM Education Programs, Australia included ICT as one of the Fields to succeeded in achieving the success of the Programs, this is a welcome initiatives because all other fields and related fields of STEM education depends on ICT, it is therefore vital for the remaining four countries to give additional priority to ICT when planning and executing the STEM education Programs.

From the results of this study, it can be concluded that all these countries succeeded in implementing STEM Education Programs. However, their strategies and achievements differed. See figure 1 of comparing the number of Programs from the result of this study, US recorded the highest number of successful STEM education Programs with 20 successful Programs that recorded remarkable achievements like Provision of scholarship, fellowship and assistance to both teachers and students and increasing the number of graduates in STEM fields. Followed by the UK with 10 achievable programs by Training of teachers and ambassadors who are engineers, revision of school science and mathematics curriculum, the third country is Australia and Japan which held 7 successful STEM education programs but, with different dimensions of achievements. Because when Australia achieved in Increasing the number of

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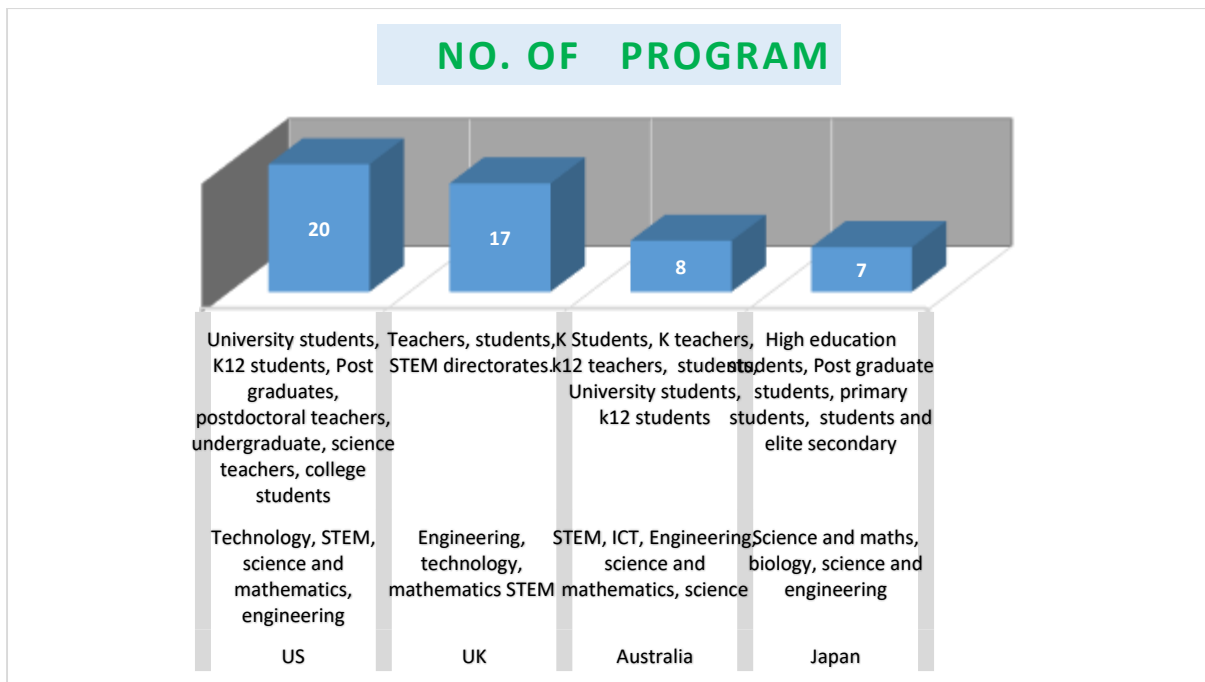
Published by the European Centre for Research Training and Development UK graduates in STEM fields, training of science secondary school teachers, motivating students to demonstrate higher level and achievement and balancing gender disparity in higher education, Japan on the other hand, has succeeded in Increasing the number of students' enrolment in science, provision of financial support to the universities for undergraduate science and maths, providing science education to elite and motivating and assisting students to achieve higher in science and math. Finally, developing and underdeveloped countries can now emulate the models of successful STEM Education from the UK, US, Japan and Australia, so that they can come up with strategies plans to implement their STEM education programs. This is necessary because for a country to be developed, such a country requires Science Technology and Engineering and Mathematics fields. These fields are the pillars of STEM Education Programs (Bybee, 2010; Jelks et al., 2020; Basu et al., 2021; Irwanto et al., 2022; Zhan et al., 2022).

Thus, a lot of lessons can be learnt from these countries (United States of America, United Kingdom, Australia, Japan). This is because despite all the complex nature and challenges of initiating and implementing STEM Education programs, these countries were able to succeed in initiating and implementing their STEM Education programs. And if other countries can who needs to initiating and implement STEM Education programs, they can adapt or adopt their strategies. Among the strategies followed includes: In US 1. Provision of scholarship fellowship and assistance to both the teachers and students and increasing the number of graduates in STEM UK. 2. Training of the school teachers and ambassadors, who are engineers, revisions of the school science and mathematics curricular. Australia 3. Increasing the number of graduates in STEM fields, training of science secondary school teachers, motivating students to demonstrate higher level and achievement and balancing gender disparity in higher education Japan Increasing the number of students' enrolment in science, provision of financial support to the universities for undergraduate science and maths, providing science education to elite and motivating and assisting students to achieve higher in science and mathematics 4. Training and increasing the academics activities of school leavers across science courses, increase the number enrolment of students in science and technology, provision of grand to STEM fields.

In addition, it was clear to note that, when planning for a program such as STEM Education or Science Education the following elements need to be considered: means of founding the program; who will implement the program to be involved; involvement of stakeholders; areas of interest; the design nature of the program and target audio. Furthermore, it is important to note that, when planning and implementing the STEM Education programs at the secondary school level, parents' involvement is required? This is because involvement of parent play a vital role the achievement of their daughter performance in science and technology involved in the activities (Castro, Expósito-Casas et al., 2015). However, most of the developing countries have not yet start implementing STEM Education Program at secondary schools. This is because, Africa in general, fared poorly in scientific disciplines and engineering compared with other continents across the globe UNDP (2009). Thus, in most of the countries in Africa their kind of STEM Education not as a program likes other countries, because they considered science, technology, engineering and mathematics individually. Hence, there is the need to design, develop and implement a science education program or module at secondary school level in African countries. Which could be included in their secondary school curriculum and textbooks than, if it is successful, they can move ahead in integrating all the fields together (STEM) and design, implement and evaluates program at the secondary level.

## SUMMARY OF THE RESULTS

The table 1 in Appendix 1 and Figure 1 below summaries the successful STEM education Programs in the USA, UK, Japan and Australia:



**Figure 1: Successful STEM Programs of USA, UK, Australia, Japan**

Based on the documents investigated in this research, it is clear from the table 1 and figure 1 that, out of the five countries compared USA has the highest successful STEM education Programs, which is indicated in blue colour followed by the UK Japan and Australia takes the least.

However, USA, Japan and Australia used university students as their target group in STEM education Programs, while only UK considered directorates, and Japan considers elites in implementing its STEM Education. All the five countries used the fields of science, technology and engineering when designing their STEM education Programs. However, only Australia was found to use Biology and it appears that all the five countries used students and teachers as their target group. All the five countries used the fields of science, technology and engineering when designing their STEM education Programs. Nevertheless, only Australia was found to use Biology and it appears that all the five countries used students and teachers as their target group.

## **CONCLUSIONS AND FURTHER RESEARCH**

In conclusion, the backbone of any nations growth and development in this era is STEM education, despite the declines in this vital instruments many countries across the globes such as UK, USA, Japan and Australia initiated Programs with the aim to stimulate and boost their citizen in STEM, based on the analysis of this paper we found that, such Programs were implemented and recorded remarkable success which in turn assisted motivated and encouraged the teachers students and elites in the area of STEM fields, and increase the number of enrolments and scientists and engineers across these countries, but, it has been seen that US has highest areas of STEM fields compared to other countries. Thus, countries who has not stated initiating and implementing STEM education Programs, and needs to increase the number of engineers, technologists and scientists could learn that, STEM education Programs were planned, initiated, implemented and found successful by countries like UK, U.S, Japan and Australia, therefore, they could use their framework as an avenue yto plan initiates and implement various STEM Education Programs.

### **Limitation**

This paper is only restricted to successful STEM Education Programs in UK, U.S.A, Japan and Australia besides, did not consider all STEM Education Programs such as STEM Education Modules and other government initiatives, therefore, there is the need to carry out a research that will develop and implement modules, and other government initiatives in the areas of science, technology, engineering and mathematics (STEM) especially at secondary school level, and consider the gender differences in both developed and developing countries, and additional countries across the globe.

### **Implications of the Study**

The findings of this study have significant implication for curriculum design, as it can be used to re-design curriculum in such a way that the school curriculum, science and technology policies of the concern countries could be reviewed. Consequently, it could be a lesson for developing countries to adapt or adopt the strategies of the STEM education programs of these countries (UK, US, Japan and Australia) to review, and reform their educational policies particularly in the areas of science, technology education and mathematics (STEM).

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**Appendices****Appendix 1:****The Summary of STEM Education Programs, Target Group and Achievement in the USA, UK, Japan and Australia**

<b>Country</b>	<b>STEM Fields</b>	<b>Target Groups</b>	<b>No. of Program</b>	<b>Achievement</b>
US	Technology, STEM, science and mathematics, engineering	University students, K12 students, Post graduates, postdoctoral teachers, undergraduate, science teachers, college students	20	Provision of scholarship, fellowship and assistance to both teachers and students and increasing the number of graduates in STEM fields (Kuenz, Mathews and Mangan 2006; Kennedy and Odell 2014; NSF, 2016 and The Institute for Broadening Participation Resource last updated: 2014)
UK	Engineering, technology, mathematics STEM	Teachers, students, STEM directorates.	17	Training of teachers and ambassadors who are engineers, revision of school science and mathematics curriculum ((The STEM cohesion Program 2011 and Royal Academy of Engineering, 2013)
Japan	Science and maths, biology, science and engineering	High education students, Post graduate students, primary students, and elite secondary	8	Increasing the number of students' enrolment in science, provision of financial support to the universities for undergraduate science and maths, providing science education to elite and motivating and assisting students to achieve higher in science and math (Freeman, 2014; Mayumi, Shot and Ashlyn 2013 and Global education through PIRE 2015).
Australia	STEM, ICT, Engineering, science and mathematics, science	K Students, K teachers, k12 teachers, students, University students, k12 students	7	Increasing the number of graduates in STEM fields, training of science secondary school teachers, motivating students to demonstrate higher level and achievement and balancing gender disparity in higher education (Chief scientist of Australia, 2012; Report Bernard Fitzsimons Churchill Fellow 2011; Elster, 2014; and Focus 2014).