STEM: A study in the Schools of Dubai,UAE.

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***Abstract*— Science, Technology, Engineering, and Math (STEM) is a mode of education to mold scientists, engineers, and technocrats to mitigate the challenges of the 21st century. The STEM curriculum has been designed for school education (K-12) to cultivate the habit of critical thinking and problem solving from childhood. This study has been conducted in the STEM schools of Dubai, UAE to determine the interest of students in pursuing STEM education and STEM career. Also, the effectiveness of teaching and efficiency of teachers have been assessed. The overall results of the study proved that STEM students in Dubai schools have a genuine interest in the subjects and the Schools are providing a nurturing environment for STEM education. However, the lack of teachers' commitment to the delivery of topics in the classroom is to be tackled by appropriate measures.**

Keywords- Dubai, effectiveness, four Cs, K-12, STEM.

I. Introduction

STEM education was commenced in the US at the beginning of the 21st century to meet the upcoming demand for engineers and technocrats in the country and to produce highly capable scientists to meet the challenges of the era. It is a curriculum and methodology to create interest in Science, Technology, Engineering, and Math (STEM) among the students at the school level (K-12). Later on, many countries followed the pattern realizing the fact that the society is becoming more and more knowledge based [1] and the physical and social systems within which people operate are becoming more complex and dynamic [2]. The competitive edge of a nation in this era depends on how effective is it in developing human capital and in nurturing individuals with capabilities for new ideas and innovations. However, STEM disciplines and careers have not been attractive to American students, and the crisis in the STEM fields is nationally recognized [3] [4] [5] [6].

This study is based on a primary survey conducted in the STEM schools of Dubai which is one of the seven Emirates of United Arab Emirates (UAE). UAE is located in the middle-east region of Asia, and it is one of wealthiest countries in the middle-east and the world's fastest growing and highly developed nation [7]. Dubai is a global city as an international aviation hub and it is the most populous city in UAE. The country is giving high priority for education, and the Knowledge and Human Development Authority (KHDA) is the Educational Quality Assurance and Regulatory Authority of the Government of Dubai. The number of private schools during the academic year 2015-16 was totalled to 173 which are home to 265,299 students from 183 countries. Out of the total 173 schools 65 schools offer the British curriculum, 32 schools offer the Indian curriculum, 31 schools have the US curriculum, and the remaining 45 schools follow the National curriculum or the curriculum of some other countries [8]. All these schools are practicing STEM education to a certain level, but the degree to which they have adopted it is not available from any data source or material. Therefore, it has been assumed that the total population under the study is all the 173 schools as classified above.

II. Research Objectives

1. To determine how the background factors such as gender, nationality, and school curriculum would affect the STEM learning interest in students.
2. To assess the effectiveness of teaching and efficiency of the teachers in implementing STEM education in their schools.
3. To determine the academic confidence of students in continuing the STEM education leading to STEM career.

III. Research Methodology

A. *Data Collection*

The study is based on primary data collected from 4 different types of schools (based on curriculum) in Dubai, viz., National (Arab), American, British, and Indian, which follow the STEM curriculum from the secondary level. The data are collected from students and teachers of these schools. An online survey was conducted for students through a structured questionnaire instrument developed in the US [9] and for teachers the one developed by Stohlmann M. et.al. [10]. The instrument for students consisted of 5 set of questions which are posed to examine the basic construct 'interest of the student' in STEM education while she/he has been undergoing through that process in the concerned school. Each item is to be responded in a 5-point Likert scale (strongly disagree-1 to strongly agree-5) which the students could answer easily without much thought and time. The adjectives used in the items are 'fascinating', 'appealing', 'exciting', 'means nothing', and 'boring' for Science, Math, Engineering, Technology, and STEM career; and thus there are 25 items plus 5 items seeking the profile of student.

The instrument for teachers mainly consisted of 5 set of items which basically measures the constructs of support, teaching, efficacy, and materials (called s.t.e.m.) for STEM integrated education. The 'support' for teachers in equipping them for STEM education has been measured by 4 items, articulated as, partnership of the school with nearby university/ college/school for STEM education, opportunity to attend orientation program for the development of professionalism in STEM education, adequacy of time to collaborate with other teachers of STEM education, and support of the curriculum company for training or clarification of doubts in curriculum. The effectiveness of teaching in STEM education is examined from two angles, namely, 'lesson planning' and 'classroom teaching'. There are 8 items for each one of this sub-variable of teaching effectiveness which are related to integration of the subjects, student-centered approach, relating a topic with big ideas, emphasis on real world and cultural aspects, encouragement given to students for critical thinking, to pose questions, for cooperative learning, and to write their own reflections on the topic. The perception on self-efficacy of the teacher is measured by 5 items which are related to content and pedagogical knowledge, commitment to STEM education, and planning and organization for STEM program. The materials are the physical resources for effective implementation of STEM program in the school. It is measured by 5 items which are related to technology, room space, and material kits for the students. Thus there are 30 items in total for the above 5 variables and all these are measured on a 5-point Likert scale (strongly disagree-1 to strongly agree-5) along with 7 items about the profile of the teacher.

The structured online questionnaire was opened for answering by students and teachers of the selected schools in Dubai (convenience sampling) during the months of February and March 2018. The email addresses were collected from the school authorities, and the link was sent to the respondents by convenience sampling method. A total of 313 students and 41 teachers were participated in the survey, out of the mailed list of 400 and 60 respectively, from 4 different types of Schools (Arab, American, British, and Indian), when the survey was ended by March 10, 2018. On the pre-test of 30 cases selected at random from the students' data showed a reliability score of 0.55 for interest in Science, 0.83 for interest in Math, 0.77 for interest in Engineering, 0.78 for interest in Technology, and 0.76 for Career interest in STEM which are considered to be satisfactory for using the instrument. The data were analyzed by using both descriptive and inferential methods including, mean, standard deviation, and chi-square test.

B. *Research Hyoptheses*

STEM education involves the learning methodology which incorporates the 4 Cs of modern education, viz., Critical thinking and problem solving, Communication, Collaboration, and Creativity and Innovation. The P21 framework envisages a unified vision for learning to ensure student success in a world where change is constant and learning never stops [11]. This study is conducted in Dubai (UAE) where the society is a mixed population of different nationalities and languages, and therefore schools offering different curriculum are operating to cater the needs of various segments in the society. Hence, this difference is the basis for the study and to formulate the following hypotheses.

H_a1: The difference in curriculum of STEM education is not independent of the difference in the learning interests for science, math, engineering, technology, and STEM career interests in students.

H_a2: The gender difference is not independent of the difference in the learning interests for science, math, engineering, technology, and STEM career interests in students.

H_a3: The Nationality difference is not independent of the difference in the learning interests for science, math, engineering, technology, and STEM career interests in students.

C. *Data Analysis and Findings*

(i) Descriptive statistics (Students): The total sample size is 313 students (from 4 different types of schools: Arab, American, British, and Indian) of which, male 139 (44%), and female 174 (56%). The grade-gender-wise classification of the sample set is given in Figure 1, where the majority are from grade IX-120 (38%), followed by grade XI-79 (25%), grade VIII-59 (19%), grade X-49 (16%), and grade XII-6 (2%). The number of participants is less from grade X and XII due to their engagement in the final examination and full concentration on studies.

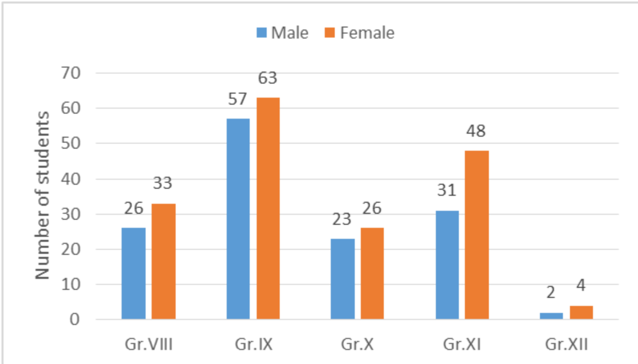

Figure 1: Grade of Students- gender-wise (in number)

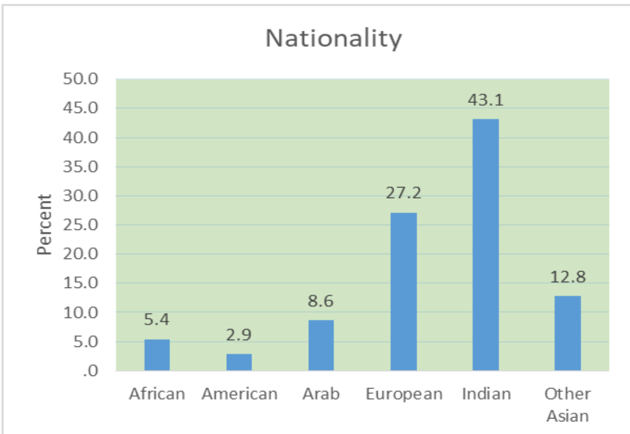

Figure 2: Nationality of students (in percent)

From the nationality-wise classification of the sample set (Figure 2), it is obvious that the majority of the students are Indian (135), followed by European (85), Other Asian (40), Arab (27), African (17), and American (9). The Indian community is a major population all over the middle-east and especially in Dubai. Four types of schools based on their curriculum are included in the study, and based on the number of students in each sub-set of the sample set, British curriculum has the majority (116), next is Indian (114), then the National (44), and the last is American (39); the percent of this classification is given in Figure 3.

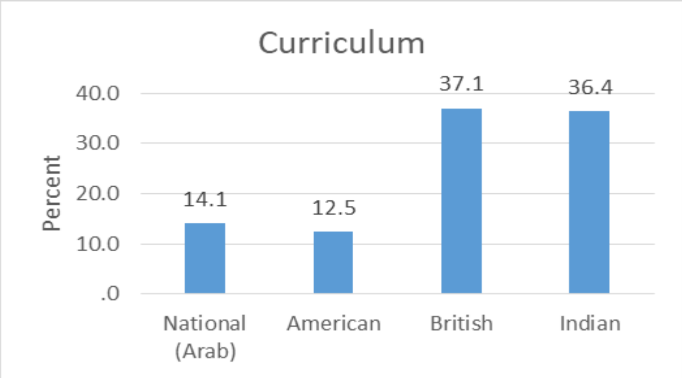

Figure 3: Students in STEM Curriculum (in percent)

Though the Indian students are the majority, from the above statistics, it can be assumed that many of the Indian students prefer the British or American curriculum for their education.

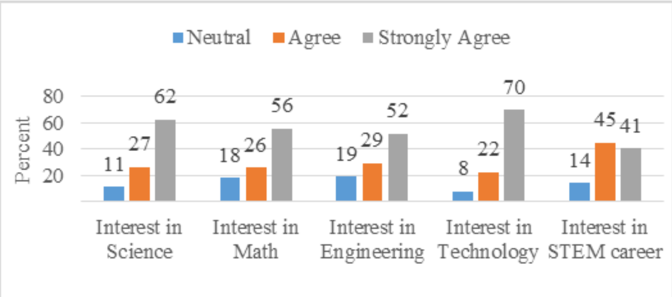

Figure 4: Interest in STEM education and career

Five adjectives are used to measure the basic construct of 'interest in' students for STEM education and continuing for the STEM career. They are 'fascinating', 'appealing', 'exciting', 'means nothing' and 'boring'; of these the first three are positive statements and the last two are negative. The scores for the negative items are reversed for the purpose of analysis and interpretation. All these five items are measured in a five-point scale, strongly disagree (1) to strongly agree (5) and the average of the score of the 5 items are brought into a class interval of 0.80 of five classes. The frequency percent of this score is given in Figure 4, and it is evident that all the responses belong to upper three categories only, and the large majority of the students (more than 80%) have given affirmative responses to the construct of 'interest in' science, math, engineering, technology, and STEM career. Therefore, from the descriptive frequency analysis it can be interpreted that the students, in general, are highly interested in the content and pedagogy of the curriculum and also highly interested in the STEM career irrespective of gender, nationality, or the type of curriculum.

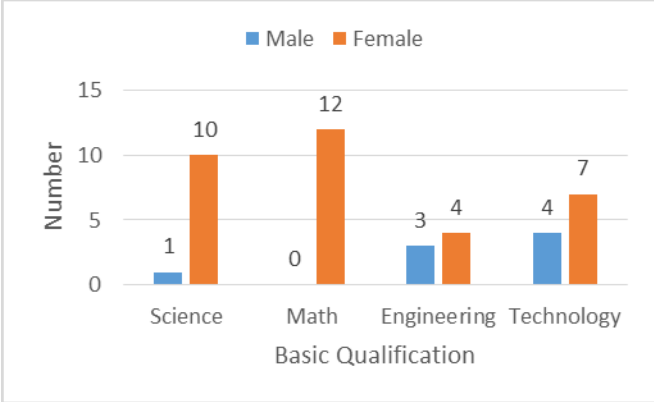

Figure 5: Teacher Distribution- Gender vs. Basic Qualification

(ii) Descriptive Statistics (Teachers): The sample size of teachers being limited to 41, only descriptive analysis has been able to do on the data. The female teachers are the majority 80.5 percent (33), and male teachers are only 19.5 percent. All these teachers have their basic qualification in accordance with the requirement for STEM education and their number in the sample set constitutes 11, 12, 7, and 11 for science, math, engineering, and technology respectively (Figure 5). Math, science, and technology teachers are almost equal in number whereas the engineering teachers are lower in number.

Table 1: Teachers' Nationality vs. Curriculum

Nationality	School Curriculum				
	Arab	**American**	**British**	**Indian**	**Total**
African	1	0	0	0	**1**
American	0	11	0	0	**11**
Arab	2	0	0	0	**2**
European	0	0	8	0	**8**
Indian	0	0	0	16	**16**
Other Asian	3	0	0	0	**3**
Total	**6**	**11**	**8**	**16**	**41**

Table 1 describes the nationality of teachers and their respective school curriculum in which they teach. On comparison, it has been found that the Indians, Americans, and the British do teach in the same curriculum schools of their nationality. But in the Arab schools there are other Asians and African in addition to the Arab which signifies that adequate teachers of their nationality are not available.

Table 2 gives the summary of the items used to measure the variables under study. Broadly, the variables are classified into 4, viz., 'support', 'teaching', 'efficacy', and 'materials', while 'teaching' is again sub-divided into two- 'lesson planning', and 'classroom teaching', and hence there are 5 variables. The mean value of 'support', 'efficacy', and 'materials' are greater than 4.20 which indicates that there is strong agreement towards those variables and 'efficacy' has got maximum mean value of 4.624, followed by 'materials' (4.512), and 'support' (4.250). Moreover, all the five items in 'efficacy' have a mean value of almost 4.6 with a uniform standard deviation of 0.5, signifies that all teachers are equally confident in their content and pedagogical knowledge, the need for organizing and planning for implementation of STEM program, and also the commitment for STEM education. The variable 'materials' is measured by 5 items where two are technology related and the other three are related to materials and space. All these 5 items have an individual mean value of 4.4 or above which signifies that the schools have invested adequately for the modern ICT infrastructure as well as in the physical infrastructure for the effective implementation of STEM program in the schools.

Table 2: Summary of Variables

Descriptive	Variables				
	Support	**Lesson Planning**	**Classroom Teaching**	**Efficacy**	**Materials**
n	41	41	41	41	41
Mean	4.250	4.180	3.683	4.624	4.512
Std. Dev.	.274	.258	.224	.273	.287
Max.	4.75	4.63	4.25	5.00	5.00
Min.	3.50	3.63	3.25	4.00	4.00

To measure the variable 'support', four items are used which are related to the environmental attributes available to the teachers for the effective implementation of STEM program. Of these the mean value is lowest (4.10) for 'partnership with nearby university/college/school for the support of STEM education', signifies that the school authorities are not taken seriously this element of support. Also the next item 'opportunity given to the teacher for the professional development' (mean 4.20) shows that the teachers are not getting adequate support in this respect. On the contrary, 'the time for collaboration with other teachers' and 'support of the curriculum company' are answered at higher score of 4.3 or above, indicating that they are highly supportive for STEM program of the schools.

The Lesson Planning is the plan and program of teaching a subject in the classroom prepared prior to a month or term by the concerned teacher. In STEM subjects each subject must be integrated with the other three subjects, it should be student-centered, a problem solving approach, must consider big ideas and themes, must be based on previous knowledge of the student, must integrate technology with the topics, and also must give emphasis on cultural and real world aspects. The overall score of this variable is 4.18 which indicates that it is done at a satisfactory level, whereas the individual mean values signifies that students' capabilities or previous knowledge, student-centered approach, and cultural and real world aspects are least considered. The other aspects mentioned above are fairly considered.

The Classroom teaching is the delivery part of the STEM program, the overall mean score of this variable is the lowest (3.683) which indicates that there is a significant gap between the plan and its execution. From the details of the individual mean score of items it could be inferred that the teachers are not giving enough opportunity to the students for critical thinking and problem solving as well as they are not continuously evaluated during the course of study. Among all the 5 variables the weakest one is the classroom teaching and therefore the authorities have to give first priority to sort out this problem for the effective implementation of the STEM program.

(iii) Inferential Statistics: The proposed hypotheses are tested by a non-parametric method called the chi-square test of Independence of attributes.

Hypothesis No. 1:

$H_a1.1$: The difference in curriculum of STEM education is not independent of the difference in the learning interests for science.

$H_a1.2$: The difference in curriculum of STEM education is not independent of the difference in the learning interests for math.

$H_a1.3$: The difference in curriculum of STEM education is not independent of the difference in the learning interests for engineering.

$H_a1.4$: The difference in curriculum of STEM education is not independent of the difference in the learning interests for technology.

$H_a1.5$: The difference in curriculum of STEM education is not independent of the difference in the career interest of STEM.

Table 3: χ^2 Results -Type of Curriculum vs. Interest

Hypotheses	**Chi-square value**	**df**	**p-value**
$H_0 1.1$: Curriculum is independent of learning interest in Science	21.408	6	0.002***
$H_0 1.2$: Curriculum is independent of learning interest in Math	28.987	6	0.000***
$H_0 1.3$: Curriculum is independent of learning interest in Engineering	16.378	6	0.012**
$H_0 1.4$: Curriculum is independent of learning interest in Technology	12.619	6	0.05*
$H_0 1.5$: Curriculum is independent of career interest of STEM	14.306	6	0.02*

*≤ 5 % level, ** =1% level, *** < 1% level

The students in the sample set are undergoing through 4 different types of curriculum, viz., the National (Arab), the American, the British, and the Indian. Majority of the students are in the British or Indian curriculum. The mean of the responses of the 5 variables (i.e., interest in- Science, Math, Engineering, Technology, and STEM career) are only in three ranges, namely, Neutral, Agree, and Strongly Agree. Hence, a 4 x 3 Contingency Table was prepared for each variable and the chi-square statistic and the corresponding *p* values are given in Table 3. All the Chi-square values are significant at 5 percent or less than 5 percent level. Thus, all the null hypotheses ($H_0 1.1$, $H_0 1.2$, $H_0 1.3$, $H_0 1.4$, and $H_0 1.5$) are not accepted and the alternative hypotheses could be accepted. Hence, it shall be inferred that the students' learning interest in science, math, engineering, and technology, and interest in

STEM career depends on the type of curriculum in which they study.

Hypothesis No. 2:

$H_a2.1$: The gender difference is not independent of the difference in the learning interests for science.

$H_a2.2$: The gender difference is not independent of the difference in the learning interests for math.

$H_a2.3$: The gender difference is not independent of the difference in the learning interests for engineering.

$H_a2.4$: The gender difference is not independent of the difference in the learning interests for technology.

$H_a2.5$: The gender difference is not independent of the difference in the career interest of STEM.

Table 4: χ^2 Results - Gender of students vs. Interest

Hypotheses	Chi-square value	df	*p* value
$H_02.1$: Gender is independent of learning interest in Science	7.930	2	0.019*
$H_02.2$: Gender is independent of learning interest in Math	7.144	2	0.028*
$H_02.3$: Gender is independent of learning interest in Engineering	1.963	2	.375
$H_02.4$: Gender is independent of learning interest in Technology	1.697	2	.428
$H_02.5$: Gender is independent of career interest of STEM	6.263	2	0.044*

*< 5 % level

The students' gender (male and female) is in the rows and the frequency of mean score of responses (i.e., Neutral, Agree, and Strongly Agree) are in columns. Hence, a 2 x 3 contingency table has been prepared for the chi-square test of independence of each variable. The summarized chi-square test results are given in Table 4. The chi-square values are significant at less than 5 percent level for $H_02.1$, $H_02.2$, and $H_02.5$, and hence the null hypotheses are not accepted or the alternative hypotheses are accepted. Therefore it could be inferred that students' interest in learning science, math, and career interest in STEM depends on gender. Conversely, the Chi-square values are not significant at 5 percent level for $H_02.3$, and $H_02.4$, and hence the null hypotheses are accepted. In other words, the students' interests in learning engineering and technology are independent of gender.

Hypothesis No. 3:

$H_a3.1$: The nationality difference is not independent of the difference in the learning interests for science.

$H_a3.2$: The nationality difference is not independent of the difference in the learning interests for math.

$H_a3.3$: The nationality difference is not independent of the difference in the learning interests for engineering.

$H_a3.4$: The nationality difference is not independent of the difference in the learning interests for technology.

$H_a3.5$: The Nationality difference is not independent of the difference in the career interest of STEM.

In the sample set, the Nationality of students is categorized into six, viz., African, American, Arab, British, Indian, and Other Asians. Since the number of Africans and Americans has been less than the minimum required (5) for each cell in the Contingency Table, these two nationalities are excluded from the Chi-square analysis, and therefore the sample set has been reduced to 287 cases. In other words, only four Nationalities, Arab, British, Indian, and Other Asian, are considered for the Chi-square test. The Nationality of the student is arranged in rows and the frequency of the mean score of responses (i.e., Neutral, Agree, Strongly agree) are in columns forming it into a 4 x 3 Contingency Table. The summary of Chi-square results

Table 5: χ^2 Results - Nationality vs. Interest

Hypotheses	Chi-square value	df	*p* value
$H_03.1$: Nationality is independent of learning interest in Science	48.086	6	0.000*
$H_03.2$: Nationality is independent of learning interest in Math	76.375	6	0.000*
$H_03.3$: Nationality is independent of learning interest in Engineering	45.890	6	0.000*
$H_03.4$: Nationality is independent of learning interest in Technology	25.403	6	0.000*
$H_03.5$: Nationality is independent of career interest of STEM	29.933	6	0.000*

*< 1 % level

is given in Table 5, and it is proved that all the Chi-square values are significant at less than 1 percent level. Hence, none of the null hypotheses are accepted and all the corresponding alternative hypotheses are accepted. Thus, it shall be inferred that the interest of students in learning Science, Math, Engineering, and Technology; and interest in STEM career depends on Nationality of the student.

IV. Discussion

The study was designed with three specific objectives, firstly, to determine the dependence of background factors such as gender, nationality, and the school curriculum on learning interest of STEM in students. Secondly, to assess the effectiveness in teaching and efficiency of the teachers in implementing STEM education, and thirdly, the confidence of students in continuing STEM education that leads to a STEM career. The students' data are collected and analyzed to describe and prove the first and third objectives. The second objective is described through the teachers' data.

It has been proved that the learning interest in the student for studying Science, Math, Engineering, and Technology is significantly affected by the nationality of the student. The scientific and technological development of a nation will definitely have an environmental influence in the students to pursue their studies in these subjects. The quantity and quality of institutes in the field of Engineering, Technology, and Scientific Research available in a Nation is a pre-determining factor for the young students to build up academic confidence and motivating them in continuing the STEM education. The

Gender difference is not proved to be a significant factor in the learning interest of Engineering and Technology subjects, whereas it would significantly affect in the learning interest for Science and Math. Therefore, the Science and Math teachers must give particular attention to male and female students based on their strengths and weaknesses for the effective delivery of the program. It shows consistency with the results of a previous study of the gender gap in STEM major selection where female students are shown as a negative predictor of STEM major choice [12]. The teacher should know the student in terms of his/her previous knowledge, the teacher should use assessment as part of the instruction, and the teacher should encourage students for critical thinking. The STEM curriculum used by the School significantly affect the learning interest in students in Science, Math, Engineering, and Technology. This is an indication to the teachers and school authorities to make curriculum according to the best practices followed in the whole system. A constant research is needed in this respect for the improvement and updating of the curriculum. The school must have a tie-up with best curriculum designing organizations, and external support and collaboration are highly essential for the success of STEM program.

The effectiveness of teachers is to be evaluated on the basis of the Support they get, Teaching methodology adopted, Efficacy of teachers, and Material resources available. Based on the descriptive analysis of teachers' data, it has been found that the Classroom teaching variable in the Teaching methodology has the lowest rank. Therefore, the school authorities have to monitor the STEM teachers' performance especially in their classroom teaching. It's advisable that there must be a definite objective plan for evaluating teachers' performance and thereby meritorious teachers could be motivated through some incentives. It is relevant to be noted here a previous finding that increasing the interests of K-12 students rests on University outreach efforts and improved K-12 instruction, not on College teaching [13]. All the other factors are highly ranked and therefore it could be explained that the STEM schools are doing their level best for STEM education.

The confidence of students in continuing STEM education which would lead to a STEM career is evaluated from the students' data analysis. Again, it depends on the curriculum followed by the School, the nationality and gender of the student. The school authorities must follow the best competent curriculum on the STEM to create learning interest in students, and further continuance of the study, because it is proved that students have a strong interest in STEM career. Broadening STEM engagement and achievement was the key finding in a country comparison report of Australia, it means improving participation in the STEM disciplines through 'T' policies (i.e., learning in both breadth and depth) and covering the full spectrum of prior student achievement level [14]. The nation should take up the task of STEM education with a broad vision to modernize the economy and to make it a knowledge-technology-based-society. The school authorities must give student-centered approach in delivering STEM education so that the difference in learning interest due to gender difference could be resolved. "The development of talent in STEM fields and the ultimate career pathway of gifted STEM students depend on the best available scientific evidence on educational environments that produce sustained interest and motivation for careers in STEM". [15]

V. Conclusion

The findings of this study is significant to all the stakeholders of STEM education, especially to the teachers who play the key role in this process, their commitment and effective delivery of classroom teaching by integrating the subjects is the key to the success of the program. The administrators and policy makers have the responsibility to create a STEM facilitating environment in the country by providing specialized and quality organizations in scientific research and technological innovation which should guarantee the effective functioning of the STEM Pipeline. A good education system for the '21st Century skills' is the integration of the 'Four Cs'- Critical thinking, Communication, Collaboration, and Creativity' in K-12 education [16]. This is what STEM education in intended for. Let us sum up the significance of this mode of education with the words of the former American President Barack Obama who has rightly described science as 'more essential for our prosperity, our health, our environment, and our quality of life than it has ever been before' [17].

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