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Investigating Elementary School Teachers' Perceptions about their STEM Teaching Practices in Karachi, Pakistan

Muhammad Akram Mankash [*] ***& Anjum Bano Kazimi*** [**]

Abstract

The STEM/STEAM schooling framework is extending fast throughout the globe, however it is confronting various difficulties and Pakistan is no exemption. There is an absence of educator proficient turn of events, educational program plans, casual learning encounters, mechanical assets, and an appropriate learning climate, besides expanding revenue in science, technology, engineering, and math (STEM). The aim of this research is to decide more about teachers' views about STEM Education System and its impact on students' learning and society in Karachi, Pakistan. The data was collected utilizing pilot study structured questionnaire. The data was gathered from n=468 teachers from public and private schools utilizing the survey technique. The data was analysed using the Statistical Package for the Social Sciences (SPSS) and Smart PLS. Survey results indicated that elementary school teachers engaged in STEM education environment revealed that skills and abilities, application of learning, curriculum and equivalent knowledge of teachers comprise the STEM education significantly. For the positive growth of the education system and to overcome the challenges and to fulfil the requirements of modern times the teachers are recommended to consider the importance of stem education.

Keywords: Elementary School Teachers' Perception, STEM, Teaching Practices

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Introduction

During the past two decades, the emerging technologies and educational demands have led the fast moving and dynamic world to undergo a paradigm shift. In 21st century, the rising trend to have scientifically educated and experienced human resource in specific fields, has led developed countries like United States, East Asia, and Western Europe, to emphasis more on Science, Technology, Engineering, and Mathematics (STEM) to address the multidisciplinary problems being faced by the world. STEM, STEAM both are acronyms, introduced in early 90's. The former stands for Science, Technology, Engineering and

[*] Muhammad Akram Mankash, Research Scholar, Iqra University, Karachi.
[**] Dr Anjum Bano Kazimi, Professor of Education, Iqra University, Karachi.

Mathematics, whereas inclusion of 'A' that makes STEAM, adds dimensions of arts to STEM education at different levels of learning. Today's students need to be well equipped with the knowledge and skills to respond to the 21st century demands with ease, making sense of the inputs. The acquisition of STEM education supports and promotes developing skills and enhance knowledge, prepare students to be the future human resource. According to an estimate by Marginson, Tyler, Freeman, and Roberts (2013), the STEM-skilled manpower reflects the ubiquitous role of science, technology, engineering, and mathematics in education. The outcomes of education systems meeting present day needs around the globe are prominent because of the results manifested in the comparative study of students' achievement.

In recent years, advances in science have raised the demand for people who are well-versed in their domains and can add innovation to their skill sets. Indeed, such persons with expert proficiency in their own domains and a thorough understanding of other Science, Technology, Engineering, and Mathematics (STEM) disciplines are required in 21st-century economy. Besides that, quality education is critical for kids' future success in Science, Technology, Engineering, and Mathematics (STEM).[1]

STEM schooling is amazingly basic in under developing countries. As far as STEM, there has been a change in the instructive interaction, as indicated by White (2014), who guarantees that the STEM model helps to fundamentally change the manner in which science is educated by bringing innovation and designing into students' exercises, furthermore, students are thoughts to deal with issues through investigation exercises.

Pakistan is a developing country facing variety of internal and external challenges. There are alarming factors that threaten its stability and contribute towards poor governance. The education system of Pakistan remained lack the basic needs of time, particularly it failed to update towards science education. The qualities of education at elementary and high school levels have remained deteriorating. The present state calls for improvement and orientation towards STEM approaches of education to meet the 21st century goals. Educational

[1] M. Stohlmann, T.J. Moore, J. McClelland & G.H. Roehrig, 'Impressions of a middle grades STEM integration program: Educators share lessons learned from the implementation of a middle grades STEM curriculum model', *Middle School Journal*, 43:1 (2011), 32-40.

challenges call for adopting an education system such as STEM, already put into play by developed countries.[2]

According to Carnevale, Smith, and Melton (2011), the labour market data indicate about the association of cognitive knowledge, skills and abilities associated with STEM.[3]

Literature Review

STEM

The term STEM was introduced in 2007 by Judith Ramaley, then director of the National Science Foundation (NSF), rebranded the older acronym SMET that dates back to 1993.[4] However, STEM flourished in variety of ways in different parts of the world. At its point of origin in the U.S., STEM emerged as 'political reaction to the political disposition of the US's global superiority' whereas in the UK, STEM was envisioned as human capital.[5] However, Asian countries such as China and Japan with their high performing education systems and growing economies have broadly emphasized science and technology in their curriculums including both university and industry driven research and development.

STEM is as often as possible utilized as a kind of perspective to contemplate disciplines, work markets, and occupations in the field of science, technology, engineering and math, as per an audit of related writing while preparing in singular STEM. As per White (2014), it is a multidisciplinary and applied strategy to learning incorporated STEM

2 S. Marginson, R. Tyler, B. Freeman & K. Roberts, 'STEM: Country Comparisons. Australian Council of Learned Academies (ACOLA)', 2013; T.J. Moore & K.A. Smith, 'Advancing the State of the Art of STEM Integration', *Journal of STEM Education: Innovations and Research*, 15:1 (2014), 5-11.

3 L.D. English, 'STEM education K-12: Perspectives on Integration', *International Journal of STEM education*, 3:1 (2016), 1-8; S. Marginson, R. Tyler, B. Freeman & K. Roberts, 'STEM: Country Comparisons. Australian Council of Learned Academies (ACOLA)', 2013; S. Fan & J. Ritz, 'International Views of STEM Education', *PATT-28 Research into Technological and Engineering Literacy Core Connections*, 2014, 7-14; T.J. Moore & K.A. Smith, 'Advancing the State of the Art of STEM Integration', *Journal of STEM Education: Innovations and Research*, 15:1 (2014), 5-11.

4 D. Donahoe, 'The Definition of STEM', Retrieved 7 July 2017.

5 S.Blackley & J. Howell, 'A STEM Narrative: 15 Years in the Making', *Australian Journal of Teacher Education*, 40:7 (2015), 102-12. DOI:10.14221/ajte.2015v40n7.8

topics or school subjects dependent on a trans-disciplinary school educational program.[6]

Hypothesis Development

Skills and abilities of teachers and STEM

Any educational reform, particularly STEM reform, relies heavily on the teacher. It is critical to analyse teachers' understanding and abilities in order to produce a more successful STEM education. What teachers use in their classes depends on their abilities and capabilities. Teachers must be trained in order to accomplish the aim of utilizing their abilities. It is essential that teachers fully embrace the skills and abilities and integrate them into their lectures. In comparison to traditional classrooms, educational changes such as STEM necessitate a different set of pedagogical talents. Teachers must acquire new ways of teaching and improve their abilities in order to properly adopt a new instructional technique. STEM classes are structured differently than traditional classrooms, and teachers are assigned certain functions, therefore they demand a distinct set of skills than traditional classes.[7] Teachers' abilities and talents aid in the operationalization of STEM education. Teachers must have a strong understanding of STEM pedagogical content as well as efficient skills and talents in order to teach STEM effectively. It is essential for teachers to be aware of STEM occupations and to communicate possible career paths to their pupils in order to facilitate kids' STEM identity formation. Teachers' abilities and beliefs about teaching and learning have an impact on their behaviour, performance, and, ultimately, practices. Because of a better belief in their pupils and their own abilities, more motivated teachers will reflect a stronger sense of skills and ability, especially with demanding students.[8] This helped to form H1:

6 L.D. English, 'STEM Education K-12: Perspectives on Integration', *International Journal of STEM Education*, 3:1 (2016), 1-8; C. Kearney, 'Efforts to Increase Students' Interest in Pursuing Science, Technology, Engineering and Mathematics Studies and Careers', *National Measures Taken by, 21*, 2011; D.W. White, 'What is STEM Education and Why is it Important', *Florida Association of Teacher Educators Journal*, 1:14 (2014), 1-9.

7 M.S. Corlu, R.M. Capraro & M.M. Capraro, 'Introducing STEM Education: Implications for Educating our Teachers in the Age of Innovation', *Eğitim ve Bilim*, 39:171 (2014), 74-85.

8 I. De Coito & P. Myszkal, 'Connecting Science Instruction and Teachers' Self-efficacy and Beliefs in STEM Education', *Journal of Science Teacher Education*, 29:6 (2018), 485-503.

H1: skills and abilities of teachers have a positive significant impact on STEM.

Pedagogy and communication skills of teachers and STEM

The acquisition of modern teaching skills and specifically communication skills are necessary. The communication skills of teachers should be effective as it will provide an environment and elements of communication through platforms within the context of STEM. Teachers reported perceived growth in the areas of understanding other ideas being open to differences, sharing ideas with a range of audiences and using multiple representations to present student's ideas on STEM content when they have effective communication skills among students. The communication skills of teachers will provide avenue for developing students 21st century skills related to STEM.[9] Therefore we propose H2:

H2: pedagogy and communication skills of teachers have a positive significant effect on STEM.

Application of learning skills of teachers and STEM

STEM disciplines provide opportunities to students to develop competence. However, teacher learning skills such as deep and extensive knowledge of that discipline is necessary. High learning skill, along with knowledge of relevant disciplines is essential for teacher to contribute in STEM education; teachers require knowledge of these disciplines and how to teach them.[10] Therefore we propose: H3.

H3: Application of learning skills of teachers has a positive significant effect on STEM.

Curriculum and equipment knowledge of teachers and STEM

Teachers must organise various forms of teaching material depending on their pedagogical philosophy and learning outcomes, as well as variances between target learners or school settings, in order to provide effective STEM education. Teachers have to be familiar with the curriculum in order to do so. Because all curriculum design approaches have the same purpose of helping students to understand and integrate essential STEM knowledge, it is critical that teachers have insight of curriculum

9 A. Owens & R. Hite, 'Enhancing Student Communication Competencies in STEM Using Virtual Global Collaboration Project based Learning', *Research in Science & Technological Education*, 2020, 1-27.

10 K. Beswick & S. Fraser, 'Developing Mathematics Teachers' 21st Century Competence for Teaching in STEM Contexts', *ZDM*, 51:6 (2019), 955-965.

information. Students will be unable to build cognitive skills about their design processes if teachers fail to provide clear directions on how to apply specific scientific and mathematical information while solving engineering challenges. Before implementing STEM courses, teachers should create a list of knowledge.[11] Furthermore, shifting focus on a specific academic disciplines to various themes, demands teachers to have a more systemic viewpoint and a wide understanding of curriculum content. Teachers are unlikely to be prepared to teach STEM education effectively unless they have extensive curriculum knowledge.[12] Therefore we propose: H4

H4: curriculum and equipment knowledge of teacher have a positive significant effect on STEM

Diversity in learning of teachers and STEM

The technique teachers employ to teach the information, which largely reflects how they were taught, is critical to the effectiveness of STEM education. Teachers must participate in the learning process in order to learn how to teach STEM subjects. As a result, STEM learning and teaching must be integrated.[13] Teachers must be actively involved in connecting pupils to their local real-world contexts. As a result, they have enhanced their confidence in STEM teaching and their desire to teach STEM. Furthermore, teachers' learning variety will aid them in developing an effective style of inquiry, which can only be achieved through teacher-directed activities and knowledge learning (Davis, Du, Tang, Qiao, Liu & Chiang, 2020).[14] Therefore we proposed:

H5: diversity in learning of teachers has a positive significant effect on STEM

11 S-C. Fan, K.-C. Yu & K.-Y. Lin, 'A Framework for Implementing an Engineering-Focused STEM Curriculum', *International Journal of Science and Mathematics Education*, 2020, 1-19.

12 L.S. Nadelson, J. Callahan, P. Pyke, A. Hay, M. Dance & J. Pfiester, 'Teacher STEM Perception and Preparation: Inquiry-based STEM Professional Development for Elementary Teachers', *The Journal of Educational Research*, 106:2 (2013), 157-68.

13 C. Kim, D. Kim, J. Yuan, R.B. Hill, P. Doshi & C.N. Thai, 'Robotics to Promote Elementary Education Pre-service Teachers' STEM Engagement, Learning, and Teaching', *Computers & Education*, 91, (2015), 14-31.

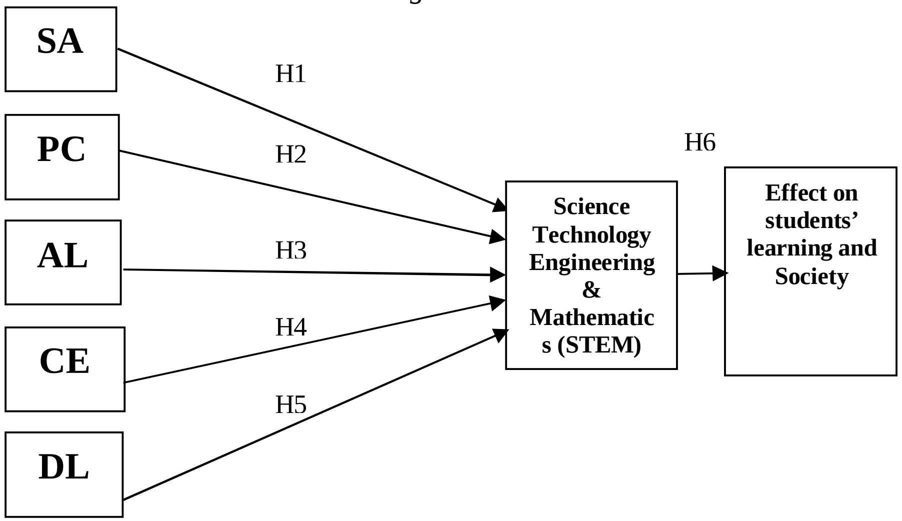
14 J.P. Davis, J. Du, J.H. Tang, L. Qiao, Y.Q. Liu & F.K. Chiang, 'Uniformity, Diversity, Harmony, and Emotional Energy in a Chinese STEM Classroom', *International Journal of STEM Education*, 7:1 (2020), 1-15.

STEM knowledge of teachers and impact on society

Developing a context framework for STEM education demands better comprehension. Teachers with sufficient topic knowledge and domain pedagogical content experiences can improve STEM education system. Teachers can obtain a better understanding of each domain and identify essential learning outcomes for it by studying STEM practices. In-service teachers can increase their confidence in teaching by providing a robust framework for an integrated STEM approach. As a result, STEM education will be more effective and have a greater impact on society.[15] Therefore we proposed:

H6: stem knowledge of teachers have a positive significant effect on students' learning and society.

Figure 1



[15] T.R. Kelley & J.G. Knowles, 'A Conceptual Framework for Integrated STEM Education', *International Journal of STEM Education,* 3:1 (2016), 1-11.

Methodology

The quantitative research approach[16] was used in the study. A survey questionnaire was employed to collect data and statistical analysis was carried out using SPSS and SMART PLS. Quantitative research design of the study focused on examining the effect of public elementary school teachers' perceptions about their STEM teaching practices. Secondly information is collected regarding perception, readiness and development, and gradual implementation of STEM education system in Pakistan.

Instrumentation

The self-developed survey questionnaire was used to collect the data for the study. Each dimension of the instrument consists of five items on a 5-point Likert Scale ranging from 1 (strongly disagree), to 5 (strongly agree). Survey questionnaire was used to collect the quantitative data regarding the perceptions of the participants. Demographic information, i.e. gender, age, experience, academic qualification and professional qualification was also collected during the survey. The study comprised of a purposive sample of public elementary school teachers of district Malir, Karachi Pakistan.

Data Analysis and Results

The researcher discussed the analysis and interpretation of the data using PLS-SEM technique. There are two measurement models in PLS-SEM technique named as measurement model and structural model. Structural model helped to testify the results of developed hypothesis. Various tests in the measurement model would enable the examination and identification of constancy and dependability of the data. Analysis of the collected data is carried out in order to predict the effect of relationships between variables along with the moderation analysis. Besides, in measurement model there are various tests that include convergent validity and discriminant validity as well.

[16] J.W. Creswell, *A Concise Introduction to Mixed Methods Research,* SAGE publications, 2014.

Demographic Profile of the Respondents

The following table 4.1 shows the composition of data based on the respondents' profile using frequency measures in SPSS.

Table 1

Demographic Profile (n = 468)

		Frequency	Percent
Gender	Male	236	50.4
	Female	232	49.6
Age	25-35 years	20	4.3
	36-45 years	227	48.5
	46-55 years	204	43.6
	Above 55 years	17	3.6
Experience	1-5 years	97	20.7
	6-10 years	140	29.9
	11-15 years	143	30.6
	16-20 years	88	18.8
Academic Qualification	Graduate	282	60.3
	Masters	173	37
	MS/M.Phil.	11	2.4
	PhD	2	0.4
Professional Qualification	B.Ed.	212	45.3
	M.Ed.	256	54.7

The above table has a total of 236 (50.4%) male respondents and 232 (49.6%) female respondents. The age group has shown 20 (4.3%) respondents from less than 35 years, 227 (48.5%) respondents less than 45 years and 204 (43.6%) respondents less than 55 years. In addition, 17 (3.6%) respondents were from 55 years and above. The experience group has shown 97 (20.7%) respondents less than 5 years, 140 (29.9%) respondents less than 10 years, 143 (30.6%) respondents less than 15 years and 88 (18.8%) respondents having experience of less than 20 years. The academic group has 282 (60.3%) respondents from graduates, 173 (37%) respondents from masters, 11 (2.4%) respondents from Ms/M. Phil, 2 (0.4%) respondents from PhD, 212(45.3%) respondents from B. Ed and 256 (54.7%) respondents from M.Ed.

Measurement Model

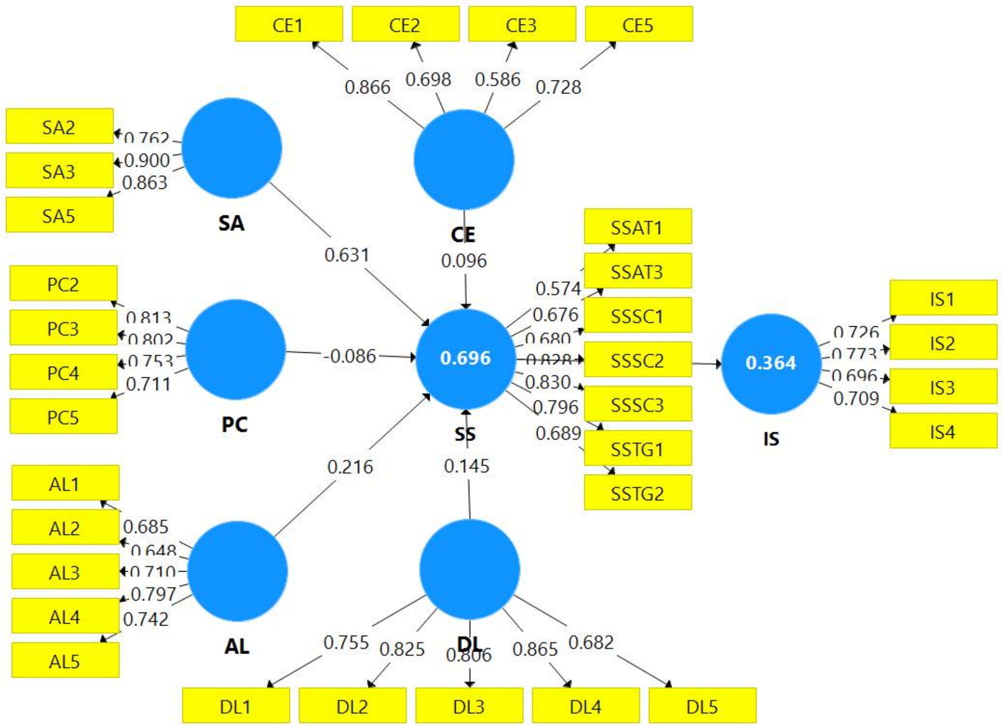


Figure 2: PLS Algorithm Illustration

Outer loadings

Table 2 describes the result of outer loadings for construct validity using PLS algorithm analysis.

Table 2: *Outer Loadings*

	AL	CE	DL	IS	PC	SA	SS
AL1	0.685						
AL2	0.648						
AL3	0.710						
AL4	0.797						
AL5	0.742						
CE1		0.866					
CE2		0.698					
CE3		0.586					
CE5		0.728					
DL1			0.755				
DL2			0.825				
DL3			0.806				
DL4			0.865				
DL5			0.682				
IS1				0.726			
IS2				0.773			
IS3				0.696			
IS4				0.709			
PC2					0.813		
PC3					0.802		
PC4					0.753		
PC5					0.711		
SA2						0.762	
SA3						0.900	
SA5						0.863	
SSAT1							0.574
SSAT3							0.676
SSSC1							0.680
SSSC2							0.828
SSSC3							0.830
SSTG1							0.796
SSTG2							0.689

AL = Application of Learning; CE = Curriculum and Equipment; DL = Diversity in Learning; IS = Impact on Society; PC = Pedagogy and Communication; SA = Skills and Abilities; SS = STEM/STEAM.

It has been recommended by Hair, Risher, Sarstedt & Ringle, (2019) that indicator reliability should be higher than 0.70 for retaining the indicator while loading below than 0.40 should be deleted from the model. Nevertheless, indicator reliability between 0.40 and 0.70 should be retained based on their considerable degree of convergence. Herein, the results have shown that four indicators of pedagogy and communication (PC), and three items of skills and abilities (SA) have indicator reliabilities higher than 0.70 and therefore, retained in the model. However, seven indicators have been retained in the STEM (SS) construct with least loading of 0.574 (SSAT1). Similarly, five indicators have been retained in the application of learning (AL) construct with least loading of 0.685 (AL1), four indicators have been retained in the curriculum and equipment (CE) with the least loading of 0.586 (CE3), five indicators have been retained in the diversity in learning (DL) with the least loading of 0.682 (DL5), and lastly, impact on society (IS) has four indicators loaded in the analysis with the least loading of 0.696 (IS3).

Construct reliability and validity

Table 3 revealed the findings of construct reliability and validity for convergent validity using PLS algorithm.

Table 3

Construct Reliability and Validity

	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
AL	0.777	0.841	0.516
CE	0.721	0.814	0.528
DL	0.850	0.891	0.623
IS	0.711	0.817	0.528
PC	0.775	0.854	0.594
SA	0.797	0.881	0.712
SS	0.850	0.887	0.533

AL = Application of Learning; CE = Curriculum and Equipment; DL = Diversity in Learning; IS = Impact on Society; PC = Pedagogy and Communication; SA = Skills and Abilities; SS = STEM / STEAM

It has been suggested by Hair et al. (2019) that two reliability estimates have been used in the PLS-SEM including Cronbach's alpha and composite reliability with the threshold of 0.70 and 0.80 respectively.

Moreover, AVE has been used for estimating the degree of convergence between indicators of a latent construct.[17] Herein, all latent constructs have achieved considerable reliability based on Cronbach's alpha and composite reliability while their AVE coefficients were also found higher than the recommended thresholds. Hence, the study has achieved convergent validity based on the results of construct reliability and validity.

Discriminant validity using Fornell and Larcker (1981) Criterion

Table 4 discussed the findings of discriminant validity using Fornell and Larcker (1981) Criterion.

Table 4

Fornell and Larcker (1981) Criterion

	AL	CE	DL	IS	PC	SA	SS
AL	0.718						
CE	0.626	0.726					
DL	0.398	0.428	0.789				
IS	0.407	0.551	0.494	0.727			
PC	0.506	0.242	0.339	0.372	0.771		
SA	0.297	0.386	0.472	0.412	0.287	0.844	
SS	0.477	0.516	0.540	0.603	0.276	0.776	0.730

AL = Application of Learning; CE = Curriculum and Equipment; DL = Diversity in Learning; IS = Impact on Society; PC = Pedagogy and Communication; SA = Skills and Abilities; SS = STEM / STEAM.

According to Fornell and Larcker (1981) criterion, the square-root of AVE for latent constructs should be higher than correlation coefficients of other latent constructs (Hair et al., 2011).[18] Herein, the table showed that all the diagonally bold coefficients are the square-rooted AVE coefficients while non-bold values are the correlation coefficients between latent constructs. Hence, it has been manifested that all the latent constructs were found statistically different from other constructs in the measurement model and therein, discriminant validity using Fornell and Larcker (1981) criterion has been achieved.

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17 M. Sarstedt, C.M. Ringle, J. Henseler & J.F. Hair, 'On the Emancipation of PLS-SEM: A Commentary on Rigdon (2012)', *Long range planning*, 47:3 (2014), 154-60.

18 J.F. Hair, C.M. Ringle & M. Sarstedt, 'PLS-SEM: Indeed a Dilver Bullet', *Journal of Marketing Theory and Practice*, 19:2 (2011), 139-52.

Discriminant validity using cross loadings

Table 5 reflects the result of discriminant validity using cross loadings technique.

Table 5

Cross loadings

	AL	CE	DL	IS	PC	SA	SS
AL1	**0.685**	0.330	0.327	0.227	0.486	0.246	0.296
AL2	**0.648**	0.296	0.228	0.268	0.497	0.145	0.238
AL3	**0.710**	0.320	0.268	0.186	0.498	0.150	0.222
AL4	**0.797**	0.629	0.325	0.360	0.240	0.289	0.477
AL5	**0.742**	0.521	0.268	0.356	0.283	0.186	0.370
CE1	0.612	**0.866**	0.297	0.384	0.144	0.288	0.500
CE2	0.540	**0.698**	0.170	0.431	0.214	0.123	0.218
CE3	0.386	**0.586**	0.185	0.346	0.192	0.179	0.182
CE5	0.315	**0.728**	0.487	0.475	0.208	0.428	0.436
DL1	0.350	0.266	**0.755**	0.348	0.324	0.239	0.339
DL2	0.327	0.400	**0.825**	0.428	0.252	0.253	0.352
DL3	0.328	0.281	**0.806**	0.388	0.275	0.274	0.339
DL4	0.339	0.428	**0.865**	0.486	0.256	0.385	0.464
DL5	0.240	0.287	**0.682**	0.294	0.238	0.572	0.536
IS1	0.358	0.417	0.272	**0.726**	0.346	0.253	0.402
IS2	0.247	0.318	0.280	**0.773**	0.276	0.261	0.424
IS3	0.350	0.229	0.270	**0.696**	0.271	0.181	0.305
IS4	0.257	0.546	0.531	**0.709**	0.211	0.428	0.551
PC2	0.383	0.214	0.251	0.339	**0.813**	0.363	0.245
PC3	0.320	0.122	0.284	0.265	**0.802**	0.178	0.250
PC4	0.438	0.205	0.261	0.305	**0.753**	0.188	0.154
PC5	0.472	0.230	0.251	0.239	**0.711**	0.121	0.176
SA2	0.267	0.260	0.409	0.262	0.253	**0.762**	0.543
SA3	0.267	0.392	0.437	0.413	0.260	**0.900**	0.744
SA5	0.222	0.312	0.352	0.350	0.218	**0.863**	0.658
SSAT1	0.698	0.539	0.324	0.450	0.170	0.216	**0.574**
SSAT3	0.484	0.625	0.370	0.633	0.233	0.390	**0.676**
SSSC1	0.308	0.260	0.513	0.295	0.269	0.621	**0.680**
SSSC2	0.270	0.367	0.465	0.458	0.249	0.766	**0.828**

SSSC3	0.229	0.260	0.408	0.409	0.148	0.680	**0.830**
SSTG1	0.212	0.285	0.402	0.415	0.200	0.734	**0.796**
SSTG2	0.314	0.313	0.254	0.408	0.131	0.468	**0.689**

AL = Application of Learning; CE = Curriculum and Equipment; DL = Diversity in Learning; IS = Impact on Society; PC = Pedagogy and Communication; SA = Skills and Abilities; SS = STEM / STEAM.

For checking the discriminant validity using cross loadings, it has been recommended that indicators should have higher factor loadings in their respective constructs compared to their loadings in other constructs.[19] Herein, the table showed that all the indicators have been loaded appropriately in their respective constructs, manifesting their statistical difference with other latent constructs. Thus, discriminant validity using cross loadings has been achieved.

Discriminant validity using HTMT ratio

The following table 6 revealed the findings of discriminant validity using HTMT ratio.

Table 6

Heterotrait-Monotrait Ratio (HTMT)

	AL	CE	DL	IS	PC	SA	SS
AL							
CE	0.773						
DL	0.486	0.484					
IS	0.526	0.748	0.593				
PC	0.734	0.358	0.419	0.508			
SA	0.358	0.449	0.532	0.503	0.353		
SS	0.562	0.589	0.604	0.741	0.328	0.919	

AL = Application of Learning; CE = Curriculum and Equipment; DL = Diversity in Learning; IS = Impact on Society; PC = Pedagogy and Communication; SA = Skills and Abilities; SS = STEM / STEAM.

[19] J.F. Hair, C.M. Ringle & M. Sarstedt, 'Partial Least Squares Structural Equation Modeling: Rigorous Applications, better Results and Higher Acceptance', *Long Range Planning*, 46:1-2 (2013), 1-12; J.F. Hair, C.M. Ringle & M. Sarstedt, 'PLS-SEM: Indeed a Dilver Bullet', *Journal of Marketing Theory and Practice*, 19:2 (2011), 139-52.

In the recent development, Henseler, Ringle, & Sarstedt (2015) proposed HTMT ratio has a novel and more efficient method for discriminant validity than FLC and cross loadings. In this regards, Henseler, Hubona, & Ray (2016); Henseler et al. (2015) suggested that HTMT ratio below the threshold of 0.90 should be considered as substantially different from other constructs, whereas HTMT ratio below 0.95 should be considered as acceptable for discriminant validity. Herein, the highest HTMT ratio of 0.919 was found between skills and abilities, and STEM. Therefore, discriminant validity using HTMT ratio has been achieved.

Predictive power of the exogenous constructs using R^2

The following table 7 shows the result of predictive power of the dependent (exogenous) latent constructs in the modelling framework using R-square and adjusted R-square based on the PLS algorithm analysis.

Table 7

R^2 and Adj. R^2

	R-Square	Adjusted R-Square
Impact on Society	0.364	0.363
STEM / STEAM	0.696	0.693

It has been shown in the above table that there were two exogenous constructs in the model including impact on society (IS) and STEM/STEAM (SS). It has been recommended by Hair et al. (2011) that R-square below than 25 percent, 50 percent, and 75 percent have been considered as weak, moderate, and substantial predictability in the structural model. Herein, IS has 36.4 percent while SS has 69.6 percent predictability in the model; therefore, all exogenous constructs have moderate predictive power.

Structural model

Hypothesis-testing using path analysis

The following table 8 describes the findings of hypothesis-testing using PLS-SEM bootstrapping technique for estimating direct-effect analysis.

Table 8

Hypothesis-testing using path analysis

	Estimate	Std. Dev.	T-Stats	Prob.	f^2	Remarks
AL -> SS	0.216	0.032	6.659	0.000	0.073	Accepted
CE -> SS	0.096	0.031	3.112	0.002	0.016	Accepted

DL -> SS	0.145	0.035	4.134	0.000	0.046	Accepted
PC -> SS	-0.086	0.029	2.935	0.003	0.017	Accepted
SA -> SS	0.631	0.031	20.361	0.000	0.946	Accepted
SS -> IS	0.603	0.027	22.114	0.000	0.573	Accepted

AL = Application of Learning; CE = Curriculum and Equipment; DL = Diversity in Learning; IS = Impact on Society; PC = Pedagogy and Communication; SA = Skills and Abilities; SS = STEM / STEAM.

In the above table, it has been shown that application of learning (β = 0.216, $p < 0.05$), curriculum and equipment (β = 0.096, $p < 0.05$), diversity in learning (β = 0.145, $p < 0.05$), and skills and abilities (β = 0.631, $p < 0.05$) have positively significant effect on STEM/STEAM while STEM/STEAM (β = 0.603, $p < 0.05$) has positively significant effect on the impact on society construct. However, pedagogy and communication (β = -0.086, $p < 0.05$) has a negatively significant effect on STEM.

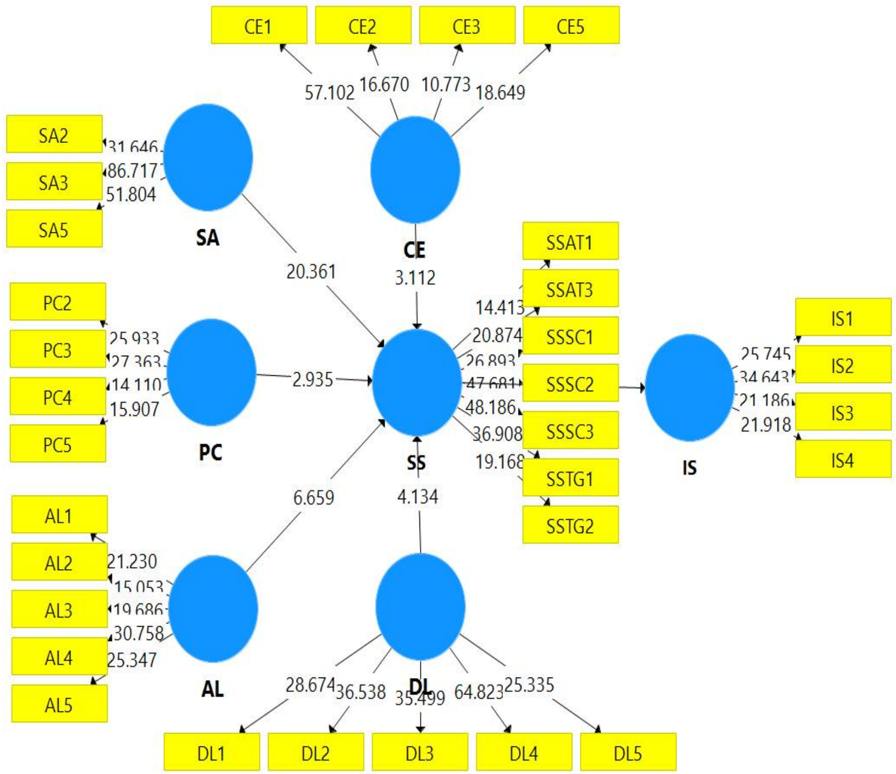

Figure 3: PLS Bootstrapping Illustration

Moreover, Hair et al. (2013) recommended that effect size (f^2) of 0.02, 0.15 and 0.35 should be considered as weak, moderate, and strong respectively. Herein, table 8 further manifested that the relationship between CE and SS, and PC and SS have weak effect size of 1.6 percent and 1.7 percent respective, whereas the relationship of AL and DL with SS found moderate effect of 7.3 percent and 4.6 percent respectively. Lastly, the relationship of SA and SS while SS and IS having strong effect size of 94.6 percent and 57.3 percent respectively.

Hypothesis-testing using specific indirect-effect analysis

The following table 9 shows the result of hypothesis-testing using PLS-SEM bootstrapping technique for estimating specific indirect-effect analysis.

Table 9

Hypothesis-testing using specific indirect-effects

	Estimate	Std. Dev.	T-Stats	Prob.	Remarks
AL -> SS -> IS	0.130	0.020	6.622	0.000	Accepted
CE -> SS -> IS	0.058	0.019	2.997	0.003	Accepted
DL -> SS -> IS	0.087	0.022	4.039	0.000	Accepted
PC -> SS -> IS	-0.052	0.018	2.903	0.004	Accepted
SA -> SS -> IS	0.381	0.025	15.352	0.000	Accepted

AL = Application of Learning; CE = Curriculum and Equipment; DL = Diversity in Learning; IS = Impact on Society; PC = Pedagogy and Communication; SA = Skills and Abilities; SS = STEM / STEAM.

It has been shown in the table 9 that application of learning (β = 0.130, $p < 0.05$), curriculum and equipment (β = 0.058, $p < 0.05$), diversity in learning (β = 0.087, $p < 0.05$), and skills and abilities (β = 0.381, $p < 0.05$) have positively significant effect on the impact on society with the complementary mediation of STEM, whereas pedagogy and communication (β = -0.052, $p < 0.05$) has negatively significant effect on the impact on society with the complementary mediation of STEM.[20]

Predictive relevance of the exogenous constructs using Q-square

20 X. Zhao, J.G. Lynch Jr & Q. Chen, 'Reconsidering Baron and Kenny: Myths and Truths about Mediation Analysis', *Journal of consumer research*, 37:2 (2010), 197-206.

The following table 10 shows the result of predictive relevance using PLS blindfolding at 7 omissions for estimating the Q-Square statistics of the exogenous latent constructs in the modelling framework.

Table 10
Predictive Relevance using Q^2

	Q-Square	Decision
Impact on Society	0.174	Weak
STEM / STEAM	0.365	Moderate

Based on the cross-validation and redundancy technique of Stone (1974), the study has estimated predictive relevance of the exogenous constructs. In this regards, Hair et al. (2013) recommended that Q2 should be greater than zero while the degree of predictive relevance varies between 0.02, 0.15 and 0.35 for weak, moderate, and strong predictive relevance. Herein, table 10 showed that impact on society has weak predictive relevance of 17.4 percent, whereas STEM has moderate predictive relevance of 36.5 percent.

Discussions

The current study found that skills and abilities have a significant effect on students' learning and society. The result indicates that teachers must fully embrace the skills and abilities and incorporate them into their classes. In contrast to conventional schools, curriculum changes such as STEM necessitate a distinct range of pedagogical skills. Teachers must learn new methods of teaching in order to improve their abilities. In order to successfully incorporate a new educational approach, teachers must investigate and comprehend the logic, think differently, and behave differently.[21] Additionally, the study identified a significant negative influence of pedagogy and communication skills on students' learning. The result indicates that teachers' communication skills should be high and they can build an atmosphere and communication across channels in the sense of STEM. The finding is also consistent with (Leung, 2020).[22]

21 C. Chanthala, T. Santiboon & K. Ponkham, 'Instructional Designing the STEM Education Model for Fostering Creative Thinking Abilities in Physics Laboratory Environment Classes', *AIP Conference Proceedings* (Vol. 1923, No. 1, January 2018), 030010. AIP Publishing LLC.

22 A. Leung, 'Boundary Crossing Pedagogy in STEM Education', *International Journal of STEM Education*, 7, 2020, 1-11.

When teachers have strong communication skills with students, they report perceived development in the areas of interpreting other concepts.

The current study found a significant positive relationship between application of learning and students' learning and society. The result indicates that the integration of skills and practices from various STEM fields to learn about or overcome challenges in the real world is a STEM education concept. The finding is consistent with Nguyen, Do, Tran, Pham, and Pham, (2020) teachers with 21st-century expertise must have excellent learning abilities. Teachers must be familiar with these disciplines and how to teach them in order to contribute to STEM education.

The findings of the current research revealed that there is a significant positive association among curriculum and equivalent knowledge of teachers and students' learning and society. As a part of the findings, teachers were found to have a need for curriculum awareness. This finding is also supported by Corlu, Capraro & Capraro, (2014) who identified that curriculum integration enables educators to see four STEM disciplines as a cohesive, interconnected entity with a direct link to real-world applications. Teachers agree that having a good curriculum will increase the chances of STEM initiatives successfully. This finding is also supported by Lehman, Kim & Harris, 2014.

Similarly, the study indicates that diversity in learning has a significant positive effect on students' effective training of teachers is reflected by the approaches they, adopts to teach STEM, successfully.[23] Teachers have strengthened their confidence in STEM teaching and their desire to teach STEM. Furthermore, teachers' learning diversification will assist them in cultivating a successful questioning style, which can only be accomplished by different activities and teacher-directed information acquisition.[24]

Finally, the study discovered that STEM education has a considerable positive impact on students' learning and society. According to the findings, in-service teachers will have a strong foundation in an integrated STEM approach and would develop interest in teaching an integrated STEM strategy. As a result, better STEM education and a stronger influence on society can be realised. Furthermore, STEM education is vital in society, and its significance is multiplied by teachers

23 J.P. Davis, J. Du, J.H. Tang, L. Qiao, Y.Q. Liu & F.K. Chiang, 'Uniformity, Diversity, Harmony, and Emotional Energy in a Chinese STEM Classroom', *International Journal of STEM Education*, 7:1 (2020), 1-15.

24 P. Kommers, 'Educational Technologies for e-learning and Stem Education', *E-learning*, 2019, 35.

who have enough topic knowledge and domain pedagogical content understanding.[25]

Conclusion and Recommendations

Adoption of newly developed and designed strategies is considered to be an essential factor in order to enhance the effectiveness of learning process. So for the positive growth of the education system — overcome the challenges and to fulfil the requirements of modern times the teachers are recommended to consider the importance of stem, education as discussed and explained in the study. Following recommendations are made:

- It is highly essential for the educator to be able to provide sufficient amount of knowledge across different educational levels. Institutes are also recommended to create innovative programs which can eliminate the continuity of unproductive methods of teaching.
- A diversified learning management system is recommended which would help to understand concepts and new aspects of the subjects. This would erase all the boundaries for the educator which restricts them from positively influencing the society.
- Furthermore, that the institutions should promote ethical conduct of STEM pedagogical processes and continuous improvement should be conferred with the abidance of curriculum changes that incorporate the students to vitalize their skills.
- Professional development programs should be organized for the teachers to improve their teaching skills. Moreover, different spectrum and diverse ideologies of teacher should be incorporated in the system to vitalize the professional development of the teachers.
- Lastly, the STEM education should be promoted in the different regions of Karachi as well as in different regions of Pakistan. Also, active learning should be promoted in the students that provide extrinsic behavioural changes in the students as well as prepare them to avail opportunities of the future.

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25 V. Voronkova, O. Kyvliuk, V. Nikitenko & R. Oleksenko, 'Stem-education" as a factor in the development of" smart-society": forming of" stem-competence', 2018.