

**EVALUATING PRE-SERVICE TEACHERS SCIENCE TECHNOLOGYENGINEERING
MATHEMATICS PEDAGOGICAL CONTENT KNOWLEDGE:
A QUANTITATIVE RESEARCH STUDY**

Madeeha Jabeen¹

Scholar, Department of Educational Sciences, National University of Modern Languages, Karachi Campus.
Email: madeeha.jabeen@numl.edu.pk

Saad Muzaffar²

Coordinator / HoD Department of Educational Sciences, National University of Modern Languages, Karachi
Campus. Email: saadmuzaffar@numl.edu.pk

ABSTRACT

On the way to better prepare pre-service teachers for careers in STEM fields, it is essential to comprehend their professed technological pedagogical content knowledge (TPACK). Along with these appearances, this study intends to look at pre-service mentors' views of TPACK from understudies of two unique universities in Karachi, Pakistan. There were 60 people involved: 30 students from Karachi University and NUML University, respectively. Data was gathered through a 56-item STEM-PACK Survey. The outcomes indicated that pre-service teachers fared least confidently in their knowledge of technology and most confident in their understanding of pedagogy. They gave themselves a five-point rating above four. There were no discernible disparities in terms of gender or age for any of the STEMPCK parameters. Additionally, there was a strong positive association between each of the six STEMPCK domains. It is recommended that programs for pre-service teachers teach future STEM educators in what way to combine pedagogy, material, and technology to provide successful technology-enhanced learning in their respective fields.

KEYWORDS: *Technological Pedagogical Content Knowledge (TPACK), Pre-service teachers, Teacher training, Quantitative research*

INTRODUCTION

The rapid development of ICT in twenty-first century has significantly accelerated all aspects of education. Pre-service teachers, on the other hand, ought to assimilate their technical knowledge, in addition put it to use in a specific informative setting in order to use digital technology tools effectively. As a result, it appears crucial for teacher education programs to effectively foster pre-service teachers' technological pedagogical and content knowledge (TPACK). Since Shulman (1986, 1987) introduced the term, Pedagogical Content Knowledge (PCK) has received a lot of attention in the science education literature. He alleged that PCK was "the unification of content and pedagogy hooked on an indulgence of how specific topics, glitches, or matters are organized, embodied, and altered to the diverse interests and abilities of learners, and presented for instruction." This understanding was what he meant when he said that PCK was the concept. As it examines how PCK can be used to shape learning about teaching, this study contributes significantly to evaluating the knowledge of STEM and the PCK field in pre-service teacher education. In current years education has been undergoing prompt variations, primarily because of the expansion of Internet technology and deviations in day-to-day communal accomplishments. Frequent changes are being observed in digital technologies. The teaching and learning process in schools is highly affected by the rapid changes in digital technologies in new software and their applications. (Hamilton et al. 2016; Koehler & Mishra, 2009). Recent research has emphasized the significance of developing students' 21st-century skills for effective learning and participation in STEM (science, technology, engineering, and mathematics) fields (Scherer, 2017; Stehle & Peters-Burton, 2019). The goal of curriculum developers is to make the most of this prospect to assist apprentices in effective learning in the digital age. To address substitute needs in a steadily changing innovation scene, educator teachers who plan future instructors try to coordinate innovation into the showing system successfully while preparing instructors on the most proficient method to best involve innovation in teaching space (Hennessy, 2005; Mishra & Koehler, 2006; Puentedura, 2006). Abebe, (2021) also emphasized that pre-service teachers believed that technology also improved self-efficacy and learning. Hence, this research engrossed a public academia fundamental teacher learning platform that formulates imminent teachers to evaluate their knowledge of and how to integrate STEM in the classroom.

STATEMENT OF THE PROBLEM

The scholars felt that there have been specific skills that are very vital for teaching with a value focus that ought to be stressed in pre-service teacher teaching programs. These enclosed questioning skills, listening skills, and therefore the ability to recognize distinction within the area and differentiate learning consequently. Science, Technology, Engineering, and mathematics (STEM) integrated information tactic has become the leading style of education reform worldwide. This paper presents a STEM-integrated cooperative activity to boost STEM data among pre-service teachers. STEM education encourages science acquisition, innovation, and critical thinking. The current study will evaluate the science, technology, engineering, mathematics, and pedagogical content knowledge of students of two public universities in Karachi, Pakistan by focusing on a quantitative research study.

RESEARCH QUESTION

1. Do the pre-service teachers of a public academia aware of the STEM PCK?
2. Are they able to integrate the STEM protocols into their regular pedagogical content knowledge?
3. What is their opinion about integrating STEM into conventional teaching methods?
4. Is it practically effective to imply these techniques in public schools in Karachi?

RESEARCH HYPOTHESIS

1. The students of public universities have sound knowledge about STEM PCK.
2. The teachers need to learn the new STEM methodologies so they can effectively apply them in their services. STEM knowledge is very important for new teachers so they can inculcate them in students to meet the current needs of educational level globally.

PURPOSE OF THE STUDY

Developing pre-service educators' content and education data is important, given that high-quality instruction in science, technology, engineering, and mathematics (STEM) disciplines. Specifically, pedagogical content knowledge (PCK) has been known collectively of the foremost critically required analysis areas inside our pre service academics. However, restricted analysis exists on STEM PCK in developing countries like Pakistan. For that reason, this research explored whether or not explicit educator research exertion and casual instructional experiences influenced high school instructors' teaching of content and practices.

SCOPE OF THE STUDY

STEM is an abbreviation of the combination of science (S), innovation (T), designing (E), and math (M). In many nations, STEM education is promoted as a means of preparing citizens to comprehend STEM and possess multifaceted capabilities that can be utilized in modern life. In addition, it is frequently anticipated that STEM will address the issues of declining student interest in careers in science and technology and low scores on international tests like TIMSS and PISA. For instance, the USA has a public intention to expand the number of graduates with STEM degrees to keep up with America's serious position in the worldwide economy. Pearson (2017) also stressed that in order to help educators comprehend the cause of integration and make obvious the connections between science, technology, engineering, and mathematics in addition to their knowledge of pedagogical content, a STEM professional development program is required. In order to make Pakistani students able to move globally it is very important to integrate STEM in our education system and this can only be achieved by preparing young teachers as critical thinkers.

DELIMITATION OF THE STUDY

The current study only focused on the evaluation of the preservice teachers of only two public universities in one of the cities of Pakistan, Karachi. The study can be done on a larger scale by properly sampling the population. Similarly, it only emphasizes evaluating the knowledge of the pre-service teacher but does not explain any practical application of it. As it is a qualitative study so it is only based on the responses gathered in the given questionnaire. There is a large gap present for other researchers to carry on their work based on my study.

BASIC ASSUMPTIONS IN THE STUDY

This study assumed that the pre-service teachers of Karachi, Pakistan have enough knowledge about the content and technology and have a sound hold on the effective way of teaching. It also anticipates that they also inculcate the strategies of STEM in their routine teaching practices. They all are quite technologically friendly and can easily manage difficult tasks in less period of time. The pre-service teachers are so well trained that they will easily handle the tasks once they are in teaching practicum.

LITERATURE REVIEW

STEM is considered an integrated approach to education by the majority of educationists. The advantages of STEM education embrace making STEM courses more relatable, boosting student action and perseverance, and fostering critical thinking, collaboration, and propensity. The teacher's role is vital in desegregating STEM concepts and abilities, as well as in providing guidance and supervising the students. Since the majority of educators were trained in one or more STEM fields, they may not be very familiar with the teaching and learning of integrating these strategies

as a methodology in practical teaching. Extending STEM PCK is one of the objectives of integrated STEM education in order to track changes in teaching practices. It's necessary for teachers to increase their PCK as this can facilitate to realize the specified outcomes for academics and students. Academics need to be required to have in-depth knowledge of the relevant areas in order for college students to acquire the right thoughts. An essential component of any integrated STEM education program or activity is the solution to the discourse problem. The problems are occasionally ambiguous, and finding an answer will require considering several facets of science, mathematics, engineering, and technology. Therefore, it is crucial for instructors to be knowledgeable about the content of STEM subjects in order to help students employ the appropriate concepts and techniques to solve problems. Without a proper understanding of the definition, particularly with regard to the character and scope of integration, teachers may still find themselves thinking of or having an impact on STEM education as the typical individual STEM subject teaching and learning. Teachers should even have the correct orientation in terms of their beliefs and angle toward the goals and outcomes of integrated STEM education for the students.

In group activities including STEM ideas and abilities, instructions, and student management, the teacher's involvement is essential. This study found that instructors were lacking in PCK for integrated STEM teaching. This means that in order to plan and carry out successful STEM programs, academics require mediation in the form of significant integrated STEM PCK. Academics may find it easier to construct the STEM education PCK with the help of teachers' professional growth and collaboration with STEM experience. Academics are given STEM PCK through short-term courses or ongoing professional learning communities (PLC), which may change teachers' classroom practices and boost their efficacy in delivering successful STEM teaching programs or classes. Similarly, collaboration with the STEM community of follow may additionally improve academics' STEM PCK as teachers are exposed to the authentic application of integrated STEM ideas and skills within the real-world setting. Impact studies are done to see the effectiveness of the varied programs. It's hoped that each one of these can facilitate the implementation of integrated STEM education (Ling et al., 2020).

Akçay & Avcı (2022) stated that the advancements in information and technology are accompanied by completely new wants. The under-training service lecturers are expected to have knowledge of science, technology, and engineering, to be prepared to apply what they have learned and integrate it with other subjects, and to support their technology knowledge with content knowledge and industry-specific education methodology knowledge. Similar to this, programs for pre-service teachers should give STEM lecturers a means to combine pedagogy, content, and technology to create successful technology-enhanced learning in their fields. The study's findings included the observation that pre-service STEM professors tend to have a favorable opinion of each of the six TPACK disciplines (Irwanto et al., 2022). Rahman et al., (2021) also explored that science, technology, engineering, and mathematics (known as STEM) field and connected jobs square measure more and more demanding, thus lecturers should be equipped with STEM-based data throughout schoolroom instruction in getting ready students with STEM-relevant skills. However, past studies showed that a lot of lecturers were less assured in applying the data that much affected students' interest in STEM opportunities. Ali et al., (2020), also concluded it was found that participating lecturers had a thorough comprehension of and perceptions of the contents of TPACK. The Unified Nations agency was unified or strongly united with the positive methods in their field of study, with science having the best proportion of educational content data and mathematics having the lowest percentage. The STEM PCK Scale is a genuine and trustworthy tool that aspiring lecturers will likely live STEM PCK. Yildirim et al., (2019) commented that there have been no valid and reliable STEM PCK instruments for preservice and in-service lecturers. Understanding teacher candidates' STEM PCK can facilitate teacher educators to strengthen their courses and establish gaps in teacher candidates' data that require to be self-addressed.

RESEARCH METHODOLOGY

The research totally based on quantitative examination of the data gathered as of a registered close-ended questionnaire. The study focused on 60 pre service teachers of the academic year 2022/2023. 30 pre service teachers voluntarily participated from Karachi University and other 30 from Numl University, Karachi Campus Pakistan. The STEM PCK questionnaire comprised of three key divisions, which are Pedagogical knowledge (12 items), STEM integration knowledge (science - 8 items; technology - 7 items; engineering - 7 items; mathematics - 8 items), and 21st-century learning (14 items). The items are given in the Likert Scale 5-point (1 through 5). Written permission was obtained before the collection of the data. The purpose, and the instructions for completing the survey were explained to the pre-service teachers at the commencement of the survey. Their individualities were retained unidentified. All teachers were permissible to complete the STEM PCK survey at a place of their choice at a convenient time for them over a self-administered study (Robson & McCartan, 2015). Finally, respondents were required to provide some of their demographic information in terms of gender, age, and grade level without mentioning their

names. The collected data was organized by MS Excel 2019 and interpreted and analyzed by making graphs and tables.

DATA ANALYSIS AND PRESENTATION

In the present study, the data analysis showed that the pre-service teachers have enough knowledge about the STEMPCK as the majority of them rate the statements at an average of four on Likert scale. This specifies that the mean score is moderately high paralleled to the mid-point. The results exhibit alignment with the null hypothesis that the students of public universities have sound knowledge about STEMPCK. This might be because the current needs of the global world about STEMPCK and the use of internet is easy for the respondents. It also interpret that although they have the knowledge but the teachers must learn the new STEM methodologies that can be practically applied in schools. Bingimlas (2018) also explained the same trend as the current study that the participants are tremendously optimistic About STEMPCK and its application in the education system. STEM awareness is vital for fresh and novel educators so they can instill them in learners to come across the current prerequisites of education. The following table explains the demographic data of the respondents under study which shows that more females are associated with the teaching profession as compared to the male and are more enthusiastic about teaching as a profession.

Table 1

Vivid Data About the Learners in the Study			
		Frequency (f)	Percentage (%)
University	Karachi University	30	50
	NUML University	30	50
Gender	Male	12	20
	Female	48	80
Age (years)	21-25	44	73.3
	26-30	16	26.6
Class	3 rd Year	38	63.3
	4 th Year	22	36.6

PEDAGOGICAL KNOWLEDGE

The data analyzed represent that more than 70 % of the respondents were confident and sure about their pedagogical knowledge. This trend also showed their self-confidence about the content knowledge. They are also good in communication skills and maintain effective learning skills as compared to assist and use the knowledge in research studies. 50 % of the students were also reluctant to use multiple teaching strategies at a time. Irwanto et al., (2022) also explained the same trend that teachers are quite confident about their pedagogical knowledge and rate them higher than average.

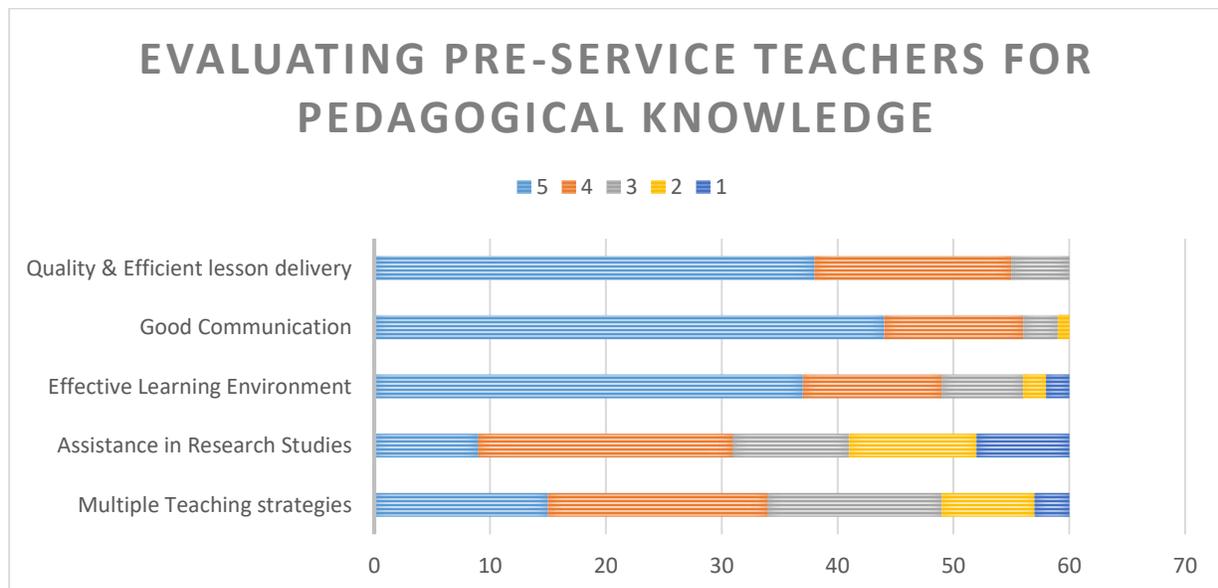


Figure 1

SCIENCE

The respondents are also very confident about their basic knowledge of science as it is the major course in the schooling system in Pakistan. Secondly, great emphasis is given by the two universities in scientific knowledge and its implications. The majority of the students rank above the neutral point showing a strong optimistic response except for their expertise towards critical thinking as explained by the graph below. Nilsson& Loughran (2012) also emphasized to use of Content Representation (CoRe) methodology in science through involvement in research and to enhance critical thinking in pre-service teachers as the aim of educating teacher is not to articulate teachers in what way to teach, then to train them to aim deeply nearby their training as sound as to aid to overt the important needs and concerns about how to teach the students.

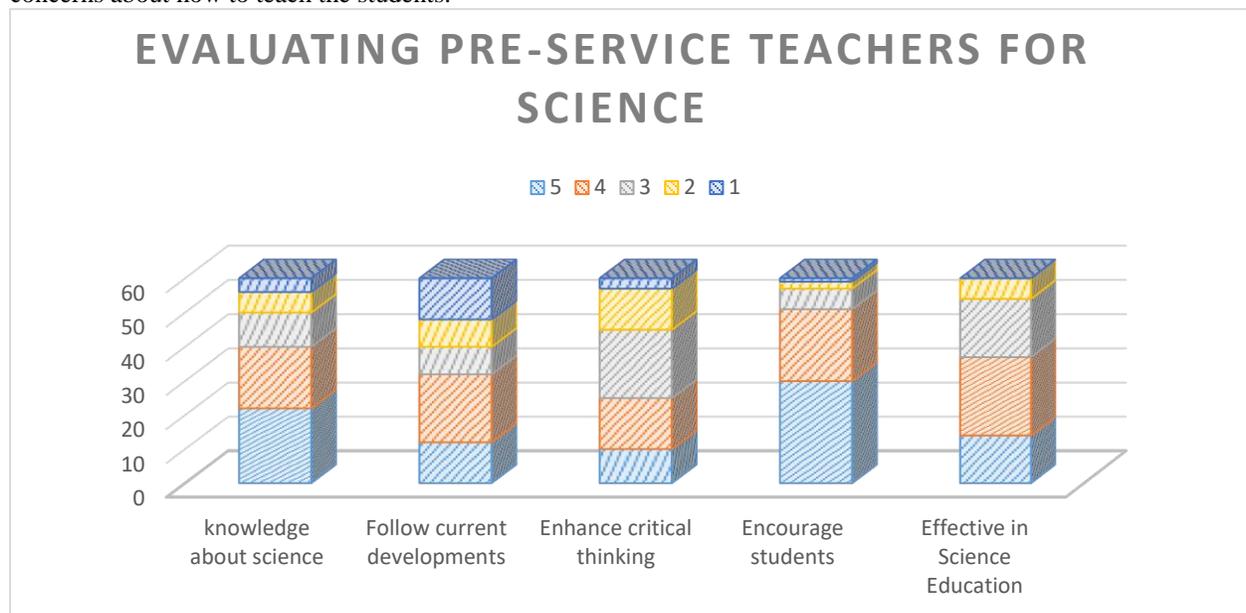


Figure 2
TECHNOLOGY

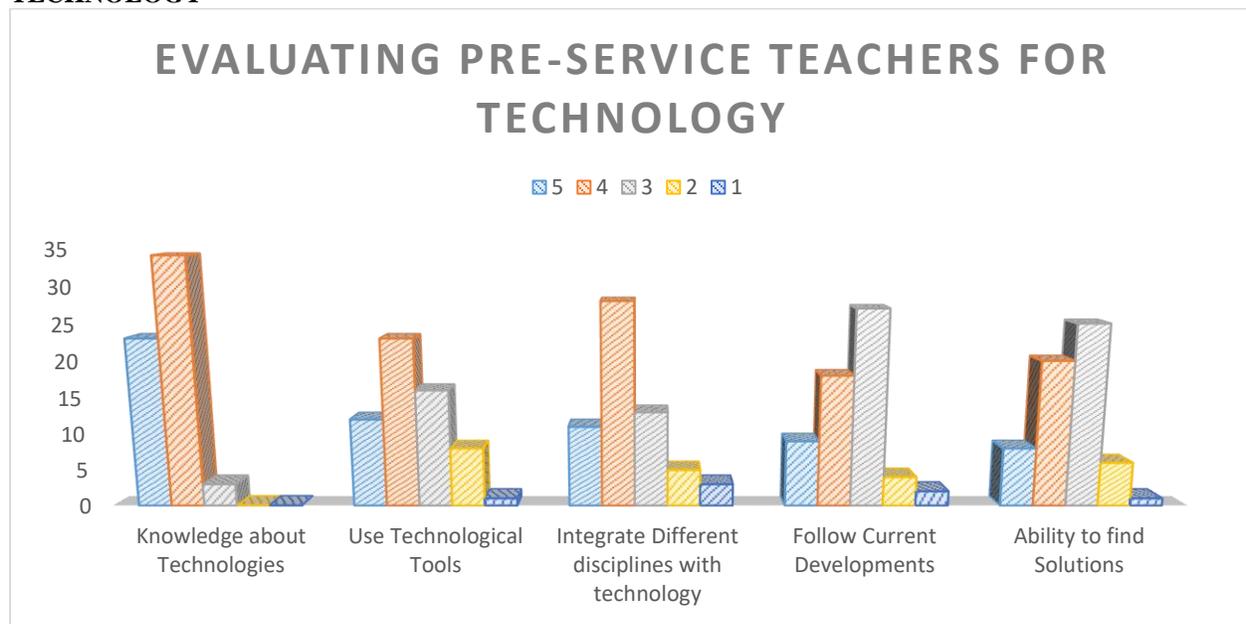


Figure 3

The response of technology use was a little different from the rest of the factors as the majority of the respondents have knowledge about technologies but are less assertive about the use of technology and its integration with the current developments. They also feel that they lack the ability to find new solutions by using technology. Many researchers also showed the lowest score in technological knowledge and implications as compared to pedagogical knowledge. Precisely, they were more informed in the area of pedagogy and content rather than technology based studies (e.g., Schmidt et al., 2009; Chai et al., 2010; Roig-Vila et al., 2015). The findings show that there is a critical need for teacher training programs to educate not just about pedagogy (PK), but also about how to successfully integrate pedagogy, content, and technology into the curriculum.

ENGINEERING

The outcome indicated that the majority of the pupils consider that engineering is grounded on Maths and science. Mixed responses were observed where few showed positive responses and interest in engineering, majority stayed neutral about the response and knowledge where few also disagree about their knowledge and interest in engineering. French & Burrows (2018) also illustrate that preservice teachers are adept on developing inquiry-based instructions that provide chances for their imminent apprentices to cooperate, use scientific equipment, and assemble and scrutinize data, but they entail more aid when creating learner accomplishments where pupils cultivate testable queries, review the already used questions and methods, partake in peer analysis, and present the findings to their colleagues or the superior scientific community. The pre-service should be provided with such courses where they learn to integrate engineering education with other courses.

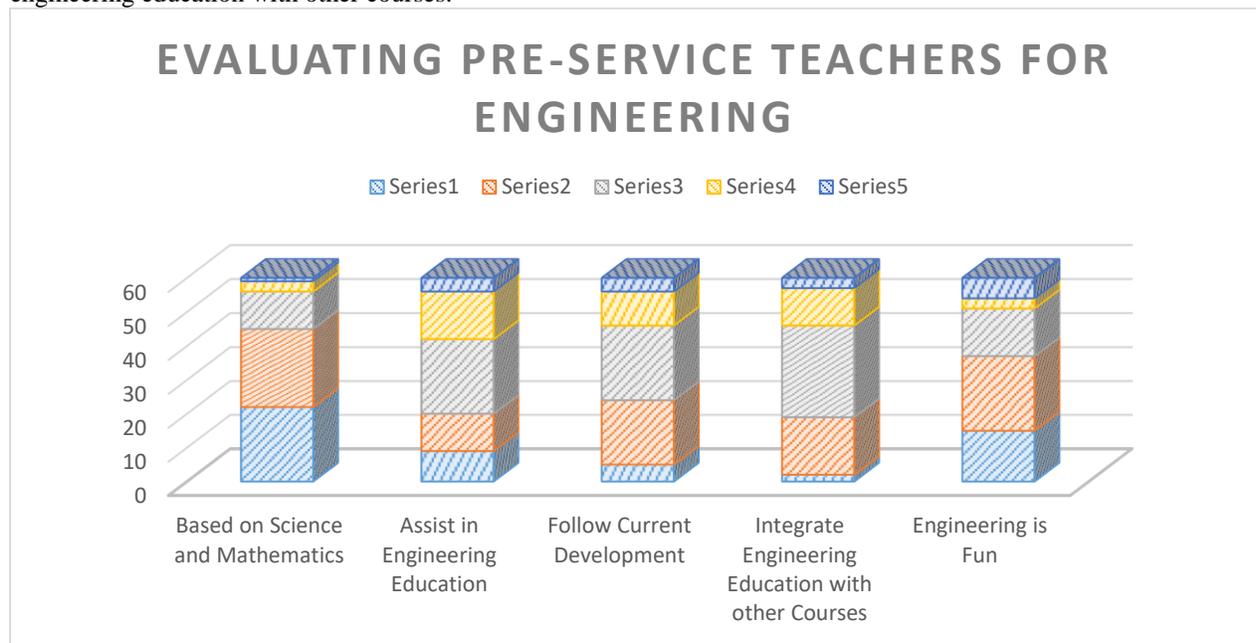


Figure 4

MATHEMATICS

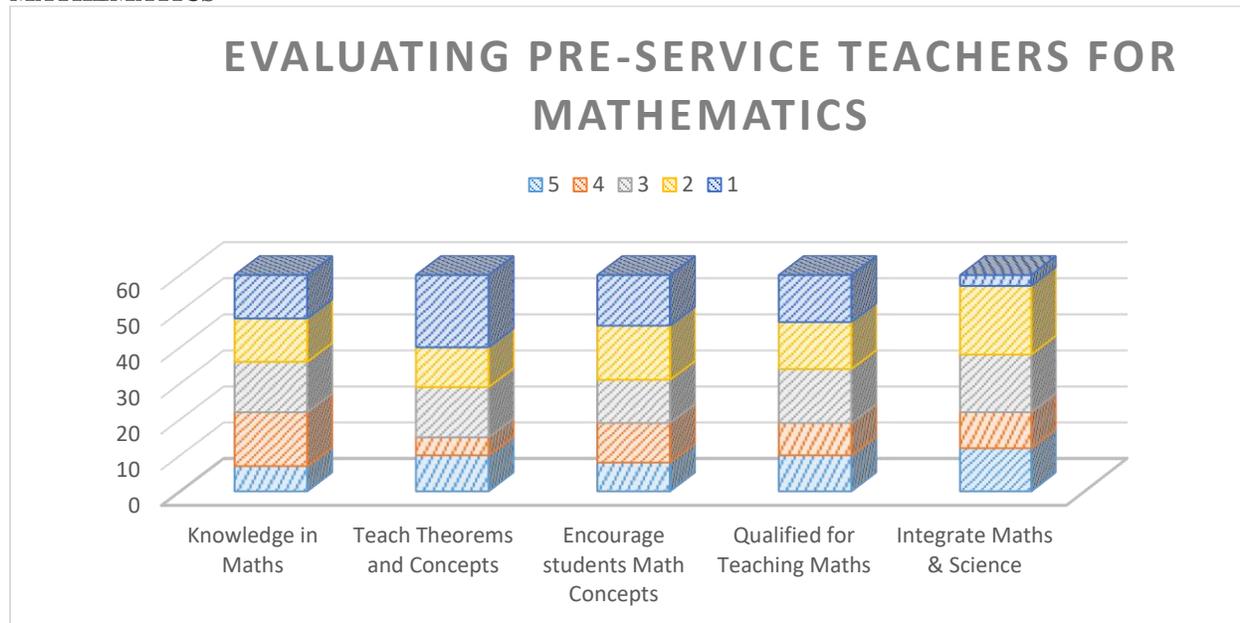


Figure 5

The students were doubtful in their mathematical knowledge. Few showed positive response who have their own interest in mathematics. Later, it was discovered that they have learned many courses regarding mathematics and statistics. Majority of them lack the concept to teach theorems and their implication in everyday life. Sintema & Marbán (2020), also showed the similar results about teaching mathematics, pre-service teachers are likely to lack the required amount of self-concept and confidence with less expertise in clearing up students' misunderstandings. Additionally, they lacked sufficient understanding of the various functional representations.

21ST CENTURY SKILLS KNOWLEDGE

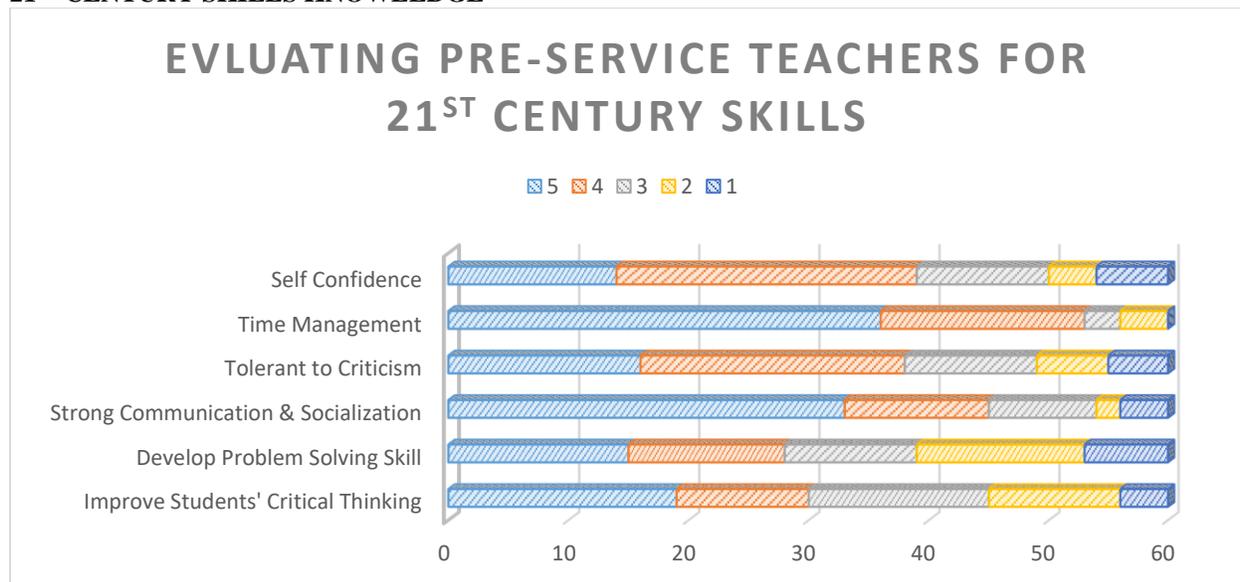


Figure 6

The respondents were extremely positive toward 21st-century skills. They have self-confidence, time management, good tolerance to criticism, and working to develop problem-solving skills. Contrary to this, many of them need to work on critical thinking skills. Programs can be offered to enrich the critical thinking abilities of pre-service teachers so they become able to implement the same at ground level. Haviz (2020), also supports the findings and claims that pre-service teachers have access to valid and trustworthy 21st-century skill tools.

DISCUSSION

Advancement in technology and teaching methodology are pre requisite of contemporary era. To meet the emerging requirements in educational field, it is necessary to equip our instructors with new teaching techniques and strategies. Speedy headway of knowledge in fields like medicine, Engineering and Accounts require multi integration approach to support field specific pedagogical methods. The importance of STEM is very much evident and it has become a valuable weapon for teachers and candidates to excel academically. As regard to the above-mentioned subject matter, the pedagogical institutes work with STEMPCK to reinvigorate new avenues and polish their existing skills. Smart program management and practical courses will enhance the confidence of pre service teachers greatly. Critical thinking and GPEST analysis will provide further aid to make Pakistani teachers relevant in the global village. STEMPCK related activities and inclusion of relevant courses will help students to critically and multilaterally analyze the provided situation. Therefore, I strongly present my case in favor introduce STEMPCK in an integrated fashion rather than offering discrete technological content and courses.

CONCLUSION

The above-mentioned discussion concludes my stance on high proficiency levels of STEMPCK. This research work provides lucid results by sheer groundwork at two public institutions at Karachi. The research further prove that how the six STEMPCK disciplines appear to be perceived by pre-service STEM teachers. The participants possessed a higher level of pedagogical content rather than technical knowledge to process that data. Yual Noah Harari, author of 21 lessons of 21st century, has very rightly highlighted the down side of knowledge illusion and stressed on the need of learning navigation through the big sea of data. Therefore, numerous STEM courses should be raised in order to foster technical literacy and critical thinking among students. Thus, implementation of STEM tactics is crucial to excel the students in future classrooms.

REFERENCES

- Abebe, (2021). *Pre-Service Teachers' Technological Pedagogical Content Knowledge, Self-Efficacy and Development in K-6 Math* (Doctoral dissertation, The University of Nebraska-Lincoln).
- Akçay, B., & Avcı, F. (2022). Development of the STEM-Pedagogical Content Knowledge Scale for Pre-service Teachers: Validity and Reliability Study. *Journal of Science Learning*, 5(1), 79-90.
- Ali, Zahid & Thomas, Martin & Ahmed, Nazir & Ahmed, Imran & Ahmed, Ishtiaq. (2020). Assessment of Pre Service Teacher's Perceptions on Technological Pedagogical and Content Knowledge (TPACK) in Karachi Pakistan. *International Journal of Scientific and Engineering Research*. 11. 1402-1408.
- Bingimlas, K. (2018). Investigating the level of teachers' Knowledge in Technology, Pedagogy, and Content (TPACK) in Saudi Arabia. *South African Journal of Education*, 38(3).
- Chai, C. S., Koh, J. H. L., & Tsai, C. C. (2010). Facilitating preservice teachers' development of technological, pedagogical, and content knowledge (TPACK). *Journal of Educational Technology & Society*, 13(4), 63-73.
- Fraenkel, J. R., Wallen, N. E., & Hyun, H. (2019). *How to design and evaluate research in education* (10th ed.). McGraw-Hill.
- French, D. A., & Burrows, A. C. (2018). Evidence of science and engineering practices in preservice secondary science teachers' instructional planning. *Journal of Science Education and Technology*, 27, 536-549.
- Hamilton-Smith, S., & Stuart, J. (2016). Quest for a connected curriculum: English, digital technologies and 'the forests of silence'. *Literacy Learning: The Middle Years*, 24(3), 31-35.
- Haviz, M. (2020). Assessing pre-service teachers' perception on 21st century skills in Indonesia.
- Irwanto, Irwanto & Redhana, I & Wahono, Bevo. (2022). Examining Perceptions of Technological Pedagogical Content Knowledge (TPACK): A Perspective from Indonesian Pre-service Teachers. *Jurnal Pendidikan IPA Indonesia*. 11. 142-154. 10.15294/jpii.v11i1.32366.
- Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)?. *Contemporary issues in technology and teacher education*, 9(1), 60-70.
- Ling, L. S., Pang, V., & Lajium, D. (2020). A Case study of teachers' pedagogical content knowledge in the implementation of integrated STEM education. *Jurnal Pendidikan Sains Dan Matematik Malaysia*, 10(1), 49-64.
- Nilsson, P., & Loughran, J. (2012). Exploring the development of pre-service science elementary teachers' pedagogical content knowledge. *Journal of Science Teacher Education*, 23(7), 699-721.
- Pearson, G. (2017). National academies piece on integrated STEM. *The Journal of Educational Research*, 110(3), 224-226.
- Pimthong, P., & Williams, J. (2018). Preservice teachers' understanding of STEM education. *Kasetsart Journal of Social Sciences*.

- Rahman, N. A., Rosli, R., & Rambely, A. S. (2021). Validating STEM Pedagogical Content Knowledge Scale for Secondary School Mathematics Teachers. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, 12(14), 3666-3678.
- Robson, C., & McCartan, K. (2016). *Real World Research*, 4th Edn. Hokoben.
- Roig Vila, R., Mengual Andrés, S., & Quinto Medrano, P. (2015). Primary teachers' technological, pedagogical and content knowledge. *Comunicar*, 2015, vol. 45, num. 23, p. 145-149.
- Scherer, S., Talley, C. P., & Fife, J. E. (2017). How personal factors influence academic behavior and GPA in African American STEM students. *SAGE Open*, 7(2), 2158244017704686.
- Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (2009). Technological pedagogical content knowledge (TPACK) the development and validation of an assessment instrument for preservice teachers. *Journal of research on Technology in Education*, 42(2), 123-149.
- Sintema, E. J., & Marbán, J. M. (2020). Pre-service secondary teachers' mathematical pedagogical content knowledge self-concept related to their content knowledge of functions and students. *International Electronic Journal of Mathematics Education*, 15(3), em0598.
- Stehle, S. M., & Peters-Burton, E. E. (2019). Developing student 21st Century skills in selected exemplary inclusive STEM high schools. *International Journal of STEM education*, 6(1), 1-15.
- Yildirim, Bekir & Sahin Topalcengiz, Emine. (2019). STEM Pedagogical Content Knowledge Scale (STEMPCK): A Validity and Reliability Study. *Journal of STEM Teacher Education*. 10.30707/JSTE53.2Yildirim.