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Technology-enhanced Teaching in Engineering Education: Teachers' Knowledge Construction Using TPACK Framework[1]

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This study investigates the knowledge that engineering teachers should possess in order to effectively implement technology-enhanced instruction in their teaching practice using Technological Pedagogical Content Knowledge (TPACK) framework, although its (TPACK) use in HEIs is inadequate. The objectives of this investigation are to investigate what TPACK construct is using in engineering education (Eng. Ed) and to study how different attributes of a teacher affect their level of TPACK knowledge. In order to accumulate engineer teachers' knowledge, a descriptive self-assessment tool designed in a Google form was administered via email to 220 teachers from two different universities of Bangladesh located in the business district of Dhaka. Descriptive analysis, Pearson's correlation coefficient (r), Exploratory Factor Analysis, Cronbach Alpha test, ANOVA, and Levene test were carried out to analyse the collected data. The outcomes of this investigation confirmed the practicality of the framework and discovered significant differences regarding technological knowledge (TK), conventional knowledge (PK/PCK) in field of study of the teacher and a significant difference in technology-enhanced instructions in regard to age group of the teacher. The results support the previous argument that only availability of technology and teachers' technology knowledge in Eng. Ed may not accelerate technology-enhanced teaching. The findings add knowledge to prior research whose objective is to find ways of incorporating technology-enhanced instructions in HEIs and thus, provide recommendation to Eng. Ed towards formulating policies on incorporating TPACK components in their teaching.

Keywords: technology, engineering education, TPACK, technology-enhanced teaching, ICT, knowledge

[1] This study was produced from the data of the master thesis.

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INTRODUCTION

Many Higher Educational Institutes (HEIs) around the globe have embraced Information Communication Technology (ICT) as a key component for enhancing educational processes (teaching and learning) (Cubeles & Riu, 2018; Rodríguez-Moreno & Rochina-Barrachina, 2019; Shah, Khan, & Reynolds, 2020; Tømte, Fossland, Aamodt, & Degn, 2019) amidst the scourging Covid-19 pandemic (Ali, 2020). Advanced ICT-enhanced education platform, such as Learning Management Systems (LMS), video collaboration tools (Microsoft Teams, WebEx, and Zoom), offers diverse learning experiences that are used to organize course content, provide learning opportunities to diverse categories of learners, and provide flexible course delivery mechanisms for long distance and blended learning (Ain, Kaur, & Waheed, 2016; Bahri, Idris, Muis, Arifuddin, & Fikri, 2021). These technologies are the reasons for introducing Massive Open Online Courses (MOOCs), Mobile learning for students, Virtual labs that allow simulations of a physical experiment, serious games that engage and retain learners' attention, personalized blended learning using learning analytics, mobile devices for engaging students (Callaghan, Savin-Baden, McShane, & Eguiluz, 2017; Carannante, Davino, & Vistocco, 2020; Khan, Abdou, Kettunen, & Gregory, 2019). Thus, ICT continues to provide new and emerging opportunities that simplify ways of representing and delivering teaching and learning experiences in HEIs around the globe.

Despite the above benefits offered by technologies to HEIs, there is no size that fits all approaches to effective integration of ICT in teaching and learning processes in developing countries (Kalolo, 2019). Previous research confirmed that teachers are the key agents for successful integration of ICT in HEIs (Khan, 2015; Tondeur et al., 2019). Accordingly, Bibi and Khan (2017) claim that “teachers are the ones who decide whether or not to integrate technology and bring changes into the classroom” (p.2). Teachers’ decisions of using technology in their teaching practices depend on their knowledge (Bibi & Khan, 2017) and attitudes (Teo, 2014) towards technology which have been directly linked to teachers’ ICT self-efficacy (willingness to choose and to participate ICT-enhanced teaching) (Tondeur et al., 2019). Sipilä (2014) experiment showed that almost half of teachers feel under prepared to use ICT infrastructure to support their teaching and learning practices while (Kretschmann, 2015) carried out a small scale study in German involving teachers of Physical and Health Education and reported that teachers are resistant and struggle to integrate ICTs in pedagogically sound ways.

Majority of researchers investigated teachers' knowledge (e.g., Jääskelä, Häkkinen, & Rasku-Puttonen, 2017; Saubern, Urbach, Koehler, & Phillips, 2020) and attitudes (e.g., Canals & Al-Rawashdeh, 2019; Teo, 2014) towards use of technology in educational processes, and other studies concentrated on teachers’ way of accepting TPACK (technological pedagogical content knowledge) (e.g., Çam & Koç, 2019; Tondeur, Scherer, Siddiq, & Baran, 2020) in higher education (HE). Most studies do not concern teachers' knowledge and attitudes towards integrating technology in Engineering Education (Eng. Ed). This creates an academic gap to investigate technology-enhanced teaching in Eng. Ed considering a view that looks at Technological Pedagogical Content

Knowledge (TPACK) domains. Moreover, research on technology integration in Eng. Ed using TPACK framework is not only important in a global context (developed countries) but also it is one of the national priorities of less developed countries (e.g., Bangladesh).

Theoretical Underpinnings

The TPACK Framework and Its Application in Higher Education Context

Since the inception of the TPACK notation by M. Koehler, Mishra, Yahya, and Yadav (2004) in a bid to find ways of integrating technology in educational processes, much of the focus of the framework was directed towards primary and secondary education. However, due to the potentials that the framework offers, researchers picked interest in further applying this framework to HEIs (Alzahrani & Cheon, 2015; Bibi & Khan, 2017; Reyes Jr, Reading, Doyle, & Gregory, 2017). In this line, Cubeles and Riu (2018) extended the application of this framework to the university setting and provided useful insights into seven knowledge domains (see figure 1).

To develop the TPACK framework, M. Koehler et al. (2004) expanded on Shulman (1987) theory of Pedagogical Content Knowledge (PCK) by introducing Technology Knowledge into the framework. The framework illustrated different knowledge constructs that an individual teacher has to possess in order to be able to effectively teach and the interdependence between the knowledge bases. Based on the PCK framework, M. J. Koehler and Mishra (2005) developed TPACK framework to explain the knowledge that a teacher needs to possess in order to introduce technology into his or her teaching practice. Therefore, the importance of the framework lies in the interaction and interdependence of the three base knowledge domains i.e. Content Knowledge (CK): the subject matter (knowledge) that a teacher teaches to the learners; Technological Knowledge (TK): Knowledge about technologies that can be integrated into the subject matter; and Pedagogical Knowledge (PK): Knowledge about different teaching and learning methods, strategies that enhance teaching and learning. This framework shows that the three base knowledge domains (CK, TK, PK) interact with each other that result into three more secondary knowledge domains such as, Technological Pedagogical Knowledge (TPK): technology knowledge adds with pedagogical modules which enable teachers to supplement their pedagogy with specific technologies; Technological Content Knowledge (TCK): the knowledge concerning the mutual correlation between content and technology; and Pedagogical Content Knowledge (PCK): teachers' pedagogy knowledge is linked with their content (subject) knowledge. These six knowledge domains interact with each other and form the seventh knowledge domain, Technological, Pedagogical, Content Knowledge (TPCK): it is combined knowledge resulting from the compound relationships among technology, content, and pedagogy which permits a teacher to cultivate teaching methodologies that are appropriate and precise to the subject matter. Thus, the seven knowledge domains that were used to measure engineering teacher's ability to use technology for enhancing teaching and learning are illustrated in Figure 1.

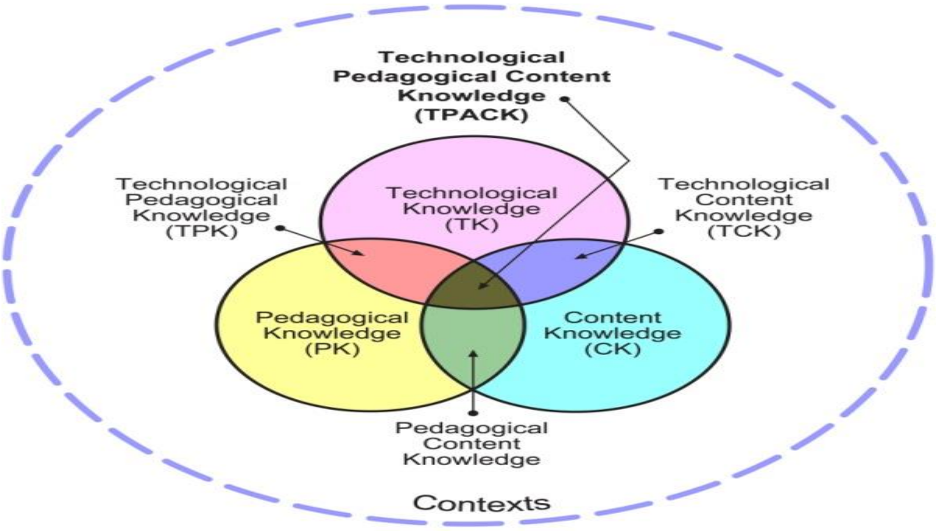

Figure1
Graphical representation of tpack framework and its knowledge constructs
Adapted from (Mishra & Koehler, 2008) p.3.

The TPACK Framework and Its Application in Engineering Education (Eng. Ed**)**

Teachers, in this digital age, should have a certain level of digital competencies in their profession (Tondeur et al., 2019). Due to globalization, introducing diverse technology-supported workplaces, and facing COVID-19 pandemic, the graduates of engineering education (Eng. Ed) require updated knowledge and skills to meet labour market demands. Therefore, teachers of Eng. Ed are facing challenges to address these current demands. Developing countries, hence, are giving rise to the need of developing policies, expectations, and standards for using technology as a tool to prepare future workforce capable of satisfying the 21st Century global labour demands (Abduvakhidov, Mannapova, & Akhmetshin, 2021). In order to meet this challenge, TPACK framework is the total package for teaching in the 21st Century not only for higher education but also for Eng. Ed in any country in the world. However, the curricula, in most cases, used in teaching engineering in the HEIs of developing countries particularly were developed in 20th century using PCK framework (Shulman, 1987) without consideration of technology knowledge construct which is a necessary attribute of a professional teacher, teaching Eng .Ed in the 21st century (Finger, Jamieson-Proctor, & Albion, 2010). Introduction of technology into Eng. Ed context particularly is not a matter of mere adding technology construct (component) into the existing pedagogy and content framework (See Fig. 1). It requires creative strategies of combining the seven knowledge domains by the teacher (Mishra & Koehler, 2006). Therefore, there is a need to understand which kind of knowledge a teacher should possess while integrating technology in teaching Eng. Ed, how the different knowledge domains interact while they are integrating technology, and lastly, how the different attributes of a teacher affect his or her degree of TPACK knowledge in ICT integration.

In relation to TPACK framework, teachers in Eng. Ed should have knowledge of specific hardware and software (TK) which will be applied in teaching specific content in the curriculum (TCK). Teachers' knowledge about ICT-enhanced learning materials and other related resources is important in Eng. Ed because it facilitates teachers to justify choosing appropriate tools (ICT-enhanced) in relation to meeting domain specific learning (TCK) and pedagogical (TPK) requirements. Teachers in Eng. Ed also should have knowledge of how to use technology rich curricular resources that will support them to employ ICT in pedagogically meaningful ways to achieve learning in specific content areas (Technological Pedagogical Content Knowledge, TPACK). Therefore, the knowledge of this framework is crucial for empowering engineering teachers to integrate ICT in their teaching practice as it enables them to select and use technology supported resources (both software and hardware), and to use the tools in a pedagogically appropriate and effective way to promote a subject's knowledge (contents) of Eng. Ed (Voogt & McKenney, 2017).

For effective integration of ICT, teachers in Eng. Ed, should concentrate on minimizing the gap between knowledge of technical skills, pedagogical practice, and content knowledge (M. Koehler & Mishra, 2009; M. J. Koehler, Mishra, & Cain, 2013). Therefore, teachers should possess seven knowledge constructs (see Figure 1) for effective integration of ICT that facilitate shifting in teaching approach from content-centred curricula (teacher-centred) to competency-based curricula (student-centred) where students are encouraged to take responsibility for their own learning unlike previously when students were comfortably receiving information from teachers that formed the curriculum (Bala, 2018; Lee & Hannafin, 2016). In this way, teachers in Eng. Ed face a lot more challenges when integrating technology into their teaching practice as they have to adapt new teaching approaches, construct different knowledge domains, and content to fit available technology resources in myriad disciplines in Eng. Ed and in different cultures (Reyes Jr et al., 2017). However, very little attention is explicitly given to the knowledge that engineering teachers need to possess for effective integration of ICT in their teaching and learning generally and Eng. Ed particularly (Voogt & McKenney, 2017). A search in the academic repository on studies involving integration of ICT in HEIs and TPACK in particular reveals, "limited research is available in a higher education context" (Rienties, Brouwer, & Lygo-Baker, 2013, p. 124). Some of the available studies point out lack of universal satisfaction with regard to integrating new technologies into higher education (Reyes Jr et al., 2017). Despite these recommendations, Cubeles and Riu (2018) investigated the knowledge required by professors to integrate ICTs in Spanish universities and identified useful knowledge needed for implementing TPACK in HEIs.

They specifically found that the TPACK knowledge of a university teacher is not affected by his/her field of disciplines and by the age group to which he/she belongs. Although two other studies found contradictory findings when age group and TPACK constructs were analysed (see, Alzahrani & Cheon, 2015; Blackburn, 2014). The little research which had been conducted in the university setting for investigating teacher's knowledge domains in TPACK showed commonalities and differences in their findings. Therefore, Cubeles and Riu (2018) recommended future research to be carried out in different geographical areas in this domain. In order to extend this limited research, the focus of our research is to analyse and evaluate how different variables such as age, professional teaching experience, and field of study of a teacher affect his/her degree of TPACK knowledge in engineering education.

Research Context and Need of Conducting Research

Bangladesh is among the fast-growing economies around the global based on the 2018-2019 financial year (The World Bank, 2019). Its economy heavily depends on Eng. Ed that produces skilled manpower (Alam, 2008). Now the growing concern of Bangladeshi economics is the "Fourth Industrial Revolution (4IR)" which is driven by the new technologies, such as digital machines, artificial intelligence, robotics, and big data that are linked to technology knowledge (TK) (Bloem et al., 2014). The challenges come up because of the nature of work and future labour market requirements. These challenges could be translated into three main reasons, such as; (a) many new tasks have been created in the employment market since last decade which simply did not exist ten years ago (Fallows & Steven, 2000), (b) employers in the current workplaces prefer an employee who has diverse skills combination of cognitive, non-cognitive (soft) and technical skills rather than only having technical skills (specific skills) (Suleman, 2018), (c) the new technology introduces new work practices in the industry which has led to the emergence of new level of skills **requirement in the job sectors**. In order to solve these challenges specifically in Eng. Ed of Bangladesh as well as other developing countries, then recognizing integration of ICT into their teaching and learning by using TPACK framework is necessary.

Integration of technology in Eng. Ed of Bangladesh is now gaining priority due to three more reasons: Firstly, although Bangladesh as a developing country is in the early stage in regard to digitalization of its sectors like the economy, health, transportation, real estate, education and others (Mahmuda, 2016). The education sector in general and engineering education in particular is progressing towards a more advanced and highly digitalized approach from a conventional teaching and learning method due to pressure raised from the Government of Bangladesh (GoB). An arsenal of modern tools and cutting edge inventions are making waves in engineering institutes around the country such as interactive whiteboards, multimedia projectors for enhancing ICT-enhanced teaching and learning (Al-Zaman, 2019). Moodle packages are being used in some public and private universities around Bangladesh to dynamically create online teaching and learning environments (Mahmuda, 2016) as evidenced during the Covid-19 lockdown. These two examples provide evidence of shifting from traditional teaching to ICT-enhanced teaching and learning in Eng.Ed of Bangladesh. Secondly, in order to accommodate a large number of students in Eng.Ed, technology-enhanced teaching and learning is considered to be an effective means to provide better learning outcomes to the ever-increasing numbers. It is expected that when digital technology is properly used in Eng. Ed of Bangladesh, teachers can create innovative and engaging methods of teaching and learning so that they can find better and simpler ways of conducting instructions to the ever-increasing number of students. Thirdly, student focused activity-oriented teaching favours curricula that promote competency and performance of students (Khan & Markauskaite, 2017) demands integration of technology in Eng. Ed. This is because, the main purpose of any engineering information (knowledge) learnt is concerned with how the information will be used to solve problems in the society, hence improving the living conditions of the society rather than what the information is (Bala, 2018).Thus, teaching approaches in Eng. Ed in this digital age would require diverse strategies that demand using myriad forms of new and emerging technologies. Teachers should play a vital role for integrating technology in Eng. Ed of Bangladesh. Unfortunately, there is a lack of empirical evidence, to our knowledge, and there is no empirical evidence in Bangladesh that shows teachers' knowledge of integrating technology in engineering education by means of the seven knowledge domains of TPACK framework.

METHOD

A descriptive survey method was used to investigate the knowledge required by university teachers in order to incorporate ICT into their teaching practices. A questionnaire was considered the data collection tool for this study since a significant number of prior descriptive studies were conducted using a questionnaire as their data collection tool. Similarly, prior literature recommended that in a descriptive survey involving beliefs is appropriate to use a questionnaire for data collection because it allows the respondents to easily express their perception (Bernard & Bernard, 2012; W Lawrence Neuman, 2014; William Lawrence Neuman & Kreuger, 2003).

Research Participants

The purpose of this study was to investigate knowledge needed by Eng Ed teachers to effectively implement technology enhanced instruction in teaching and learning processes in accordance with TPACK framework. Hence the population of this study was the Eng Ed university teachers. Two universities (U1 and U2) were purposively chosen as a sample of HEIs due to two main reasons: first, these two universities were considered to be having noticeable education instruction technology capabilities, and *second*, they had more female teachers compared to other universities. Thus, an open invitation was circulated via email to the entire teaching population of these universities which was 220 fulltime teachers. A cohort of 136 teachers filled the questionnaire completely out of 220, which represented 61.8% overall return. Cubeles and Riu (2018) carried out similar nature of research where the sample size was 113 participants. Thus, the sample of 136 in this study was reasonable (See, Krejcie and Morgan, 1970). Out of 136 respondents, 99 (72.8%) were male and 37 (27.2%) were female and 75.7% of this sample was aged between 26 and 40. Over half of the respondents (55.1%) had teaching experience ranging from 1- 4.99 years. 14.7% were from 5 – 9.99 years, 17.6% were from 10 – 14.99 years, 8.1% were from 15 – 19.99 years, and lastly 4.4% were of over 20 years teaching experience in Eng. Ed. In terms of field of study, majority of respondents were from: 25.7% Electrical and Electronic Engineering (EEE), 17.6% Civil and Environmental Engineering (CEE), and 11.8% Computer Science and Engineering (CSE). Other departments were as follows: 2.9% Technical and Vocational

Education (TVE), 4.4% Chemistry (CHE), 0.7% Architecture (ARC), 2.9% Business Technology Management (BTM), 11.8% Mechanical Engineering (ME), 7.4% Industrial and production engineering (IPE), 5.9% Textile Engineering (TE), 8.8% Physics (PHY).

The Research Tools

The questionnaire was adopted and modified from Cubeles and Riu (2018) who had adopted and modified it from two prior studies such as: Chen and Jang (2014) and Schmidt et al. (2009) to suit the university level as the prior tool was developed for the secondary and primary level. The adopted questionnaire had 33 items across seven TPACK constructs with five point Likert scale response that were ranging from strongly disagree (1) to strongly agree (5). A pilot test was conducted to validate the adopted tool and to check clarity of the items. The result of the pilot study revealed that two items generated confusion and we removed them leaving the final number of items 31. The survey-questionnaire was composed of two sections. Section A: composed of demographic data of the participants while Section B: was composed of close ended questions testing different TPACK knowledge of the respondent spread across seven different constructs as stated (TK) - 7 items, (PK) - 6 items, (CK) - 3 items, (PCK) - 4 items, (TCK) -3 items, (TPK) - 4 items, and (TPCK) - 4 items (see Appendix A). In this study, mean scores 1.0 - 2.9 were interpreted as low, whereas scores between 3.0 - 3.9 were considered average and mean scores over 4.0 were considered high.

Data Collection Procedure

The data collection was completed during the academic year of 2018-2019 by following an online strategy. More specifically, the questionnaire was first designed using an online tool (*Google forms)*. Likewise, a number of studies before in literature used online questionnaires to collect data which yielded useful knowledge (see, Habibi et al., 2015; Lakhal, Khechine, & Pascot, 2013). The first author shared the online link of the questionnaire to the respondents via email addresses obtained from university computer centres with approvals from the academic registrars' office. Along with that, the data collection process followed ethical requirements of U1 and U2. Being an online form, all responses were received in real time upon the completion of the form by the respondents.

Analytic Strategy

The data collected by the questionnaire was managed and analyzed using *IBM Statistical Package for the Social Sciences* (SPSS) version 20 for windows. Separate tables were prepared for different parts of the questionnaire and each table was followed by their own interpretation. A quantitative approach using different statistical methods was used for analysing the data collected from the structured questionnaire. A descriptive analysis was used to gain the mean values of the TPACK constructs basing on the items assigned for each construct. The Pearson's correlation coefficient (r) was applied to analyse the degree of association between different knowledge constructs of the TPACK framework. An Exploratory Factor Analysis (EFA) was applied to decide the final number of factors and then, Cronbach Alpha test was carried out to evaluate the *reliability* of the entire questionnaire and each TPACK construct. To analyse the effect of the university teacher's factors (age, experience, and discipline) on the TPACK framework, analysis of variance (ANOVA) was used because all factors had more than two values, together with Levene test to verify the similarity of the variances.

RESULTS

Table 1
Descriptive statistics for seven constructs

Constructs	Items per Construct	Mean	SD	Cronbach's Alpha
Technology (TK)	7	4.25	0.82	.833
Pedagogy (PK)	6	4.17	0.77	.821
Content (CK)	3	4.32	0.77	.782
Pedagogy Content (PCK)	4	4.16	0.74	.823
Technology Content (TCK)	3	4.04	0.83	.830
Technology pedagogy (TPK)	4	4.10	0.83	.836
Technology Pedagogy Content (TPACK)	4	4.14	0.81	.851
Overall Reliability	31	4.17	0.80	.950

Cronbach's Alpha test was applied to test the reliability of the survey tool. Table 1 shows an overall reliability score of 0.950. However, for individual construct reliability test scores are: 0.833 TK, 0.821 PK, 0.782 CK, 0.830 TCK, 0.823 PCK, 0.836 TPK, and 0.851 TPACK. The above reliability scores are adequate as all scores are ranging from .7 to .950 (Lance, Butts, & Michels, 2006). Moreover, it was closely similar to those that were obtained while validating the tool used by Schmidt et al. (2009), who reported the values were between 0.75 and 0.92.

Table 2
Pearson correlation coefficients

	TK	PK	CK	PCK	TCK	TPK	TPCK
TK	1						
PK	.553**	1					
CK	.368**	.521**	1				
PCK	.473**	.687**	.616**	1			
TCK	.498**	.389**	.571**	.526**	1		
TPK	.432**	.552**	.532**	.593**	.519**	1	
TPCK	.457**	.541**	.533**	.606**	.523**	.746**	1

For the relationship among different constructs (seven knowledge constructs), we used Pearson's correlation coefficient (r) to generate a matrix of correlation, as seen in Table 2 above. The test results are significant as it shows a strong (greater than .5) positive correlation in several constructs (Chen & Jang, 2014).

To confirm the applicability of the TPACK framework in Eng. Ed at universities in Bangladesh, we calculated the correlation among different subscales (constructs) after which we performed an EFA (Gorsuch, 1997). This analysis was done basing on the matrix of correlations found in (Table 2). The sample-size of this study (N = 136) had a ratio of 1 item per 4.4 respondents. Previous study however, considered a larger sample than this study (N=136) for conducting *EFA* (see, Black, Babin, & Anderson, 2010).

However, the number of items per construct and high-communality gotten in our study permit us to contemplate a reasonable position that justify our sample-size was suitable to apply current study (Henson & Roberts, 2006).

Basing on the Jackson rule to identify the appropriate number of TPACK factors that an engineering teacher requires to integrate Technology in engineering universities of Bangladesh (Jackson, 1993), the test (EFA) was carried out initially with the Eigen-value of 1, and 7 factors were extracted with an explained variance of 64.5%, then basing on the screed plot, the factors were fixed to 3 and we later applied Promax oblique rotation and obtained a 48.4% explained variance as shown in Table 3. All items whose weight is less than 0.4 were eliminated (few items) due to their insignificance. Three inter-related constructs (factors) were identified by the analysis. *Construct one* is a combination of technology-enhanced teaching (CK, TPK, TCK and TPCK), and traces of pedagogy knowledge (PK). *The second construct* is directly related to technology knowledge (TK), and *the third construct* is linked to conventional teaching with no technology aid (PK and PCK). In relation to the study of Chen and Jang (2014), our findings match three - *Technology Knowledge (TK)*, *Conventional teaching Knowledge (PK,PCK)* and *Technology-enhanced Teaching Knowledge (TPCK)* - out of four of their constructs which were Technology knowledge (TK), Content knowledge (CK), Conventional teaching method (PCK) and Technology-enhanced Teaching Knowledge (TPCK).

The first construct, *technology-enhanced teaching* has four components such as CK/TCK/TPK/TPCK. The data showed a strong connection among *technology* driven domains, *content knowledge* domain, and few items from *pedagogy*, and *pedagogy content knowledge* domains because they loaded together into a single domain (see Table 3). Basing on the data from the first construct, we concluded that, CK, items of PK loaded together with technology-enhanced teaching, because when teachers want to teach particular content (subject matter) in Eng. Ed, the methods and strategies of delivering it to the learners were contemplated as part of the content and in this case, *technology-enhanced teaching* is the method of delivery. Likewise, PK and PCK items found in the first construct (Technology-enhanced teaching) that was due to teachers adopting their pedagogical methodologies to suit available ICT resources in Eng. Ed while conducting their instructions (lesson). For instance, during CK, PCK, and PK preparation and presentation, teachers usually depended on ICT tools such as interactive whiteboards, projectors and computers within the classroom environment.

Table 3
TPACK factors with corresponding communalities

		1	2	3	Communalities
TPCK2	*Technology-enhanced Teaching Knowledge* (TPCK/TPK/TCK/CK/PK/PCK)	.736			.572
TPCK4		.734			.569
TPK1		.733			.613
TPK2		.719			.484
TPCK3		.718			.568
TPK4		.677			.408
TCK2		.663			.460
TPK3		.658			.494
CK3		.636			.478
TCK1		.623			.513
CK2		.594			.517
TPCK1		.581			.493
PCK3		.551			.567
PCK4		.541			.516
CK1		.409			.212
PK6		.408			.329
TK6	*Technology knowledge* (TK)		.818		.694
TK4			.775		.553
TK1			.684		.491
TK5			.639		.503
TK7			.622		.454
TK3			.452		.373
PK2	*Conventional teaching Knowledge* PK/PCK			.723	.496
PK5				.707	.471
PK3				.637	.515
PK1				.572	.471
PK4				.549	.460
PCK2				.498	.536
PCK1				.400	.440

Table 4
Descriptive scores of TPACK constructs

Variables	Mean	SD	Median	Mode
TK	4.13	.597	4.17	4.50
PK/PCK	4.18	.495	4.29	4.29
TPCK/TPK/TCK/CK/ PK/PCK	4.21	.499	4.25	4.44

Table 4 shows the mean, standard deviation, median, and mode for three constructs (factors). The factor with highest mean is technology-enhanced teaching (TPCK/TPK/TCK/CK/PK/PCK) closely followed by traditional teaching (PK/PCK) and Technology Knowledge (TK). It is paramount to point out that all mean-values are strong (above 4.0) which shows a positive general perception of teachers in regard to TPACK framework.

After analysing all the data, the means of all factors were scrutinised to find out if there was any significant difference in respect to teachers' attributes such as *age*, *teaching experience* and *field of study*. In reference to differences that may arise due to different age groups of teachers, the result shows (Table 5) significant differences (p value .050) in the technology-enhanced teaching (TPCK/TPK/TCK/CK) of the teachers, but no significant differences in the other two TPACK constructs (TK and PK/PCK) (P value .576 and .432, higher than .05). That means, the view of teachers on use of technology-enhanced teaching in educational practice is influenced by their age-group. Teachers with high conventional knowledge (older teachers) are more likely to achieve high technology-enhanced teaching knowledge despite their low knowledge in technology while teachers with low conventional knowledge (young teachers) are likely not to achieve high technology-enhanced teaching (TPACK) despite having high technology knowledge (Table 5).

In reference to the years' experience in teaching, *Table 6* shows that a teacher's experience does not affect any of the three TPACK constructs (p values such as .732, .218, .589 are higher than .05). Therefore, the self-perception of a teacher on use of TPACK in teaching seems not to be influenced by the number of years (experience) the teacher has in the teaching profession.

In reference to the discipline (specialization) taught by the university teacher, the result shows significant differences in two factors, i.e. TK (p value is .001) and PK/PCK (p value is .045) of the teacher but no significant difference in technology-enhanced teaching (TPCK/TPK/TCK/CK) (p value is .305 which is higher than .05). The *Table 7* shows no significant difference in self-perception of a teacher in technology-enhanced teaching construct regardless of the teacher's specialization (field of teaching) whereas, the significant difference was found in other two constructs when teachers taught in different engineering disciplines.

Table 5
Analysis of age groups of different teachers

	Levene	Mean by group							ANOVA	
Factor	p	20-25	26-30	31-35	36-40	41-45	46-50	51+	F	p
TK	.133	4.0444	4.0609	4.3086	4.2083	4.0694	4.3333	3.9000	.794	.576
PK/PCK	.354	4.0667	4.1236	4.2804	4.1845	4.2262	5.0000	4.3429	.994	.432
TPCK/TPK/TCK/CK	.370	3.8667	4.1719	4.3773	4.2161	4.2500	4.8125	4.3625	2.172	.050

Table 6
Analysis of teaching experience of different teachers

	Levene	Mean by group					ANOVA	
Factor	p	1 - 4.9	5 - 9.9	10 - 14.9	15 - 19.9	20+	F	p
TK	.365	4.093	4.233	4.229	4.076	3.972	.505	.732
PK/PCK	.818	4.143	4.336	4.071	4.273	4.452	1.460	.218
TPCK/TPK/TCK/CK	.118	4.149	4.266	4.245	4.267	4.438	.706	.589

Table 7
Analysis of different fields of study (disciplines) for teachers

	Levene	Mean by group											ANOVA	
Factor	p	TVE	CHE	ARC	CSE	EEE	CEE	BTM	MCE	IPE	T.E	PHY	F	p
TK	.000	3.83	4.33	4.17	4.34	4.34	3.98	3.33	4.04	3.68	4.56	4.00	3.20	.001
PK/PCK	.000	3.64	4.55	3.43	4.04	4.27	4.20	4.54	4.04	4.01	4.34	4.24	1.95	.045
TPCK/TPK/TCK/CK	.000	3.66	4.26	4.38	4.01	4.29	4.22	4.42	4.18	4.06	4.41	4.28	1.19	.305

DISCUSSION

This study primarily investigated the applicability of the TPACK framework in the faculty of Eng. Ed in Bangladesh universities and analysed the consequences of different attributes (age, teaching-experience, and field of study) basing on the seven knowledge constructs (domains) of this framework to find out knowledge required by Eng Ed teachers to enable them implementing technology enhanced instruction successfully. The reliability scores obtained after adapting and modifying the questionnaire further confirm the applicability of the framework in Eng. Ed contexts because the scores of this study are similar to those correlations published in the application of the TPACK framework in higher education (see, Cubeles & Riu, 2018).

However, researchers found out that the theorized seven knowledge constructs of TPACK Framework were practically not possible to separate into individual domains in Eng. Ed contexts. This study faces the challenge of proving the existence of these seven domains in actual practice in the contexts of Eng. Ed which are also supported by the prior study (see, Cubeles & Riu, 2018). Finally, this study found that the seven knowledge constructs of TPACK framework reveal three categories of factors: first, *technology-enhanced teaching knowledge*; second, *technology knowledge*; third, *traditional teaching without technology*. Only technology knowledge (TK) clearly distinguishes itself with no items from other domains joining this TK. This has led researchers to conclude that the framework (TPACK) faces identical challenges similar to Shulman (1987) PCK faced over three decades ago (i.e. separating Pedagogy-Content

Knowledge, into individual PK and CK). Similar findings were found by (Archambault & Barnett, 2010) when they explored the nature of factors making up the TPACK framework p.3) .

The main reasons of finding three necessary knowledge constructs in this study could be explained, *first*, the ways Eng. Ed teachers combined the different knowledge constructs (seven knowledge domains) while conducting their teaching (the purposes of conducting engineering subjects) are not the same as other disciplines of HEIs; *Second*, value of ICT in pedagogically appropriate and effective ways for integrating ICT in their teaching may not be the same as other disciplines. This categorization (findings) enabled the researcher to develop explanations for relationships found between the teachers' ways of using ICT while considering TPACK framework in Eng. Ed.

The general results obtained after extracting the three constructs indicate a strong view of universal familiarity in TPACK framework. The highest mean (average) value is that of technology-enhanced teaching knowledge followed by traditional (conventional) teaching knowledge and lastly, technology knowledge. These results partially contradict other studies conducted at HEIs where conventional knowledge of teaching had the highest average followed by technology-enhanced teaching and finally technology knowledge (see, Blackburn, 2014; Cubeles & Riu, 2018). The change in position between conventional teaching knowledge and technology-enhanced teaching knowledge may be because of the nature of the universities where researchers conducted this study that is, engineering universities which have implemented a significant amount of technology resources to enhance teaching and learning. The teacher may also be influenced to embrace technology-enhanced teaching because they know their students are going to compete globally in employment and scientific research, thus, teachers are motivated towards incorporating technology aimed at ensuring minimum standards.

In reference to the variables of the university teacher and age group in particular, this study found significant differences in the teacher's self-perception in respect to technology-enhanced teaching, but not in technology knowledge construct or conventional way of teaching construct between different age groups. The significant difference in technology-enhanced teaching can be explained by the way technology-enhanced teaching construct is nurtured and developed by a teacher of Eng. Ed. This knowledge is achieved as a result of combining conventional teaching knowledge (PK, PCK) and Technology Knowledge (TK) in specific ratios. From Table 5, comparing data from the youngest age group and the oldest age group, this study discovered that although oldest age group possessed lower TK, but they had a higher PK/PCK which translates into higher TPCK. In contrast, young age group had a higher TK but lower PK/PCK which translates into a lower TPCK. These findings are in line with Benson and Ward (2013) findings where they reported that high values of technology knowledge (TK) does not necessarily translate into high levels of technology-enhanced teaching (TPCK) whereas higher knowledge levels in conventional practice (PCK) usually contributes increasing teachers' knowledge of technology-enhanced teaching that guides a teacher in making decisions in their teaching towards choosing suitable technology.

The findings of our study also coincide with a study of Alzahrani and Cheon (2015) in Saudi Arabia where a significant correlation was found between the respondents' age group and technology-enhanced teaching (TPCK and TPK). Furthermore, our findings partially support previous similar studies (see, Blackburn, 2014; Cubeles & Riu, 2018; Marcelo-García, Yot-Domínguez, & Mayor-Ruiz, 2015) where no significant difference was found in teachers' self-perception on technological knowledge and conventional teaching knowledge constructs in relation to the age group. In contrast to our study, these studies further reported, there was no significant relation to technology-enhanced teaching construct in the age factor.

This study further found out that teaching experience did not influence a teacher's self-perception of TPACK familiarity. Therefore, a teacher's decision to use technology in learning context is not affected by the number of years that the has spent in the teaching profession. This finding may also be influenced by the nature of engineering universities where the general practice is that teachers should have at least minimum knowledge on the use of educational technologies. Likewise, these findings confirm those obtained by Lin, Tsai, Chai, and Lee (2013) in Singapore and in the United States of America by Blackburn (2014).

There were substantial differences in the teachers' self-perception of technological knowledge aspect and conventional way of teaching knowledge constructs with regard to the discipline, but no significant difference in relation to technology-enhanced teaching knowledge construct. This gives us two possible conclusions about the self-perception of a teacher in using TPACK in respect to their discipline. *First*, the results show no substantial differences in self-perception of a teacher in technology enhanced teaching construct regardless of the teacher's discipline. This may be due to the nature of universities (Engineering and Urban) where participants(teachers) were generally exposed to technology. This concurs with other studies, such as Cubeles and Riu (2018), Lye (2013) and proves that the university teachers have similar self-perception of knowledge related to technology-enhanced teaching regardless of the discipline to which they belong. Second, the significant difference in self-perception of a teacher in TPACK constructs related to technology knowledge and conventional teaching knowledge can be explained by the nature of discipline i.e., Computer Engineering, Electrical engineering deal in computer resources thus teachers have a lifelong learning to connect with technology unlike Civil Engineering, Physics where teachers view technology as a mere tool to accomplish a specific task at hand (when the task requires technology) and abandon it immediately after accomplishing the intended task. The difference in conventional teaching factor (PCK) in relation to discipline is probably due to pedagogical approaches used by teachers to deliver instruction in different disciplines i.e. Newer discipline like computer science encourage student-centred learning (Dębiec, 2017) while old discipline like civil engineering, mathematics prefer teacher-centred learning although efforts are currently on to enable a paradigm shift to the former (Hwang, 2021; Yehia & Gunn, 2018).

IMPLICATION

The practical implications of this study as stated earlier is using the TPACK framework as a tool to guide teachers with knowledge and competences that can be used effectively in Eng. Ed of Bangladesh and other developing countries. The three knowledge constructs identified in this study enable a teacher to use technology in a pedagogically sound and appropriate way. More specifically, the findings highlight how knowledge of conventional teaching positively affects knowledge of technology-enhanced teaching i.e., the results of this study show strong a correlation between conventional teaching knowledge and technology-enhanced teaching knowledge.

The assumption and approach towards integrating technology in educational context was to train teachers in technology knowledge. Such approaches however, can easily create resistance in conservative teachers who may feel technology knowledge is aimed at displacing their conventional teaching knowledge. This study shows a better approach that is to first develop their conventional teaching knowledge, then introduce technology knowledge as a vehicle to support, improve and simplify their teaching and learning practice. Therefore, policy makers should look into advocating for continuous professional development in both technology knowledge and conventional teaching knowledge and how they can be applied in Eng. Ed context.

Focused on higher education and engineering education in particular, the outcomes of this study endorse the independence of technology knowledge from other knowledge domains, and further show a strong association between content and technology-enhanced teaching in Eng. Ed. This provides us with a number of insights on how to integrate technology-enhanced teaching into engineering education. Firstly, the need to progressively train teachers in trending and emerging technologies and how those technologies can simplify their teaching practice. Secondly, intertwining of content knowledge with technology-enhanced teaching knowledge guides teachers in a direction where they should rethink ways of reconstructing content so that it will be adapted to the ever-changing technologies thereby benefiting both learners and teachers. For example, in Eng. Ed, teachers having both technology-enhanced knowledge with conventional teaching knowledge provide useful teaching methodologies change 2D models into 3D or augmented reality for better insights and understanding for their students.

This study is in position to guide the course designers of Eng. Ed. During the design stage, they should keep in mind that effective design depends on integration of different knowledge constructs with subject knowledge that is contents of Eng. Ed could be intertwined with TK, TPK, TCK and TPCK for better learning outcomes. Besides, the study provides useful knowledge to the professional creators who will organize professional development programs for the teachers in Eng. Ed. In order to achieve effective integration of technology in Eng. Ed, the professional developers should focus on integrating different knowledge constructs since our results show close intertwining among the knowledge constructs with no practical demarcations (Benson & Ward, 2013; Cubeles & Riu, 2018).

LIMITATION

The first limitation is linked to the TPACK model used in this research. It is not the only framework used to introduce technology in the education context. Many alternative frameworks have been proposed and established to enable educators integrate technology in the classroom context (Davis & Thompson, 2005). Although all the frameworks have different philosophies, they all coincide on one common issue regarding technology integration to educational practices. However, the TPACK framework widely accepted to analyse teachers' different kind of knowledge and to visualize how application of technology will transform the content, knowledge and change ways in which content is delivered to learners (Davis & Thompson, 2005; Schmidt et al., 2009; Voogt, Fisser, Pareja Roblin, Tondeur, & van Braak, 2013).

In relation to the participant universities, and sample size, the study was conducted in two engineering universities in Bangladesh which had one specific area of knowledge i.e. engineering, and were located in the business division of the country, Dhaka. Besides, 136 respondents are not enough to do deeper diagnostic studies of confirmatory factors (Suhr, 2006). However, many outstanding studies in the literature were found with a smaller sample size (Cubeles & Riu, 2018) compared to our study.

CONCLUSION

This research examines the application of the TPACK framework in Eng. Ed of Bangladesh. It further highlights the knowledge that the university teacher needs in order to introduce and use technology in his/her teaching practice. The verdicts show the significance of refining the development of the core awareness i.e., technology, pedagogy and content so that the interaction between them is further understood in Eng. Ed. Furthermore, it shows that TK in isolation cannot obtain effective technology-enhanced instruction but it compliments conventional PK knowledge. We are optimistic that this study will stimulate more research on the knowledge required by an engineering educator in order to effectively adapt technology-enhanced teaching in developing countries and also further look into how the different attributes of an engineering educator affect the degree of their TPACK. Future researchers should consider tripling the sample size so that a confirmatory test can be carried out. Furthermore, future research could be conducted focusing on extending this study to cover more engineering institutes and also a broader geographical region. Developing a future line of research around adopting TPACK to the attributes of an engineering educator would be interesting. The professional development programs linking with technology integration should be organised based on the findings of this article in Eng. Ed of similar contexts like Bangladesh.

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Appendix A

SD – Strongly Disagree; D – Disagree; N – Neutral; A – Agree; SA – Strongly Agree

Technological Knowledge Section The knowledge and skills of various traditional, current, and emerging technologies used in academic environment					
Question	SD	D	N	A	SA
1. I know how to solve my own technical problems. e.g. connecting a projector to a computer, solving software related malfunction on a laptop like installing an operating system					
2. I can learn technology easily. e.g. using power-point to create a presentation, easily learning to use different tools to write a research paper					
3. I keep up with important new technologies. e.g. any new technology which simplify teaching and learning					
4. I frequently play around with the technology. e.g. use a smartphone to chat, auto cad to draw engineering models, the internet to learn new things.					
5. I know a lot of different technologies, which facilitate teaching and learning.					
6. I have acquired knowledge and technical skills to use technology.					
7. I have had sufficient opportunities to work with different technologies.					
Pedagogical Knowledge Section knowledge about methods (approaches) and process of teaching for achieving desired learning outcomes					
Question	SD	D	N	A	SA
8. I can adapt my teaching based upon what students currently understand or do not understand.					
9. I can adapt my teaching style to different learners.					
10. I can assess student learning in multiple ways.					
11. I can use a wide range of teaching approaches in a lecture room setting.					
12. I am familiar with common student understandings and misconceptions.					
13. I know how to organize and maintain classroom management.					
Content Knowledge Section knowledge about the subject matter (content) for teaching and learning					
Question	SD	D	N	A	SA
14. I have sufficient knowledge about the subject matter that I teach.					
15. I visualize subject matter in different ways.					
16. I have various ways and strategies of developing my understanding of the subject matter that I teach.					
Pedagogical Content knowledge Section The effective way of blending content and pedagogy for developing better teaching practices					
Question	SD	D	N	A	SA
17. I can adapt my teaching based upon what students currently understand or do not understand.					
18. I can select effective teaching approaches to guide student thinking and					

learning in specific content (topic) that I teach.					
19. I can choose suitable teaching approaches (methods) based on subject's content (topic) that I teach.					
20. I know how to create a classroom circumstance to promote students' interest in specific subject area for learning.					
Technological Content knowledge Section The knowledge of media selection (technology) based on the topic that need to be taught.					
Question	SD	D	N	A	SA
21. I know about technologies that I can use to simplify and elaborate on subject matter.					
22. I know about technologies that allow me to represent concepts that would otherwise be difficult to teach.					
23. I know about technologies that allow me to record data that would otherwise be difficult to obtain such as Mat lab					
Technological Pedagogical Knowledge Section The knowledge of the affordances of technologies and what teaching strategies can be combined with those affordances to leverage learning outcomes					
Question	SD	D	N	A	SA
24. I can choose technologies that enhance the teaching approaches for a lesson.					
25. I can choose technologies that enhance students' learning for a lesson.					
26. I think critically about how to use technology in my lecture room.					
27. I can adapt the use of the technologies that I am learning about to different teaching activities.					
Technological, Pedagogical, and Content Knowledge Section Professors' understanding of the interplay among content, pedagogy, and technology, as well as the procedural knowledge of integrating technologies into their teaching routines.					
Question	SD	D	N	A	SA
28. I can teach lessons that appropriately combine the subject matters, technologies, and teaching approaches.					
29. I can select technologies to use in my lecture room that enhance what I teach, how I teach, and what students learn.					
30. I can use strategies that combine content, technologies, and teaching approaches.					
31. I can choose technologies that simplify content for a lesson.					