SCIENCE TEACHING-LEARNING IN ONLINE MODE: A STUDY OF TECHNO-PEDAGOGICAL KNOWLEDGE DEVELOPMENT IN TEACHERS

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Digital Technologies (DTs) are a widely recognised aspect of 21st century skills for teachers. The unprecedented COVID-19 pandemic has forced schools to suddenly close down and shift to complete online teaching. This paper explores the practicalities and reflection of teachers in terms of their confidence in teaching science using various digital technologies during online classes using TPACK framework. The sample constitutes of 81 government and private school science teachers of Delhi NCR (India) and the study used mixed methods approach. The study focused on the four technological dimensions of TPACK i.e., TK, TCK, TPK. It was found that most of the teachers had taken self-initiative to learn and adapt to sudden shift to complete online teaching. Though initially teachers found it daunting and challenging to adapt to completely technology-based teaching, they gradually gained confidence in using various digital platforms in teaching of science. Analysis of the data revealed that increase in teachers' confidence levels was most in TPK and least in TCK. There is positive and moderately high correlation between all domains of TPACK. The findings of this study have implications for professional development programmes which can focus on use of various DTs to support inquiry in science classroom than mere sharing of information.

Keywords: Digital Technologies (DTs), Technological Pedagogical Content Knowledge (TPACK), science teachers.

Introduction

Knowledge and skills of using digital technologies are widely recognised aspects of 21st century teachers. Technology has now moved from being an "accessory" to playing a central role in inquiry teaching. The developments in technology are fast paced and in a short span of time computers have been replaced by interactive phones, mobile technologies, video editing systems, etc., to name a few. This has also led to emergence of internet-based learning systems as the first priority of digital technologies. With the advent of new technologies, science teaching-learning has moved beyond the classrooms and school laboratories to the domains of E-learning portals. However, it is important to understand that digital technology alone would not contribute to the learning process unless it is integrated with content domain and pedagogical knowledge. This study explores the enhancement of digital competencies and skills in science teachers using TPCK or TPACK (Technological Pedagogical Content Knowledge) Framework.

The COVID-19 pandemic in the beginning of 2020 has led to the sudden closure of schools in India and in rest of the world and shifting to online mode of classroom teaching. School education is one of the worst affected areas due to the pandemic (UN 2020, SDG report 2020). Needless to say, science teaching-learning in schools has been

impacted severely as it involves laboratory experiments and hands-on activities. Added to this, is the digital divide, limited availability of devices for online classes, and lack of preparation for conducting online classes and assessment. One entire academic year has passed with many stop-gap arrangements like reduced workload, syllabus, teaching hours, flexible assessment, etc., to mitigate some problems. The teachers' role had been critical in this sudden change from classroom interaction to digital learning or completely online classes. However, teachers have tried to navigate through this crisis by upgrading the much-needed digital skills for online teaching and conducting classes and assessment completely in the online mode for an entire academic year. This paper explores how online teaching and use of DTs has contributed to TPACK development in science teachers.

Theoretical background

The most notable work done in the area of integration of technology with pedagogy and content is by Kohler and Mishra (2006, 2008) i.e., TPACK or TPCK Framework. This framework is an extension of PCK Framework of Shulman (1986). The TPACK Framework has seven distinct domains or categories of teacher knowledge namely Content Knowledge (CK), Pedagogical Knowledge (PK), Pedagogical Content Knowledge (PCK), Technological knowledge (TK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK) and Technological Pedagogical Content Knowledge (TPCK). TPACK Framework is a flexible framework for teacher education and research purpose and can be used for developing teacher readiness for 21st century skills (Fig & Jaipal, 2012; Koehler et al., 2011) and is suitable for various pedagogical orientations (Brantley-Dias & Ertmer, 2013).

Initial research in the area of TPACK in teacher education (in-service and pre-service) focused mostly on technological literacy (Jang & Tsai, 2013) and gradually moved into the integration of technology in PCK components. Review also indicates that high PCK levels increases TPACK confidence (Jang et al., 2010). Studies also focused on effect of training and contexts on confidence and self-efficacy in TPACK (Graham et al., 2009; Voogt 2014), perceptions and self-efficacy (Kiray et al., 2018) and influence of context on TPACK levels of teachers (Owusu, 2015). Studies focusing on technological components of TPACK revealed that self-confidence of teachers was varied in various dimensions. For instance, Graham et al. (2009) found that after intervention, the confidence of teachers ranked from highest to lowest in TK, TPK, TPACK, TCK and in studies based on self-efficacy (Voogt, 2014), the greatest increase in self efficacy was in the order of TCK, TPACK and TPK. Research in the area of TPCK in science education has indicated that digital technology can be used in variety of ways like simulating and modelling science experiments, data collection and manipulation (McCrory, 2008), enhance scientific inquiry (Novak & Kracjick 2006), problem solving (Niess et al., 2009), collaboration and communication skills (Keong et al., 2005). By integrating technology in pedagogical design and specific content domain, teachers not only gain knowledge of content and pedagogy but also engage in dialogue and collaboration (Koehler et al., 2011).

Hence the review of literature indicates that several tools have been constructed to assess TPACK in science teachers. However, there is dearth of literature on research done to assess development of TPACK in the contexts of complete online education. In a recent study, Pareto and Willmark (2019) recommends a need to investigate how TPACK can be developed within practice teaching or teaching context and argues for TPACK development in specific situation and contexts rather than generally addressing. This study explores development of TPACK of science teachers in Delhi in the context of online teaching by using TPACK framework and focused on enhancement of confidence levels in using digital technologies.

As mentioned before, the TPACK framework consists of seven dimensions. However, this study focusses on four components or dimensions namely TK, TCK, TPK and TPACK as the focus is on use of digital technology for effective science teaching during pandemic induced online education. Here, Technological Knowledge (TK) refers to teachers' knowledge and understanding of various software and digital tools. Technological Pedagogical Knowledge (TPK) refers to teachers' knowledge of impact of a particular technology on the pedagogy and Technological Content Knowledge (TCK) refers to the knowledge of suitable technologies to integrate with specific content. The last dimension TPCK or TPACK refers to knowledge of how technology, pedagogy and content relate to each other and strategic use of technology in a particular context. This knowledge is 'dynamic and adaptable as per the needs of students and teaching context' (Mishra & Koehler, 2006).

Research Focus

As mentioned previously, the use of technology in science teaching-learning is widely recognised as important aspect for promotion of scientific inquiry. In the Indian context, teachers have been using various digital technologies like web-based resources, simulations, interactive white boards, power point presentations, assessment strategies like quiz, etc., in science classrooms and laboratories in schools. However, most of the time the choice was with the teacher as to when and what to use. Apart from the textbook transaction through lectures, the hands-on activities, laboratory activities, demonstrations etc., were part of dominant discourse of science teaching. Digital technologies were mostly used to supplement classroom teaching. However, the sudden shift to online classes in schools and universities in India has put the use of digital technologies to the forefront. Those teachers who were novice to technology had to adapt suddenly to this mode. Even the teachers who were familiar with digital technologies had to adapt them to suit to online classes and students who do not have access or have limited access to digital devices. Informal conversations with teachers revealed that this entire experience had been 'learning while teaching'. Some teachers shared that they did some activities and demonstrations at home and shared the videos to explain science concepts. Teachers tried to innovate within the digital constraints.

So, in the process, many teachers have learnt new skills and gained confidence in using digital technologies effectively. Hence, one can say that the pandemic had created a context to learn, explore, adapt and adopt new skills of using digital technologies. This

study focusses on this aspect of enhancement of confidence levels in using various digital technologies in science teaching-learning and how it had contributed to the development of TPACK in teachers. The study has implications for further professional development of teachers and how science teaching-learning can take place more effectively in future in online or blended mode. Hence the following research questions formed the premise for this study.

1. How has online teaching contributed to development of TPACK in science teachers?
2. What are the confidence levels of teachers in using various digital technologies in science online teaching in the four domains of TPACK i.e., TK, TCK, TPK and TPCK?

Methodology

This study was conducted in Delhi NCR in India and used mixed methods approach. The following sections discuss the methods and materials used for data collection and analysis.

In order to understand the ground realities of online teaching in the schools , five government school science teachers (mentor teachers) and five private school science teachers were interviewed. For this purpose, mentor teachers and coordinators who were actively involved in mentoring were chosen. The government school teachers were mentor teachers who were coordinating with a number of schools in that particular district and private school teachers were coordinators or senior teachers in their schools. Telephonic interviews using semi-structured questionnaire were conducted. The interaction helped to get an insight into the various school activities pertaining to teaching-learning and assessment in general and science in particular, during online mode of teaching. This was followed by the second stage which involved data collection from 81 science teachers of Delhi NCR. The following section describes the development of tool, sample and methodology.

Tool: A lot of research has been done in designing a psychometrically sound tool or questionnaire to measure various dimensions of TPACK, both in areas of pre-service and in—service teacher education. Some of them are original TPACK by Koehler and Mishra (2008), SPTKTT by Schmidt et al. (2009), Chai, Koh and Tsai (2013), Bilci et al. (2013), Valtonen et al. (2017). Some of these questionnaires measured all dimensions, whereas some like Valtonen et al. (2017) measured only dimensions related to technology i.e., TK, TPK, TCK and TPACK necessary for 21st century teaching skills. Some questionnaires were designed to gauge the confidence and self-efficacy of pre-service/in-service teachers, whereas others gauged their knowledge in these domains. Review of these tools by keeping in mind the research questions helped to frame a questionnaire to collect data from in-service science teachers. The questionnaire also consists of adapted version of few items from the literature review of standardised tools focusing only on TK, TPK, TCK and TPACK. The questionnaire had total 30 items divided in four sections as TK (10 items), TCK (5 items), TPK (10 items) and TPCK (5 items). All the questions were based on a five-point rating scale. The teachers were asked to rate their confidence levels ('not at all confident' to 'completely confident') in using

various digital technologies in the TPACK framework as compared to their experiences prior to the sudden shift to online teaching. There was also one open ended question seeking the information about the challenges and difficulties experienced by the science teachers. The reliability of tool was statistically tested and Cronbach's alpha came out to be 0.951. As it is greater than 0.7, the tool was found to be reliable. The questionnaire was anonymous and was circulated through Google Docs Link.

Sample: The final sample consists of 81 science teachers of both Private and Government schools in Delhi NCR in India. Snowballing sampling technique was used. Teachers who were using only WhatsApp medium to teach or sending notes and worksheets were not considered in this study. Perhaps due to this reason, the sample of government school teachers is less than private school teachers. Only those teachers were considered who were willing to participate in this study voluntarily and reflect on their experience of online teaching. The teachers were assured of complete anonymity and that the data no way reflects their professional competencies and will not be shared with any administrators. Table 1 represents the demographic profile of the sample.

Table 1: Sample Profile

Gender	Male Teachers	11.1%
	Female Teachers	88.9%
Age Group	20-40 years	36%
	Above 40 years	64%
Type of School	Government school	35.8%
	Private school	64.2%
Qualifications	Graduation	7.4%
	Post-Graduation	75.3%
	M.Phil./Ph.D.	17.3%
Teaching Experience	Less than 5 years	6.4%
	5 to 15 years	37%
	15 to 25 years	32.1%
	More than 25 years	24.5%

Statistical analysis of the data was done using SPSS and an attempt was made to triangulate the quantitative data with qualitative data emerging from interviews and open-ended question of the questionnaire

Results and Discussion

Analysis of interviews with the government school mentor teachers and private school teachers gave insight into how the online teaching of science was carried out in most schools. The government teachers shared that science teachers in each district were connected in groups through messenger platforms like WhatsApp. Few expert teachers used to share videos of their own experiments and demonstrations. Few sessions on use of basic digital technologies were organised by calling resource persons. The mentor teachers also shared that the resources like videos, presentations, worksheets in some topics were posted for teachers. Also, some teachers were asked to record their teaching of lessons in the school setting and these

recordings were shared within the group of teachers. Teachers were allotted topics on rotation basis. These videos were also shared with students so that they can study at their convenient time. As compared to private schools, the frequency of online live classes was less in government schools as many students in government schools were not able to attend classes due to lack of devices at the time of teaching. Also, teachers shared that resources from DIKSHA portal were used. The private school teachers shared that they used apps like 0-LABS for simulating experiments. Companies like Edumart were invited to conduct sessions (one or two only were conducted per subject). Teachers also used YouTube videos and self-made presentations extensively. For making questionnaires and assessment they used CBSE test generator, Microsoft and Google forms, quiz apps.

The analysis of data emerging from questionnaire given 81 teachers regarding using digital technologies in science classrooms in the various domains of TPACK is discussed in the following paragraphs.

Technology Knowledge (TK): Technology Knowledge (TK) broadly refers to "the understanding of application and limitations of various technologies and skills to use them efficiently". It also encompasses the interest of teachers in keeping up with new technologies. Keeping these in mind, ten questions were framed to understand science teachers' knowledge of digital technologies and confidence in using them during online classes. Teachers were asked to rate their confidence level compared prior to the online classes on a five-point rating scale. Regarding basic pre-requisites of technological knowledge, majority of teachers (67.5%) are completely confident and 26 per cent are quite confident in searching website for information. 81 per cent have become completely confident in saving an image from website. Other aspects in which teachers have become quite confident are keeping up with new technologies, taking and editing a digital photograph and 56 per cent have become completely confident in creating documents with graphics. In other technological skills like producing a video clip, use of blogs and podcasts, the confidence levels are less than previous aspects as only 17.5 per cent are completely confident in producing videoclip and 21 per cent have gained complete confidence in using blogs etc. One area in which majority of teachers have not become confident is in creating own websites, blogs, YouTube channels, etc., as only 9 per cent are completely confident and hence needs training. Figure 1 illustrates the confidence levels of teachers in various aspects of TK. The increase in confidence levels can be attributed to the fact that many of them were involved in active learning while teaching. One teacher shared that "Everything was challenging initially as I had no exposure to any online medium except sending email, typing question paper and entering marks. But in this one year, I have learnt so much as it was need of the hour".

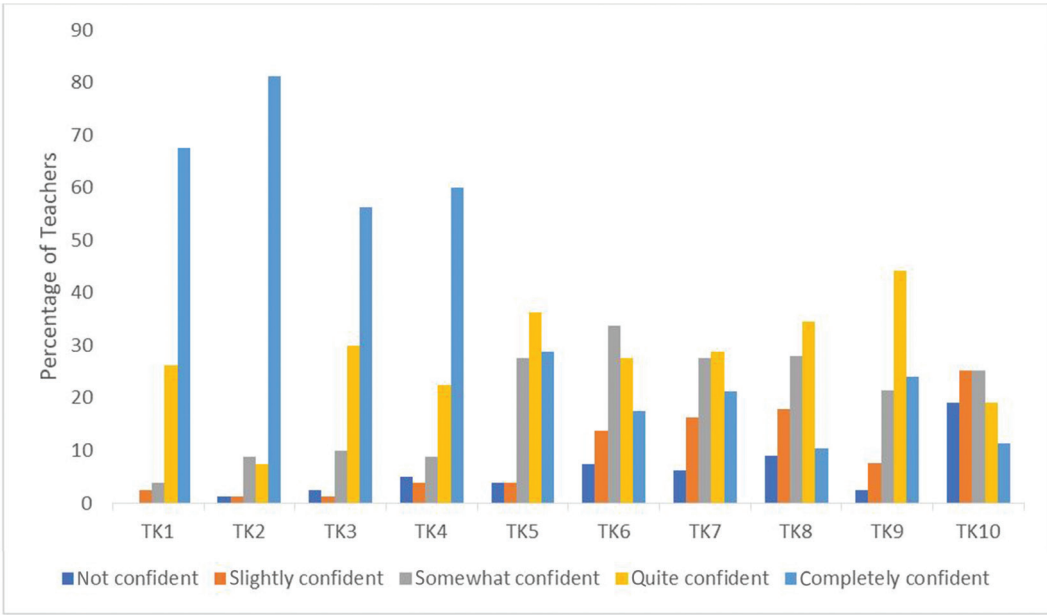

Fig. 1. Aspects of Technological Knowledge (TK) Dimension

Table 2: Mean Scores in various aspects of Technological Knowledge (TK) dimension

Item	Aspect	Mean Score	SD	Government school teachers		Private School teachers		p-value
				Mean	SD	Mean	SD	
TK 1	Search website for information	4.58	0.69	4.46	0.92	4.65	0.51	0.242
TK 2	Save image from website to documents	4.66	0.79	4.14	1.11	4.94	0.30	0.002*
TK 3	Create document with graphics	4.36	0.90	3.92	1.15	4.59	0.63	0.001*
TK 4	Create PPTs with visuals and graphics	4.28	1.10	3.71	1.35	4.59	0.79	0.00*

TK 5	Take and edit digital photographs	3.82	1.02	3.57	1.25	3.96	0.83	0.102
TK 6	Produce and edit video clip	3.34	1.15	3.25	1.32	3.38	1.05	0.620
TK 7	Using blogs, podcasts, etc.	3.42	1.18	3.28	1.43	3.5	1.01	0.441
TK 8	Troubleshooting ICT related problems	3.19	1.13	2.96	1.33	3.31	1.04	0.194
TK 9	Keeping up with new technologies	3.80	0.98	3.71	1.04	3.84	0.94	0.579
TK 10	Create own website, blogs YouTube channel etc.	2.78	1.28	2.67	1.33	2.84	1.25	0.587
		3.80	0.74					

*Significance level at 0.05 assuming equal variance

In order to know the differences between responses of government and private school teachers, the data was subjected to two-tailed t-test using SPSS package. It is found that at significance level of 0.05 assuming equal variances, there is no significant differences between the responses of the two sets of teachers except in three area represented by items TK 2, TK 3 and TK 4 (Table 1). These areas in which there is significant difference in the responses between government and private school teachers in creating documents with graphs, creating presentations with visual effects. The mean scores of private school teachers are higher than government school teachers and this may be attributed to the reason government school teachers were mostly using videos and resources from the common pool or repository of resources created as shared by the mentor teachers in the interviews while private school teachers were creating their own resources.

Technological Content Knowledge (TCK): The next set of items focused on teachers' TCK. TCK refers to "the teachers' knowledge about various technologies which are used within the content and understanding of the connection between content knowledge of the subject and technology. Integrating technology with the content effective knowledge and using some of the technologies and applications used by scientists and professionals, using technology for data collection and analysis and modelling scientific phenomenon using technologies are some aspects which comes under the domain of TCK. Teachers were asked to rate their confidence levels

in these aspects during online teaching as compared to their experiences of pre-pandemic classroom teaching. Majority of teachers (41%) have expressed that they are completely confident in integrating digital technologies with content successfully. Majority of teachers are somewhat confident (35%) and quite confident (30%) in using digital technologies and applications used by scientists and other science professionals like advance programming softwares, simulations, virtual lab activities, etc., and modelling scientific phenomenon either using simulations or programming and only 16 per cent have gained complete confidence in this area. However, only 8 per cent of teachers have become completely confident and 26 per cent somewhat confident in modelling scientific phenomenon. This implicates need of training workshops specifically in the area of modelling scientific phenomenon. Using digital technologies to demonstrate science experiments as using virtual lab activities is very important in the online teaching especially in the absence of opportunity of real experimentation in the laboratories. As shared by private school teachers in the interviews, many teachers have used O-LABS for simulating experiments (example shared was demonstration of Ohms' law). Also, teachers use videos created by publication companies (examples given were Pradeep classes, H.C. Verma, etc.) to explain the concepts and expressed that they were able to integrate successfully. The responses of teachers in TCK dimension are represented in Figure 2.

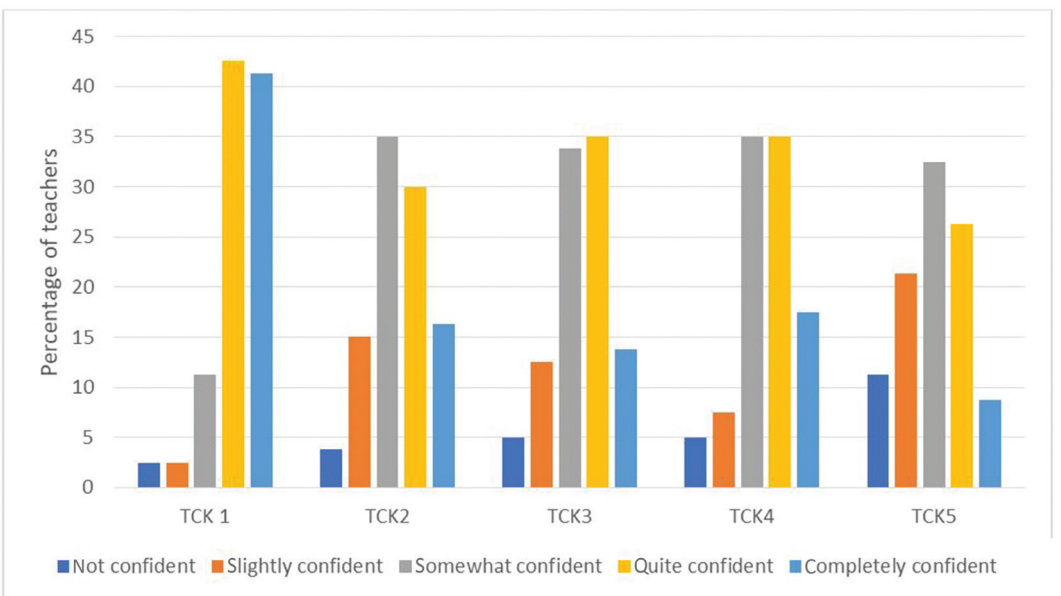

Fig. 2. Aspects of Technological Content Knowledge (TCK)

Table 3: Mean scores in various aspects of Technological Content Knowledge (TCK) Domain

Item	Aspect	Mean	SD	Government school teachers		Private school teachers		p-value
				Mean	SD	Mean	SD	
TCK 1	Integration of content	4.17	0.91	4.14	1.04	4.19	0.841	0.819
TCK 2	Using digital technologies used by scientists and professionals	3.40	1.05	3.35	1.17	3.50	0.988	0.536
TCK 3	Using applications by professionals	3.40	1.04	3.37	1.13	3.46	0.991	0.667
TCK 4	Using technologies for data collection	3.52	1.03	3.52	1.38	3.54	0.980	0.946
TCK 5	Modelling scientific phenomenon	3.00	1.14	2.98	1.2	3.04	1.11	0.838
		3.5	0.88					

In order to know the differences between responses of government and private school teachers, the data was subjected to two—tailed t-test using SPSS package (refer Table 3) and it is found that at significance level of 0.05 assuming equal variances, there is no significant differences between the responses of the two sets of teachers.

Technological Pedagogical Knowledge (TPK): TPK refers to teachers' knowledge and understanding of the nature of teaching-learning on integrating with technology and choice of pedagogical practices which amalgamate suitable technologies. So, in order to understand teachers' confidence levels and self-efficacy in using digital technology for effective pedagogy, classroom management, assessment, 10 items were posed. Majority of teachers expressed increase in confidence levels in using digital technologies during online science classes for effective communication (65%), class management (78%), assessment (73%), effective presentation of topics (78%) and for motivating students (75%). However, in the open-ended questions, majority of teachers also expressed these aspects as challenges.

Analysis of open-ended question on challenges faced reveals that high absenteeism, lack of eye contact, effective feedback mechanism,

and less scope of personal interaction were issues faced by majority of teachers. The responses of teachers in TPK dimension are represented in Fig. 3. Majority of teachers have expressed increase in confidence levels in engaging students in collaborative work, problem solving and 44 per cent are somewhat confident in using ICT for promoting critical thinking as group projects were given to students. However, only 27.5 per cent are confident in thinking critically the choice of technology in science classroom. There are still quite a number of teachers who have to gain more confidence in using technology in these areas (Refer Fig. 3). Majority of teachers also expressed gaining confidence in choice of tools for effective classroom transaction, indicating that teachers have spent a lot of time in exploring various tools of digital technologies for their teaching.

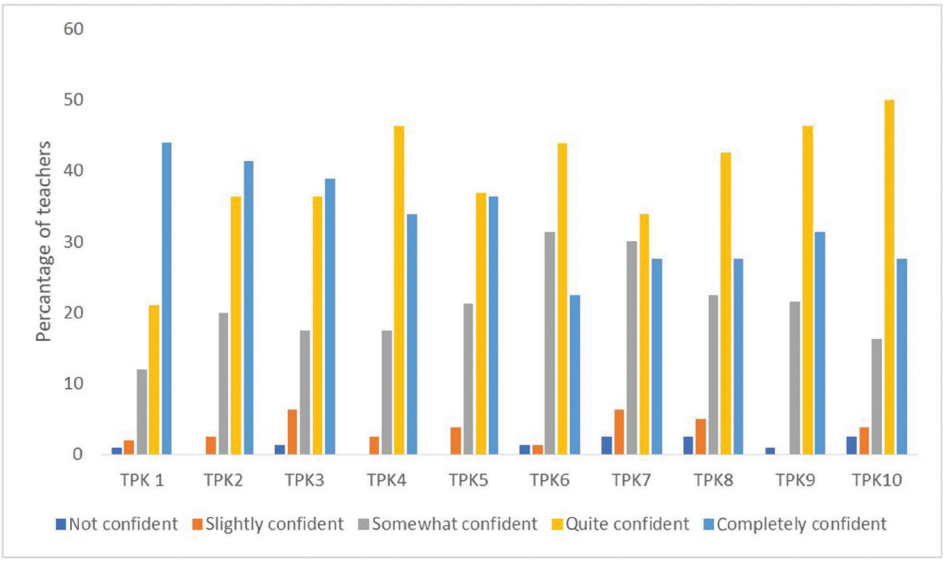

Fig. 3. Aspects of Technological Pedagogical Dimension (TPK)

Table 4: Mean scores in various Aspects of Technological Pedagogical Knowledge (TPK) Dimension

Item	Aspect	Mean	SD	Government school teachers		Private school teachers		p-value
				Mean	SD	Mean	SD	
TPK1	Using DTs for effective communication	4.30	0.91	4.00	1.12	4.48	0.727	0.023*
TPK 2	Using DTs for effective class management	4.16	0.83	4.04	0.92	4.23	0.78	0.321

TPK 3	Using DTs for motivating students	4.05	0.97	3.82	1.12	4.17	0.85	0.121
TPK4	Effective presentation of content	4.11	0.78	3.93	0.98	4.21	0.64	0.122
TPK5	Using STs for assessment	4.07	0.85	3.96	1.04	4.13	0.74	0.398
TPK 6	Use of DTs to promote critical thinking	3.85	0.83	3.82	0.98	3.87	0.74	0.823
TPK 7	Use of DTs for collaborative work	3.77	1.01	3.68	1.05	3.83	0.98	0.533
TPK 8	Promoting DTs for problem solving	3.87	0.96	3.79	1.03	3.92	0.92	0.545
TPK 9	Enhance pedagogy	4.06	0.80	3.96	0.96	4.12	0.70	0.424
TPK 10	Critical choice of DT tools	3.96	0.91	3.89	0.99	4.00	0.86	0.617
		4.00	0.75					

*Significance level at 0.05 assuming equal variance

In order to know the differences between responses of government and private school teachers, the data was subjected to two-tailed t-test using SPSS package. It is found that at significance level of 0.05 assuming equal variances, there is no significant differences between the responses of the two sets of teachers except in item TPK 1 i.e., for effective communication (refer Table 4). Here the mean scores of private school teachers are significantly higher than government school teachers and reason may be ascribed to more digital divide in government school students. Due to this, communication between teachers and students during the class may be hindered or not taking place much. This is supported by the qualitative analysis of open-ended question seeking information on challenges faced where majority of teachers have shared that lack of devices for the students or sharing of devices within family is a major issue during online classes.

Technological pedagogical content knowledge (TPCK): Next set of questions addressed teachers' TPCK which refers to their understanding about integrating content knowledge with pedagogical and

technological knowledge. In this all the three domains i.e., content, pedagogy and technology are integrated for meaningful and effective learning in science.

Majority of teachers have gained confidence in using digital technologies in — engaging learners in scientific inquiry 33 per cent have become completely confident and 38 per cent somewhat confident in using online simulations for demonstrating scientific principles and activities. Though majority of teachers said that they have become confident in identifying and addressing learners' misconceptions, they may be referring to the conceptual understanding as most of them were using MCQs for assessment. In facilitating science activities in the online mode ,no one is completely confident whereas 42.5 per cent are quite confident. The responses of teachers are represented in Figure 4.

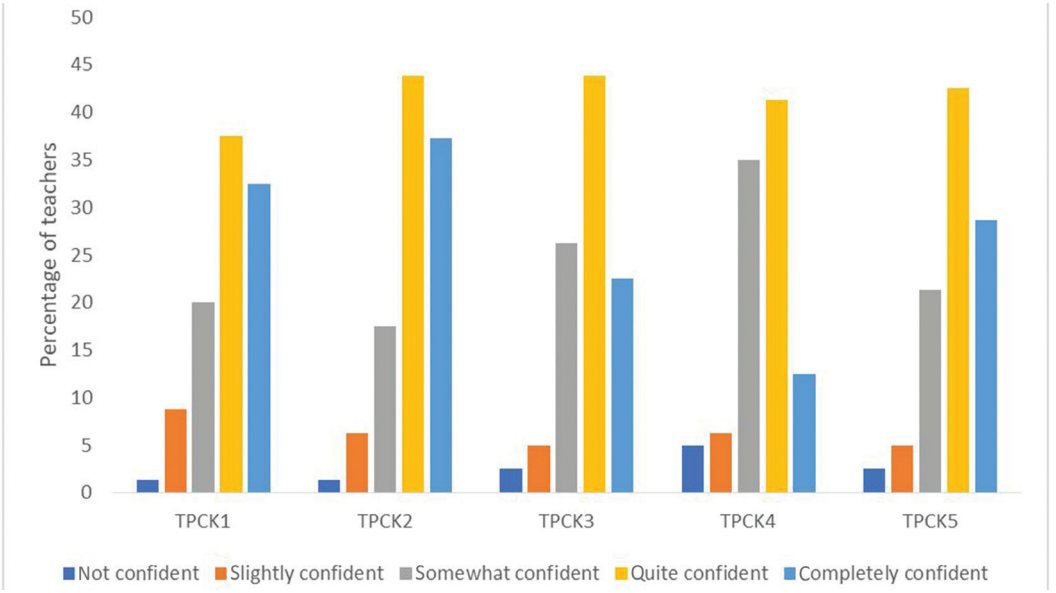

Fig. 4. Aspects of Technological Pedagogical Content Knowledge (TPCK) Dimension

Table 5: Aspects of Technological Pedagogical Content Knowledge (TPCK) Dimension

Item	Aspect	Mean	SD	Government school teachers		Private school teachers		p-value
				Mean	SD	Mean	SD	
TPCK 1	Using DTs for demonstration of scientific principle	3.91	1.0	3.68	1.18	4.04	0.86	0.132
TPCK 2	Using web resources for identifying and addressing misconceptions	3.97	0.93	4.0	1.08	3.96	0.84	0.861

TPCK 3	Using DTs for facilitating scientific inquiry	3.79	0.94	3.86	1.01	3.75	0.91	0.629
TPCK 4	Using DTs for Modelling scientific phenomenon	3.50	0.97	3.68	1.02	3.40	0.94	0.228
TPCK 5	Using DTs for facilitating science activities	3.90	0.96	3.89	1.03	3.90	0.94	0.962
		3.8	0.83					

In order to know the differences between responses of government and private school teachers, the data was subjected to two-tailed t-test using SPSS package. It is found that at significance level of 0.05 assuming equal variances, there is no significant differences between the responses of the two sets of teachers in any aspect of TPCK (refer Table 5).

Associations between various domains of TPCK

In order to find out the correlations between various domains of TPACK, the data was analysed using SPSS and correlation coefficients are depicted in the Table 6.

The analysis reveals that there is positive and moderately high correlation between various dimensions of TPCK indicating that technological knowledge, technological content knowledge has effectively translated into and technological pedagogical content knowledge.

Table 6: Correlation between various domains of TPACK

		TK	TCK	TPK	TPCK
TK	Pearson Correlation	1.00	0.72	0.75	0.72
TCK	Pearson Correlation		1.00	0.72	0.78
TPK	Pearson Correlation			1.00	0.76
TPCK	Pearson Correlation				1.00

Correlation is significant at the level 0.01 (2-tailed)

Conclusions and Implications

This paper explored the practicalities and reflection of teachers in terms of their confidence in teaching science using various digital technologies during online classes. This study found that teachers, though initially found daunting and challenging to adapt to complete technology-based teaching, gained confidence in using various digital platforms in teaching of science. Most of the teachers had taken self-initiative to learn and adapt to sudden shift to complete online teaching situation created by the COVID-19 pandemic. The study focused on the four technological dimensions of TPACK i.e., TK, TCK, TPK and TPCK and analysis reveals that increase in teachers' confidence levels is most in TPK and least in TCK. This implicates that teacher were confident in using and integrating various pre-prepared digital technologies in their classroom pedagogy but need to enhance their technological content knowledge i.e., knowing more about advanced DTs like data collection and modelling tools for scientific inquiry. There is positive and moderately high correlation between all domains of TPACK. It is also found that "learning communities" created seems to have positive impact on teachers' using of various DTs and continuous support is needed to overcome inhibitions and challenges.

The findings of this study have implications for professional development programmes which can focus on use of various DTs to support inquiry in science classroom than mere sharing of information. Bell and Gilbert' Model (2004) which focus on collaboration among the teachers for effective professional development can be designed in more sustained manner.

The professional development programs and in-service training workshops need to focus on integrating technology for scientific inquiry and empower teachers to use advance technologies for simulations, virtual lab activities, data collection and modelling of science phenomenon.

This study is significant in terms of using DTs in science teaching in authentic context i.e., when teaching is completely based on extensive and continuous use of online medium rather than an occasional or additional use as accessory. The pandemic has created a new 'world view' in education (Tsybulsky and Levin 2019) of integrating novel technologies in learning and it cannot be successful without teachers' beliefs and confidence in adapting to digital technologies for not merely to sharing of information but rather for more inquiry driven science discourse in classrooms.

Limitations and Scope for Further Research

This study focused only on teachers' perspective and gain in their confidence level in using various digital technologies in science teaching. The study did not involve an in-depth comparison between the government and private school teachers on various aspects of TPACK and reasons for it. Further studies can be undertaken to assess the effectiveness of various technology-driven online classes on students' understanding of science concepts, their attitudes and motivation. Action research studies on the basis of reflection of teachers can also be undertaken. Research is needed in terms of teacher preparedness for blended learning models in the future. NEP 2020 also emphasises on digital literacy and digital

integration in curriculum and pedagogy. Future researches can focus on teacher and institutional preparedness for this. As digital divide has been quoted by majority of teachers as big challenge and hindrance for successful integration of technology, further research is needed in this area for successful initiatives to overcome digital divide for an unhindered learning. As this study focused only on school teachers in cosmopolitan area of Delhi NCR, further research is needed to gain insights about the use of digital technologies for science teaching and teacher preparedness in rural and semi-rural areas.

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