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Revisiting Challenges and Issues in ICT Integration in Science Education: A Qualitative Study

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Abstract
The multiple modes of presentation strengthen ICT's usability in teaching and learning process. As science deals with observations, experiments, and natural phenomena, often, it becomes difficult in schools to record observations and conduct experiments in natural settings due to hazardous laboratory conditions, limited resources, time, and risk involved. ICT helps in science teaching to counter all the issues. therefore, it has gained momentum in science education. Nevertheless, there are many impediments in using ICT in science education. In this paper, the researchers conducted a study on school science teachers and teacher educators to report: (1) their views on using technology for science teaching, (2) the availability of technological tools in their schools and institutions, (3) their perceptions towards administrative support for using ICT, (4) their views on the scope of training in technological skills in existing teacher training curriculum, and (5) their awareness about technology integration as per the recommendations of NEP 2020. The paper gives comprehensive recommendations for further research in this direction and significant implications for ICT integration in science education.

Keywords*: ICT, NEP 2020, Science Teachers, Teacher Educators, Pedagogy of science*

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I. Introduction

Since times immemorial, the imaginative mind of human beings always has observed wonder and awe of nature, viz., physical and biological phenomena in the ecosystem, and they attempted to draw out the meaningful patterns and relations that help them to interact with nature and develop a conceptual understanding of the phenomenon. This endeavour is called science. However, science comprises empirical-based observations. At the time of C.V. Raman, Jagdish Chandra Bose, James Watt, and Michael Faraday, information about natural phenomena was directly experienced through the senses, which was very limited in understanding the mystery of this world and universe. Since then, there has been remarkable development in technologies from the first industrial revolution to the fourth industrial revolution that has transformed science, viz., revolutionizing the way of observation, data collection, and performing experiments. Now, technology has matured to the extent that it makes us feel wonderful experiences and opens new dimensions of learning.

Pentode, floppy, Punch card, and Cathode Ray Tube monitors have evolved in such a way that these are not limited only to professional users. Instead, Interface between technology and user have become compatible that facilitate seamless interaction with technology. Artificial Intelligence, Virtual Reality, Augmented Reality, and Web 2.0 have indeed elevated the quality of experiences of human beings. Hence, AI gadgets and the internet are indispensable components of the human ecosystem and that is why Railways, Banks, and Tourism industries are leveraging the latest technologies. In fact, online banking, online bookings of tickets, e-mails, biometrics etc are the examples of these latest technologies.

Along with this, schools are also leveraging technology for instruction, assessment, and creating portfolios. It became necessary for schools to create a link between learning in the schools and life outside of the schools (NCF, 2005). So that prospective human resources in the school will be techno-savvy and able to adapt to the changing technological world. However, technology has not been used as appropriately in the schools as it is used in other fields. After considering the benefits of technology in school education, NEP 2020 emphasizes the leverage of technology while acknowledging its limitations. Certain key areas have been identified by NEP 2020 for the equitable use of technology as mentioned in the following table:

Table 1: **Areas Identified in NEP 2020**

S.No.	Areas
1	Digital infrastructure
2	Content creation
3	Virtual labs
4	Training of teachers
5	Digital repository
6	Addressing digital divides
7	Laying down standards

Because of the use of technology, the 21st century students are different than 20th century students in their outlook, likings and interests. As a result, the contemporary ways of learning differ significantly from earlier, and this focuses on skills development. Today learning takes place through the amalgamation of technology with plays, toys, stories, field trips, conversations, music, and arts. The combination of whiteboards, projectors, audio system, and internet connectivity make smart classroom. The environment in smart classrooms creates new approaches to teaching and learning, such as Blended learning models and Flipped classrooms. In this technological environment, teachers can facilitate learning and manage the classroom environment effectively. Therefore, knowledge for the effective use of technology has become an essential factor in becoming a 21st-century educator (Savec, 2020) to improve the teaching learning process, assessment, educational planning and functioning and management of educational institutions.

Technologies which are used for dissemination of information and communication are called Information and Communication Technology. ICT is the combination of software, hardware, and internet-based applications. These wide ranges of tools give teachers various opportunities for ICT intervention in science classrooms that can be used to improve science learning. As the teaching-learning process includes various stages. hence, it requires stage-specific ICT intervention (Medh, 2020). ICT use has been continuously increasing in education since COVID-19, though before, it was limited to manufacturing, construction, the film industry, and transportation. This, in turn, has a significant impact on education (Sarvan kumar, 2018), and now ICT has become an indispensable part of the education system, and traditional education has been transformed into digital education (Jie & Sunze, 2023). ICT could not itself bring changes in education; we as science teachers must consciously analyze how and when to use ICT in science classrooms appropriately.

II. Review of Related Literature

Integration of ICT in education is a challenging task (Viberg et al. 2023). Most of the time, teachers face difficulties in teaching with ICT tools because they do not know how to synthesize ICT in their instruction. Although science teachers do not have any challenge to integrate mobile technology in pedagogy of science but pedagogical roles, learning flexibility and psychological anxiety are key challenges for them (Jie and Sunze, 2023). Teachers have consented to the advantages of ICT in education but also agree with the issues and challenges with them (Paul et al., 2023). Studies conducted on challenges and issues in using ICT in education found that schools and institutions have insufficient infrastructure for effective use of technology such as poor electricity, poor internet connectivity, and lack of computer devices, and improper installation of Wi-Fi network. Digital technologies are very costly, so the institutions are unable to purchase them. Even if they buy tools, then their maintenance becomes difficult in the absence of maintenance funds. Therefore, it is difficult for schools or institutions to cope with continuous innovations in technology (Disruptive Technologies), which are highly costly to earlier technologies.

Even if the schools and institutions install technologies, then teachers are incapable to use technologically effectively because they are not familiar with software and hardware. There are so many barriers in the way of effective integration of ICT in science education. Bingimlas (2009) analyzed these barriers into four categories which are shown in the following Table 2

Table 2: Categories of Barriers

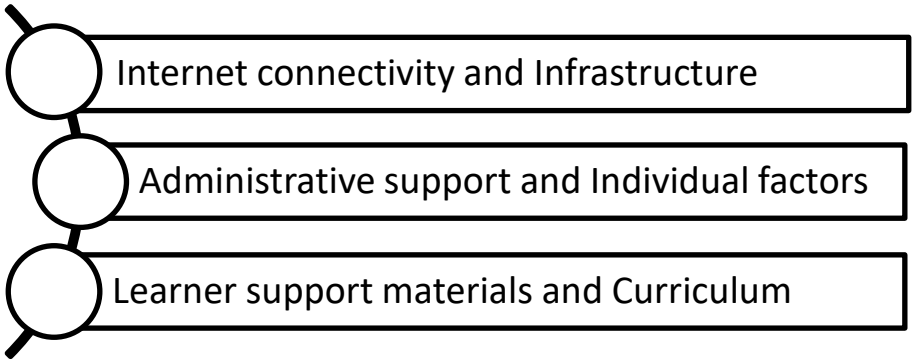
Extrinsic Barriers	Intrinsic Barriers	Teacher level Barriers	Students level Barriers
❖ Access ❖ Time ❖ Support ❖ Resource ❖ Training	❖ Attitudes ❖ Beliefs ❖ Practices ❖ Resistances	❖ lack of time ❖ Resistance to change ❖ lack of confidence	❖ Lack of access of resources ❖ Lack of effective training in solving technical problems

Similarly, Kibirige (2023) found a lack of institutional support and a lack of EdTech organizations (service providers in designing, developing, and maintaining educational software) which makes technology weird, the teachers become frustrated and demotivated. Students also lose their motivation due to poor in-person interaction and abundant disturbances.

In some studies teachers admitted that they face challenges in accessing ICT tools, they have poor skills, there is inequality in the availability and poor quality of ICT tools in the schools (Karunakaran et al., 2023 and Okoed, 2023). These studies further reported other barriers, such as rigid rules and regulations, pressure of completing syllabus in time, and lack of transition time in between successive periods.

Hence, on the basis of the above review the researchers summarise these barriers in the following three main categories:

Table 3: Barriers to Integration of ICTs



However Indian conditions are different in so many ways and NEP 2020 also has pointed out the challenges which have been mentioned in the aforementioned paragraphs. Therefore, an empirical study is required to know about those barriers so that we may find the solutions accordingly.

Purpose of the study

There is a reasonable amount of literature available on the barriers to the integration of ICTs in education. However, there were few studies that look at barriers, particularly in science education. This leads to administrators and teachers to rethink on teaching methods, and their role in technological environment (Sarvan Kumar 2018). However, new researchers have progressively been trying to fill the gap by analysing the features of particular ICT in particular science topics. This paper attempts to consider the barriers identified in the literature review and aims to discuss them with the science teachers and faculties who teach the pedagogy of science. Specifically, the study aimed to explore the problems faced by science teachers and faculties in integrating technology in science teaching, their knowledge of ICT, their views on the utility of technology in the classroom, and comments on the recommendation of NEP 2020. The researchers intended to answer the following research questions:

1. What are the challenges and issues in using technology in teaching of science?
2. How does administration (school or institution) facilitate in promoting effective use of ICT in science classroom?
3. Does the school have adequate facility to implement ICT in science teaching? If yes what are these? If not, what should be done?
4. Is the policy recommendation being implemented in using ICT in science teaching? If yes how it is being implemented? If not, what could be the reasons?
5. Is the curriculum of teacher training effective for developing skills for fusion of pedagogical and technological skills?

III. Methodology

In the qualitative study, phenomenological design was employed to explore the views of teacher educators and secondary school science teachers regarding the challenges and issues with integration of ICTs in science education and what are their experiences of using ICT in teaching and learning process. The phenomenological studies focus on experiences of individuals (Flynn and Korcuska, 2018) and search for the general essence related to the context (Best and Kahn, 2016). The study aimed to dive insight into the challenges and problems faced by teacher educators and Science teachers on integrating ICT into science teaching therefore, interview technique was used to collect the data.

The Study Group

Teacher Educators and Secondary School Science Teachers from Aligarh district of Uttar Pradesh constituted the population of the study. The purposive sampling method was adopted by researcher to select the sample from the population (Patton, 2002). This technique is suitable in selecting those participants who provide richest information (Best and Kahn, 2016). The sample made up of 12 Teacher Educators and 10 Secondary School Science Teachers working in government-funded colleges/universities and schools respectively in the Aligarh district of Uttar Pradesh. On average the teacher educators had 10 years of teaching experience in B.Ed. institutions and Science teachers had 15 years of experience teaching in government senior secondary schools.

Standardized open-ended Interview

In the study, interview was highly focused on the issues. Therefore, to minimize the variations among interviewer responses standardized open-ended interviews were conducted (Patton, 2002). The five open-ended questions were framed to gather information about the views of teacher educators and science teachers on the Information and Communications technology in science teaching. The participants were interviewed, and the researchers recorded the interviews if the respondent were willing to do so. Each participant received an average of forty-five minutes of time.

Data Analysis

In the data analysis first of all the interviews were transcripted. The transliterated text was considered as unit of analysis. The transliterated texts were read again and again to cluster the ideas under the theme. Researcher counted reoccurrence of the participants expressed ideas, grouped into categories as a result of the analysis of the data. After that, Researcher coded the sub-themes by tagging the transcripts and each sub-themes were coded to themes.

IV. Results

As a result of data analysis, five themes were generated to understand the challenges of integration of ICTs in science teaching. which are: administrative support for the integration of ICTs in science teaching, significant challenges in using ICTs in the pedagogy of science, availability of adequate facility in the schools to implement ICT in science teaching, the implementation of policy recommendations for promoting ICT in science teaching, and the effectiveness of curriculum of teacher training for developing technological skills.

A. Administrative support for the integration of ICTs in science teaching

The results of analysed expressions from the point of views of administrative support for using ICTs in science teaching is presented in table 4. The frequency shows how many times participants described issues related to administrative support. Where TE presents teacher educator and ST presents school teacher.

Table 4: Views on Administrative Support

Sub-themes	Categories (analysis units)	Frequency
Lack of technical Support	Technical support is not provided for installation and use of computers.	TE1, TE2, TE5, TE6, TE10
	Computers are installed in institutions but there is absence of maintenance facility.	TE3, TE5, TE11
lack of technical skills	Demonstration is required to be given for hands on experience to the science teachers.	TE1, TE2, TE3, TE5, TE7, TE8,
	Teachers do not have adequate skills to use ICT in science teaching.	TE9
Lack of funds	Institutions do not have fund for implementing the government schemes and buying ICT resources.	TE1, TE2, TE3, TE4, TE5, TE6, TE7, TE8, TE10
Lack of training programme	Administrators need to conduct continuous professional development programme at college level.	TE5
Lack of awareness about government initiatives	Government have initiated NMIECT and other lots of other schemes but they not being implemented effectively.	TE5, TE8, TE9
	Government distributes tablets but students are not using for the purpose.	
Lack of initiative	At the administration level there is no support for using ICT in the classrooms.	ST1, ST2, ST3, ST4, ST7, ST10
	There are very limited facilities in the schools.	
	WhatsApp's and YouTube are only in science teaching.	
Lack of motivation	Principal encourages us to use overhead projector, YouTube other facility and attend	ST5, ST6, ST8 ST9
	training programme at their own cost	

Table 4 presents the results of the analysed expressions. It shows that overall, all the teacher educators accepted the fact that the administration did not have funds to create the technological environment in the schools and the teacher education institutions. Moreover, any science teachers did not discuss about funds. Furthermore, they focused on the limited facilities available in the schools, viz., internet, Wi-fi, smartboard, speakers, and overhead projectors. They were motivated by the principal to use technology but at their own cost. Almost all the teacher educators opined that schools and institutions should have proper technical support for installing and utilizing technology. The teacher educators expressed their views on the technical skills of teachers: *There should be an organization of proper workshops and demonstrations of skills to give hands-on experience about technical skills to teachers*. Meanwhile, only TE5 expressed his in-depth views regarding the training program for teachers' professional development. TE5, TE8, and TE9 accepted that there was a lack of awareness about the government schemes and initiatives for promoting ICTs in science education. and school teachers were not much aware of the schemes and initiatives. They came to know about only those which their administration executed.

B. Significant Challenges in Using ICT in the Pedagogy of Science

The data of the participant's expressions were analysed, and all the participants showed similar views on issues of integration of technology in science teaching. Table 5 presents five sub-themes created after the analysis of categories. All the participants accepted that it was difficult to use ICTs in science teaching without the resources. Furthermore, teacher educators found that some schools and teacher educators' institutions (especially privately funded) had facilities, but the science teachers had attitudinal problems. However, in government-funded schools, teachers still preferred to teach with talk and chalk. such rigid attitude was due to the hectic administrative work and their old age. Whereas most science teachers were ready to use technology but, the scarcity of technology in the schools was an obstacle for them. Most of the teacher educators agreed on improper training of the teachers in developing skills, so there was a need to develop operational and functional skills among teachers about technology. ST3 and ST4 also accepted teachers had lack of technological skills and they were not ICT friendly. TE9, TE10, TE11, TE2, TE3, and TE4 expressed their view on pedagogical aspects of the effective integration of ICT in science teaching. *Every topic cannot be taught by technology, technology cannot meet the requirements of students completely; It is the teacher who presents the learning material accordingly; and adequate and need base e-contents are not available*. Only ST7 expressed their view on parents: *parents are digitally illiterate, and they do not have the fund to purchase technological tools.*

Table 5: Views on challenges of using ICTs in teaching of science

Sub-themes	Categories (analysis units)	Frequency
Lack of technological tools	There is lack of smart classroom, projector Internet connection, wi-fi connections, Electricity, computers, power backup, updated software's.	TE1, TE2, TE3, TE4, TE5, TE6, TE7, TE8, TE9, TE10, TE11, ST2, ST3, ST4, ST5, ST6, ST7, ST10
Attitudinal problems	Teacher still prefers to teach with chalk and talk supervision need to effective use of ICT Lack of positive attitude towards ICTs Teachers are not aware about policy recommendations Teachers have other departmental works that make uneasy for using ICT in science teaching. Old faculty are not much familiar with ICTs.	TE1, TE3, TE4, TE5, TE7, TE9
Improper training	Lack of training in simulation and virtual labs, workshops. and FDP, DIET, and SCERT training are sufficient but it is difficult for teacher to implement learned skills. There is need to develop operational and Functional skills. Teachers have lack of skills. Majority of teachers are not ICT friendly.	TE2, TE3, TE5, TE6, TE8, TE9, TE10 ST3, ST4
Pedagogical problem	Teachers believe every topic cannot be taught by technology. Compulsion on teachers to complete course. Sufficient and effective e-contents are not available	TE9, TE10, TE11, ST2, ST3, ST4,
Lack of digital literacy	Students are not able to purchase technology due to their poor economic conditions Parents are digitally illiterate and they have not funds to purchase technology	ST7

C. Availability of adequate facility in the schools to implement ICT in science teaching

The participants' data was analysed to know their views on the availability of adequate ICTs for the integration of ICTs in the pedagogy of science. Overall, all the participants agreed that schools did not have adequate ICT tools for utilizing in science teaching. However, they enlisted some technological tools, which were

the minimum requirement for the effective use of technology in science teaching. Table 6 presents a list of tools that came out after the analysis of participants' expressions. Overhead projectors, smart boards, and the internet were assumed to be essential technological tools, whereas school teacher did not discuss smartboards in their expression. Only one faculty member expressed his views on the educational software: *very few educational software programs are available, and most of them are in evolving stage that do not meet the requirements of content and pedagogy of science (TE10)*.

Table 6: Views on availability of adequate facility to implement ICT in science teaching

Sub-themes	Categories (analysis units)	Frequency
Audio-videos Technology	Overhead Projectors	TE2, TE9, TE10 ST1, ST2, ST3, ST5, ST7, ST8, ST9, ST10
	Recorders and Speakers	TE2, TE7
	Computers lab	TE5, ST3
Digital board	Smart boards	TE1, TE3, TE5, TE8, TE10, TE11
Internet	Wi-fi and internet	TE10, ST1, ST2, ST3 ST5, ST6, ST7, ST10
Software	Educational Software	TE10

D. The Implementation of Policy Recommendations for Promoting ICT in Science Teaching

The data analysed on the view of the implementation of recommendations suggested by the National Policy on Education 2020 on the integration of ICTs in science teaching. TE1, TE2, TE3, TE4, TE7, ST1, ST2, ST4, and ST10 were the participants who accepted that policy recommendations for the integration of technology were not being implemented due to the following reasons:

1) Lack of resources in the schools and institutions.
2) Lack of funds for the purchasing and maintenance of technology.
3) Absence of facilities in the schools
4) Little compulsion on teachers for the utilization of technology in their instructions.
5) Lack of co-ordination between teachers and principals for the planning of implementation of NEP recommendations.
6) Poor economic conditions of students
7) Lack of innovative steps and lack of sensitisation of teachers about NEP recommendations regarding integration of ICTs in schools
8) Lack of realistic aspects in recommendations
9) Lack of supervision and accountability

Whereas TE2, TE5, TE8, TE10, TE11, ST3, ST6, ST7, ST8, ST9 were the participants who accepted that policy recommendations for the integration of technology were being partially implemented through following activities:

1) By using PowerPoint presentation, pdf, online videos, webinars.
2) By giving online project work that students complete at their home.
3) *Conferences are being conducted for promoting technology and for developing skills*,
4) Technology is being used to improve teaching learning process and for the professional development of teachers.

While TE9, TE6, ST5 were not aware about the recommendations of NEP 2020 on the ICT integration in science education.

E. The Effectiveness of Curriculum of Teacher Training for Developing Technological Skills

The data was analysed on the views of the effectiveness of teacher training curricula for developing skills among science teachers for effective technological use in science teaching. TE1, TE2, TE3, TE5, TE7, TE8, and TE10 were the participants who opined there was a need for modifications in the teacher training curriculum. While TE4 and TE9 opined the curriculum was adequate, there were problems at the implementation level. While TE5 and TE10 found that the curriculum was ineffective because there were too much theoretical

aspects where science teachers could not experience the practical skills of how to effectively ICTs can be used in science teaching.

More emphasis in the curriculum is given on theoretical domain whereas ICT is a practical subject therefore certain portion should be fixed for ICT training. (TE10)

Curriculum is well designed but implementation is not adequate, whereas in self-finance colleges condition is very poor. (TE4)

Curriculum is good. Teacher educators are facing problem at their basic system therefore. objectives need to redesigned, examination pattern need to be changed, attendance should be made compulsory so that curriculum transaction should be effective. (TE9)

V. Conclusion and Discussion

The study aimed to revisit the challenges and issues of integration of ICTs in science education. In this context, Throughout the research, different views of secondary school science teachers and teacher educators focused on the integration of technology. The most important views were related to the Lack of administrative support, inadequate ICT facilities in the schools, recommendations of the NEP 2020 to integrate technology, and teacher training curriculum. In this regard, funds were the major challenge for the administration to arrange the technology in the institutions and schools, that created the issue of scarcity of ICTs. Similarly, according to 8th AISES report, there was 67.71% secondary schools in India, in which 43.80% rural secondary schools and 63.07 % urban secondary schools had computers for teaching and learning purpose. Whereas 21.28% rural secondary schools and 36.22% urban secondary schools have internet and Wi-Fi connectivity. Furthermore only 33.78% and 49.10% rural and urban secondary schools respectively had trained teachers for teaching through computers. With such limited facilities, how can science teachers amalgamate technology with the pedagogy of science? So, it is possible to say that our schools are still facing the problem of scarcity of technological tools, further discussion about pedagogically integration of technology is still far away.

The school's administration used to pressurise the teachers to complete the syllabus in time which created sense of uneasiness among science teacher to use ICTs. This may be a significant reason for not conducting training programs and the ineffective integration of technology. However, CIET has started free online training programmes such as DIKSHA to sharing knowledge through SWAYAM, Swayam Prabha, PM eVidya, ePathsala, and online workshops and the Government of India started the NISHTHA program for the professional development of school heads' and teachers. However, NISHTHA focuses on the latest pedagogies as per the recommendation of NEP 2020, but Aligarh schools were devoid of this because of lack of awareness. whereas other reasons for improper implementation of the recommendations were - Lack of funds, Lack of resources, poor economic conditions of students, and lack of supervision and accountability. While some participants agreed on gradual implementation of NEP 2020 recommendation by using PowerPoint presentations, PDF, online videos, and webinar.

Most of the teacher educators agreed that there was a need for modification in the curriculum of teacher training because, in the internship program, pre-service science teachers were following the contemporary methods of teaching. Such practices strengthen the particular attitude among prospective science teachers that teacher educators highlighted as – science teachers had a rigid attitude towards technology and did not want to cross their comfort zone.

Nevertheless, science teachers who were ready to use technology in the science classroom, they enlisted technology viz. smartboards, overhead projectors, Wi-Fi and internet, speakers, and educational software that should be considered as minimum facilities for pedagogical integration of ICTs in science teaching. So, along the lines of Operation Blackboard 1987, there is a need of flagship programme such as **Operation Smartboard** to mitigate the issues. Digital infrastructure should be provided in schools to create a virtual learning environment across the most vulnerable section of society so that, the Digital India campaign may fulfil its aim to empower the citizens of India in the field of technology.

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