What Works and Why: Insights from Science Teachers' In-Service Capacity Development Programme

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Abstract

Science, as a discipline, holds immense significance to understand this world. This subject encompasses and enhances one's ability to think critically, observe, infer, solve problems, experiment, and analyse complex phenomena. Given the importance of this subject, effective science teaching is imperative. However, science teachers in the public school system face numerous challenges like high class strength, shortages of teachers, non-academic engagements, inadequate infrastructure, and limited resources. This paper outlines the status of science teaching in public schools, shedding light on some of the issues that impede the teaching–learning process. It also discusses the significance of in-service capacity enhancement programmes for science teachers. Additionally, the paper recognises and describes effective strategies employed in in-service capacity enhancement workshops.

Introduction

India is home to a vast population and is known for its rich diversity. A country's progress is gauged by the quality of education provided to its populace. For decades, the major concern amongst our educators, policymakers, administrators, and various other stakeholders has been to achieve the goal of universalisation of education and overall literacy. Considering India's vastness and diversity of population, public schools were institutionalised with the hope to provide affordable education to all. From the aspect of accessibility, these schools can be found in urban as well as rural settings. They are primarily subsidised by various levels of government—central, state, and local. Regardless of the support, public schools and their teachers face an array of challenges, such as high class strength, inadequate number of teachers, infrastructure, lesser number of laboratories, and limited teaching–learning resources. These issues can subsequently degrade the teaching–learning process, hindering the overall quality of education.

When it comes to subjects taught in schools, science primarily focuses on developing scientific rigor among learners. This subject entails ways to deal with a complex phenomenon systematically through observation, hypothesis formulation, and experimentation. It is in the middle stage of schooling that science is introduced as a subject that includes physics, chemistry and biology. Therefore, careful attention is needed at this stage to ensure a solid understanding of science fundamentals among learners. Understanding the basics at this stage allows the learners to explore the concepts more clearly and deeply as they progress to higher classes. In a society where teachers are considered to carry the potential to shape and create new narratives in education, they bear a significant responsibility towards developing a scientific temperament among the learners.

This highlights the importance and need for quality science teaching and learning in public

schools. However, there has been a concern around public-school systems regarding the dearth of quality science teachers and the availability of resources, leading to dropout rates in the science stream and heightened dislike for the subject.

This paper brings together the present situation of science teaching in the context of Indian public-school systems, highlighting the issues and challenges that teachers often experience. Additionally, it outlines what works and why in science teachers' in-service capacity enhancement programmes.

Difficulties Faced by Teachers—The Need for In-Service Capacity Development

A series of conversations with middle school science teachers, observations of their classroom teaching and school visits unveiled a plethora of complex challenges, majorly systemic issues that impede the quality of education. A teacher's journey is not simple and linear. One of the major challenges reported as an underlying cause of teacher-centric science classrooms across the public schools in this country is the large-class strength. This unmatched student-teacher ratio leads to a myriad of problems, such as failing to attend to the needs of every learner, providing a more personalised experience while conducting experiments or activities, identifying the challenges faced by the learners, and many more. This, by large, disrupts the flow of the teaching–learning process. The issue further cascades because there is a shortage of science teachers in public schools. To address this problem, a few public schools have assigned language teachers to teach middle stage science.

The scarcity of qualified science teachers can lead to the degradation of effective teaching and learning of science, along with an increase in the dropout rate in higher education. Moreover, there are many schools that not only have a paucity of science teachers but also lack basic infrastructure like laboratories, teaching aids, teaching–learning resources, libraries, and technological access, such as Internet connectivity, computers, and e-learning resources. These problems have been persistent and make it difficult for teachers to adopt and adapt innovative teaching practices in science classes. Besides, many public-school teachers expressed concern about the amount of time they had to spend on non-academic engagements, which impacted their classroom preparation and teaching.

The conversation with the teachers further established that public schools heavily emphasised conducting examinations and had ambitious expectations in terms of performance from both teachers and students. This compelled the teachers to provide high-end results to maintain the schools' reputation, giving the entire classroom process a teacher-centric approach where they had to complete the syllabus in time and also devote enough time for revision. All these indirectly encourage rote learning and memorisation among the learners at the expense of understanding the processes involved in a scientific phenomenon.

These challenges depict the conditions under which public-school science teachers work and teach. Thus, to improve the teaching of science in public schools, a need for a capacity development workshop for Class 8 science teachers was acknowledged. The primary objective of the workshop was to enhance the teachers' conceptual engagement with Class 8 science topics and foster a shared understanding of the pedagogical practices used in science teaching in low-resource settings.

This paper explores the structure and design of physics workshop, in particular. It outlines the key attributes of the physics workshop as teachers found it relevant to their context. This approach can be further adapted by fellow master trainers or teacher educators to help the teachers maximise their capacity enhancement by keeping it more relatable and contextual.

Physics Capacity Enhancement Workshop

Rationale

Keeping with the criteria of the National Curriculum Framework for School Education (NCFSE) 2023, the workshop provided the teachers with a platform to comprehend their role in fostering essential process skills for developing scientific inquiry among the learners. These include the skill of framing questions, observing, understanding patterns, formulating testable statements, experimenting, anticipating possible outcomes, and analysing scientific data, as all of them are important in physics. So, the physics workshop focussed on teaching approaches that are easily employable in classrooms, are low cost and require readily available materials, and use technologies to help the learners develop skills to understand how the physical world functions.

From the pedagogical aspect of teaching middle stage science, the NCFSE 2023 (p. 310) emphasises incorporating hands-on activities, holistic understanding of content through an interdisciplinary approach, inquiry-based learning, project-based learning, discovery-oriented approaches, didactic approaches, and integration of arts and sports. These approaches will not only enhance the efficiency and proficiency of the learners, but will make learning more captivating and enjoyable, such that students will find the process more engrossing and satisfying. Apart from pedagogy, the other important aspect underlined in the NCFSE 2023 is to help the teachers recognise the prior concepts that the learners bring to the classrooms based on their experiences and how to apply them in active learning. This will allow the learners to understand that science is not about collecting facts, but analysing how these facts are associated and seek clarification.

Therefore, this workshop was designed to improve the teachers' understanding of physics concepts, explore teaching–learning methods, create activities with limited resources, and address the learners' alternative ideas. It also considered the resources available to the teachers and the overall contexts they operated in, including the school culture, class strength, and socio-economic backgrounds of the learners.

Structure of the Physics Workshops

As outlined in the previous sections, a lot of planning went into designing each workshop. All physics workshops were directed towards meeting the teachers' practical needs in the classroom, allowing them to flexibly adapt the pedagogical approaches, and materials used for demonstrations, and discussions, as per their school context. The structure of the workshops aimed to help the teachers recall concepts (remember and understand), and identify and address misconceptions (understand and apply). Subsequently, the sessions involved demonstrating activities and curating additional activities (apply, evaluate and create) to enhance the understanding of various topics. The workshops were intensive, as they provided a platform to the teachers to immerse in an enriching and engaging experience. The physics workshops covered topics, such as 'force and pressure', 'friction', 'sound' and 'light'. The aspects of the physics workshops are as follows.

Concept Building Using the Concept Map Tool

Due to the dearth of time and immense pressure on teachers for syllabus completion, they often have to summarise the concepts and sub-concepts of a unit in classroom. This can lead to overlooking the linkages between various sub-topics and addressing the gaps, causing non-redressal of preconceptions among the learners. Revisiting a lesson helps in recalling the concepts dealt with therein, informally gauging one's comprehension of the topic, thus, identifying and clarifying the gaps, if any.

The need to start sessions with an overview of the topic using a concept map tool was

realised in the physics workshops. The tool was used for showcasing the connections (using necessary arrows and links) between different scientific concepts and sub-concepts, thus allowing the teachers to refine and refresh their understanding of physics concepts. In addition, the tool brought out the nuances of interdisciplinary aspects of the subject, such as the history of Braille, the functioning of ears and eyes, and so on. The teachers realised the tool to be a handy resource and that concept mapping can be easily executed as a small exercise at the end of every lesson. Therefore, while planning science workshops, tools like concept maps, flow charts, mind maps, etc., must be introduced, keeping the concepts in mind, as they have the potential to broaden the learners' scientific comprehension with better visualisation.

Simulation and Software: Useful Tools at No Cost

There are certain scientific concepts such as atmospheric pressure, propagation of sound, static and kinetic friction, and so on, that teachers find a bit tricky and abstract to explain. To address this issue, simulations and software were introduced in the workshop. Simulation tools, like PhET, were used to understand and visualise the concepts of balance and imbalance force, static and kinetic friction, and the laws of reflection. A conversation with the teachers revealed that they often had to struggle to explain the difference between amplitude and frequency. To clear such conundrums, in subsequent workshops, they were introduced to two free software: Audacity, which could capture the variation in loudness in the form of waves, and Frequency Generator, which was used to demonstrate a range of frequencies from 20 Hz to 22,000 Hz. Both software helped clarify their confusion, convincing them that even schools with low technological accessibility can use these. Tools like these must be a part of everyday science teaching, making the classroom experience more enriching and engaging. Hence, teacher educators or master trainers must aim at finding more easily accessible free software, like Phyphox, and venture it through workshops to make the teachers aware of their applications and usage in science teaching.

Recognising Alternative Conceptions of the Students

Prior conceptions, largely known as alternative conceptions, refer to the students' understanding of a concept that digress from the accepted or intended explanations. Students often develop these naïve conceptions from existing experiences or beliefs. The NCFSE 2023 underscores that lack of supervision in the teaching-learning process can lead to alternative conceptions. Therefore, a teacher plays a crucial role in identifying and addressing the students' pre-conceived notions. In the workshop, a session was organised to understand the value of identifying and addressing these prior conceptions, particularly for the concepts of 'force and pressure', 'friction', 'sound' and 'light'.

To recognise and address the alternative conceptions that students bring to the classrooms, the teachers were provided with various simple approaches, hoping that they could adapt and adopt them in their classroom discussions. In the workshop, the teachers were presented with a list of misconceptions, after which they were encouraged to identify the problem in a statement and curate a group activity to address the issue. In another session, 'true or false worksheets' were employed, and the gaps were identified and attended through discussions. The teachers found these sessions helpful and assured to integrate techniques in order to recognise and respond to these prior conceptions. Therefore, teacher educators must extensively include such sessions and give priority to addressing alternative conceptions in their workshops.

Hands-on Activities

Traditional approach to teaching science may often be monotonous and not spark

learners' interest in the subject. Simple and doable hands-on activities can generate enthusiasm, curiosity, and inquisitiveness among the learners. These activities can guide them to find the reason behind some scientific artefacts, deepening their knowledge. In the workshop, the teachers were asked to use various materials to engage the learners in hands-on activities. For example, in one of the workshops, the teachers used a metal spoon and thread to observe the phenomena of the propagation of sound, in another they used two mirrors and a coin to comprehend multiple reflections. In yet another workshop, they were given all-purpose flour to showcase the effect of force, and so on. The teachers found these activities doable as the materials chosen were economical and could be easily found at home. These activities are engaging and essential as they attach a practical and experiential meaning to the concepts.

To encourage in-service teachers to incorporate hands-on activities in their lessons, teacher educators must include a diverse range of hands-on activities in workshops.

Demonstrations

Science is better explored and understood when students get the opportunity to apply the theories to practice. Teachers often find demonstrations to be time-consuming and tedious, and thus, refrain from using these in classrooms. Thus, in the workshop, an attempt was made to involve teachers in developing demonstrations on the discussed concepts of physics. In this session, the teachers were divided into groups. They were provided with a procedure sheet and cost-effective materials. The teachers were then instructed to curate a demonstration mapped to Class 8 physics concepts. Each group was encouraged to create two thought-provoking questions to ascertain students' comprehension. The whole session was designed to help the teachers go through various aspects of scientific demonstrations and explanations, such as material required, noting down the observations, analysing the data, etc. Additionally, the session aimed to make them believe that science concepts can be easily taught through demonstrations and that they should not view these activities separately. Thus, for any in-service professional development course, it is advisable to have sessions on demonstrations as this will help teachers plan activities. It will also assist them in organising demonstrations in classrooms. Thus, they will have clarity on the kind of materials, guided questions, prompts, and procedures to use. This will allow them to enhance the students' science process skills.

Thinking Out of the Box

Questions are often considered to be a useful tool for assessing students' understanding of a concept. Sometimes, these assessments are formative in nature, where a teacher asks questions in the classroom to check students' comprehension of a concept. These queues help the teacher identify the learning gaps and guide the learners to change their course of action. However, these workshops emphasised not just regular questions to check students' comprehension, but also to incorporate thought-provoking, out-of-the-book questions that can inherently ignite curiosity and evolve science learning. Like, in one of the workshops, the teachers were engrossed in a discussion to find out the reason behind the survival of fishes in the immense water pressure of an ocean, the need for airplane wings, the science behind the working principles of parachutes, and so on. The teachers felt the need to include intriguing questions in classrooms as they strengthen critical thinking and reasoning among learners.

For such prospective workshops, it is essential to provide a scope for discussions on out-of-the-box questions to teachers. This approach will guide the teachers towards employing classroom practices that nurture students' curiosity and help them see the relevance or applicability of the concepts learnt.

Promoting Inclusive Practices

Public schools often have a high class strength, making it arduous for teachers to manage the individual demands of the learners. These classrooms encompass learners of different needs. Thus, in the workshop, there was an emphasis on employing inclusive practices in classrooms. The intention was to ensure that every learner is acknowledged, and can participate and engage in various activities, irrespective of their abilities, backgrounds, or characteristics. For example, two physics chapters—'light' and 'sound' from the Class 8 science textbook—gave the scope to prompt discussions around visual and hearing impairment. This led to discuss ways to accommodate students with such impairments using adaptive technologies, appropriate seating arrangement, adapting assessments to oral cues, and multi-sensory modes of teaching.

As we are moving towards creating a just and equitable society, there is a need to organise such workshops to motivate teachers and explore ways to adapt their teaching methods, content, and assessments. This will help them accommodate the individual needs of all learners, especially children with special needs and students with different strengths, skills, and interests.

Conclusion: Insights and the Way forward

Teaching is one of the most important and daunting professions. A teacher's responsibilities in the public-school system extend beyond teaching, consisting of engagement in various government duties, school administration, meetings, and many more. Additionally, teaching in these schools has its own set of challenges like high class strength, scarcity of teaching aids, and infrastructural issues. So, the workshops were designed and contextualised with a comprehensive understanding of the challenges teachers face in the public-school system. The workshop aimed to ensure that the teachers could derive the maximum benefit from it.

To instil scientific disposition among students, it is important for teachers to engage in practices that stimulate the students' interest in science. However, it was found that most teachers attending the workshop are entrusted with teaching physics in schools, even though they do not have a degree in physics. These teachers find it taxing to teach and engage in physics-related activities and explanations. So, most of them find the lecture method an easier escape from engaging in hands-on activities and demonstrations. Consequently, it may lead to students resenting science and failing to see its depth and beauty.

All physics workshops consisted of sessions designed to help teachers revise, refresh, and update their content knowledge through the use of a concept map. This approach allowed them to understand the nuances and interconnections in every lesson.

Additionally, there was another group of teachers, with over a decade of experience, who were comfortable with traditional methods of teaching science and were initially reluctant to adopt new pedagogical approaches. Thus, along with revisiting the concepts, efforts were made to shift their mindset towards a student-centric classroom. This was done by introducing them to a range of pedagogical practices tailored to middle-stage science, such as inquiry-based learning, hands-on activities, constructivist approach, etc. Each of these was demonstrated with suitable practical examples. After the session, these teachers expressed appreciation for these approaches, noting their relevance to their school context in terms of resources, labs, and class strength. They assured to incorporate these in classroom teaching. However, such changes or shifts in teaching methodology cannot happen overnight. There is a need for teacher educators to work diligently and closely with teachers to gradually improve middle-stage science teaching. Workshops must, therefore, include updated and new

approaches that can bring meaningful reforms in the way science is currently taught.

Apart from revisiting concepts, discussions around students' preconceptions helped clarify some of the gaps teachers had in certain physics topics. The session on recognising alternative conceptions of the students allowed teachers to revisit and revive their comprehension. They were taken through a set of approaches to identify and address the preconceptions of the learners like worksheets, formative assessments, questioning, and quizzes. It is necessary to note here that the sessions on alternative conceptions must be prioritised as students build further knowledge on a clear conceptual foundation. Thus, to improve science learning, workshops must stress that it is the teachers' responsibility to recognise and grasp flawed conceptions. Further, science teacher educators must guide teachers through strategies to uncover and address those naïve conceptions that the learners bring to the classroom.

Sessions on demonstrations brought out the teachers' active engagement, and their ability to design fascinating activities and seek clarifications. These sessions provided them with the scope of carrying out and curating activities using low-cost resources. Workshops, thus, need to include sessions that offer teachers first-hand experience with interactive learning methods. This practical approach would empower teachers to carry out activities or demonstrations with confidence. This would also allow them to determine what approaches are effective and what are not, leading to improvements and refinements while executing demonstrations with understanding. It is when these refined techniques are implemented in classrooms that students are expected to grasp concepts effectively.

Besides, it was found that simulations and software stole the limelight. The teachers, initially, believed that they needed expertise in using them. However, demonstrating the easiness of handling these tools convinced them that these can magnify the joy of learning science. The workshop provided them the opportunity to explore ways to integrate tools and resources in their science lessons, enhancing their ability to utilise technology effectively.

Therefore, teacher educators should actively boost in-service programmes, allowing teachers to polish their skills and practices. It is their responsibility to train teachers in integrating various pedagogical approaches, free e-resources, assessment strategies, and many more skills in classroom teaching. There should be opportunities for teachers to gain practical exposure and experience with appropriate guidance. Ongoing follow-ups, feedback, and communication with these teachers can certainly enhance the quality of science teaching across the country.

References

National Curriculum Framework for School Education. (2023). Ministry of Education. Government of India. New Delhi.

https://www.education.gov.in/sites/upload_files/mhrd/files/NCF-School-Education-Pre-Draft.pdf