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Research Article

Exploring Science Teachers' Pedagogical Content Knowledge in an Alternative School Setup

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Abstract

In this research study an attempt has been made to study the Pedagogical Content Knowledge (PCK) of science teachers in an alternative school. This study deep dives into how teachers transform the content knowledge of science into meaningful learning experiences for their students. Using qualitative research design and drawing on observations from the classroom setup, semi-structured interviews, lesson plans created, worksheets, and reflective notes of science teachers (across middle and high school), the paper draws its findings and conclusions. The conceptual framework is based on the PCK model of Magnusson et al. (1999), along with the component of knowledge of resources proposed by Lee and Luft (2008). Upon a deep dive into the subject, one learns that science teachers in the alternative school under examination not only relied on textbook-based instruction, but their success heavily came from child-centered pedagogy, inquiry, hands-on activities, project-based learning, differentiated support, reflective assessment, and the use of varied classroom and community resources. It was also seen that with the increase in number of years of teaching experience, the teachers' PCK developed and did not remain static.

Keywords: *Pedagogical Content Knowledge, science education, alternative school, science teachers, child-centred pedagogy, experiential learning, inquiry-based learning, teacher reflection*

Introduction

Traits like curiosity, observation, reasoning, and problem-solving, for years, have been developed and strengthened through science education. However, when we look at the setup of a conventional classroom, science teaching still revolves around textbook explanation, rote memorisation of facts, and preparing for examinations. While this approach can help students memorise, rote learn, and reproduce the same information for their exams, it does little to help them understand the real functioning of the world and scientific concepts. It moves away from understanding science as a way of asking questions, observing the world, testing ideas, and making sense of everyday phenomena.

"Good education in science, including the development of a mindset of inquiry and research in students, is critical in addressing the challenges that India and the world face today, such as climate change, improving health care, technological advancement and use for sustainable development, creation of just and equitable livelihoods, and living in harmony with nature (NCFSE 2023)". The real concern starts at the middle school and secondary school stages. At these stages, the learners have developed active learning skills and are capable of observing, comparing, experimenting, and forming explanations. Parallely, they also bring in their own misconceptions, prior experiences, language limitations, and interests into the classroom, owing to their diverse exposure. For these reasons, the expectations from a teacher is not only to possesses strong subject knowledge but also the knowledge of how to represent scientific ideas and concepts into more understandable and engaging models for learners. The researcher, in this study, is interested in knowing how science is taught differently and meaningfully in an alternative school where the emphasis is on students' holistic education and teaching learning process is not based on rote memorization and examinations. (Sarojini Vittachi, 2007) in the book 'Alternative Schooling in India' has defined alternative schools through following features:

- The Approach is more individualised than that of a mainstream school. There is no one model, and so, the approach of alternative schools defies pigeonholing.
- Respect is accorded to the student, parent and teacher irrespective of socio-economic status and (special) abilities. Integration of children of mixed abilities and/or different socio-economic groups, and sometimes even of mixed ages, is a key element.
- Learning that is more experiential and interest-based is encouraged rather than learning out of a textbook or from a class lecture.
- Disciplines are cross-linked so that the boundaries of knowledge are diffused and the child is able to see connections across various fields of learning.

- Class size is kept small. Typically, one teacher does not teach more than 25–30 students.
- Class structure is experimented with, by allowing flexibility in the spread of ages or even interflow between different ‘grades’ or ‘standards’ for different subjects. Physical classroom spaces are also broken free of by many so that the walls of the conventional classroom dissolve even as they allow learning to take place outdoors.
- Administration is conducted in a democratic and somewhat flexible manner. With hierarchical structures being less and less prevalent, these schools experiment in rotating responsibilities, arriving at major decisions through consensus and taking collective ownership for the institution and what it stands for.
- Evaluation methods are explored in various ways, not always relying on conventional tests and examinations.
- Affiliation to the most popular Board may not be sought. These schools attempt to explore new topics and syllabi that are not prescribed by conventional Boards. However, this does not mean that such schools do not prepare their students for government-approved examinations to complete schooling and enter universities.
- Success rate is not measured only by the performance of the students in competitions, examinations and other such external benchmarks. Their learning outcomes are a blend of measurable and immeasurable parameters.”

To gain insights into how science is taught in an alternative school, we have to know how a teacher carries out the teaching learning process in a classroom, what knowledge and understanding of content and pedagogy does she have andhow does she implements this knowledge and understanding to make the science learning meaningful for the learners? To answer these questions the researcher used the conceptual framework of Pedagogical Content Knowledge (PCK) to carry out the study.

Pedagogical Content Knowledge: Conceptual Framework

Pedagogical Content Knowledge, as a concept, was introduced by Shulman (1986, 1987) to explain the special form of knowledge required for teaching. Shulman (1986) identified pedagogical content knowledge (PCK) as “the most useful forms of content representation, the most powerful analogies, illustrations, examples, and demonstrations in a word, the ways of representing and formulating the subject that makes it comprehensible for others” (p. 9). That area of knowledge also includes “an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons” (p.9). From

Shulman's conceptualization of PCK consisting of two components, the concept evolved over time, resulting in various conceptualizations and models of PCK. The researchers through various studies established that PCK is not only knowledge in different components but also the integration of that knowledge and includes the affective components like, beliefs (Grossman (1990) , Magnusson et al., 1999). The five components of PCK from 'Magnusson et al. (1999) model of PCK for science teaching' "(Orientations towards teaching science, Knowledge and beliefs about science curriculum, Knowledge and beliefs about assessment in science, Knowledge and beliefs about students' understanding of specific science topics and Knowledge and beliefs about instructional strategies for teaching science)" along with one component of PCK 'knowledge of resources' from Lee & Luft (2008) study are used to study science teachers' PCK in the present study.

Review of Related Studies

Research on Pedagogical Content Knowledge has shown that PCK is complex, dynamic and deeply connected to classroom practice.

M. Cheryl-Ann Madeira (2010) investigated pedagogical content knowledge development in nine in-service teachers.The study highlighted the positive role of "scaffolded reflection" and "peer exchange of lesson plans" in improving teachers planning resulting in their development of PCK.

Rebecca M. Schneider and Kellie Plasman (2011) did the review of researches between 1986 and 2010. analysis revealed that for developing PCK, teachers should think first about learners and then about teaching. The role of reflection also contributed in PCK development.

Sarah Boesdorfer and Anthony Lorsbach (2014) studied one (case study) science teachers' orientations towards science teaching by collecting data through observations, interviews and class documents. They found that knowing about orientations is relevant to study teaching practice.

Pernilla Nilsson and Anna Vikstrom (2015) in their attempt to unpack the PCK of six science teachers , used interviews and video recorded lessons to collect data and found it useful in giving insight into PCK development.

Kennedy Kam Ho Chan and Anne Hume (2019) reviewed how researchers investigate science teachers’ PCK. The review revealed that researchers operationalise and conceptualise PCK differently.

Meili Yanti, Riandi, and A Suhandi (2020) in their study described PCK of science teachers through Content Representation(CoRe). The data revealed teacher’s differing abilities in PCK are related to working experience and professional development.

Karthigeyan Subramanium (2022) investigated PCK development among prospective teachers. Data analysis indicated orientation to teaching emerged as the important component that influenced other PCK components. The orientations were mainly used to plan, enact, and reflect upon science lessons.

Aydin, Ebru; Mihladiz Turhan, Gülcan (2023) in their study deep dived into experienced primary school teachers' PCK, sub-components of PCK, and their possible interactions with science teaching. Interviews, observation, document analysis, and subject matter knowledge tests were used to explore teachers’ PCKs in-depth. Results indicated that explaining teachers' PCK over sub- categories can guide our PCK understanding.

Methodology

Ten science teachers teaching classes from sixth to ninth in an alternate school were selected for the purpose of the study. The teachers were observed while teaching then semi- structured interviews were held with them along with looking into their lesson plans, worksheets and reflections.

These sources allowed the researcher to study both what teachers said about their teaching and what they actually did in classrooms. The data collected was analyzed qualitatively and the specific categories in each component that emerged from the process of coding and constant comparison were reported. Classroom observations helped understand instructional strategies, nature of student-teacher interaction, questioning patterns of students, as well as teachers, whether teachers made a judicious use of resources, and their assessment practices. Interviews helped gain the understanding of teachers’ beliefs, orientations, planning processes, and reflections. Lesson plans and worksheets provided evidence of curriculum design, activity planning, learning objectives, and assessment tasks. Field notes captured additional observations related to classroom environment, student engagement, and contextual factors.

Findings and Analysis

About the School

The core understanding of how the school operates will influence our understanding of PCK, but also change the variables playing a part in the same. In the context of this particular school, the researcher finds that the environment was progressive and followed a child-centred approach to education. To provide meaningful education to students in the field of science, the school in which these teachers taught, worked in collaboration with various non-profit, non- government organizations, which helped the teachers in evolving child-centered, inclusive teaching methodologies that foster problem-solving skills, self-discovery, spirit of inquiry, critical and independent thinking and sensitivity in the students, and encouraged them to ask questions about their natural and social environment. The science teachers dealt with an innovative science curriculum for primary and upper primary classes, which was based on hands-on activities, project-based learning, and experiential learning, although the student strength in each class was approximately 40. Based on this innovative science curriculum, the science teachers discussed observations, shared ideas, and made comprehensive plans of science concepts in groups. They made use of different resources while planning classes around science concepts, as they didn't believe in following one particular textbook as a resource. The teachers were helped by their mentors in this process. Each concept plan was documented comprehensively and made available for all the teacher's use, which helped them to proceed systematically and uniformly in all the sections of the same class. For example, for the concept "electricity", each day's plan mentioned: learning targets for the students, skills to be learnt by the students, classroom settings, resources to be used, opening protocols, previous learning experiences of the students, teacher's notes, closure, extension, differentiation, home assignment, assessments, and reflections. Apart from each day's plan; assessment plan, study materials, pointers for reflections for the teachers related to the concept were also made available to teachers in the form of written documents. The teachers' experience ranged from 6 months to 8 years.

Knowledge of Instructional Strategies

The following three categories emerged:

i. The teachers practised child-centered pedagogy in the classroom to teach science content.
ii. The teachers used an integrated approach to teach science.

iii. The teachers asked logical, analytical questions from the students, which could stimulate their thinking skills and problem-solving abilities.

The instructional strategies implemented by the science teachers were hands-on, process based, inquiry based, project-based and experiential learning. The instructional strategies used were specific to the type of concept being dealt with, related to the objectives of learning the concept from the student's perspective, and how best the student can understand it. Some of the pedagogies were based on science process skills such as observation, classification, measuring, experimenting, collecting data, analyzing it, recording data, etc. For example, in one of the classes that was based on the observation skill, the students in groups were provided with different kinds of leaves, and the learning target for the students was to observe the leaf minutely and make a drawing that closely resembles the real leaf. After finishing their work, the students first evaluated their own work and then the work of their peers with the help of the checklist provided to them. In another class, the students learnt about different parts of a flower by dissecting the flower themselves and pasting its parts on a sheet. Labeling of the parts was done later on with the help of the teacher, who first encouraged the students to express themselves in their own language and then came to the scientific terminologies of the parts of a flower.

The classroom setting for these kinds of activity-based learning was quite nontraditional. The students sat in groups of four to five students; each group was given the name crew. The time duration for each class was one hour so that the activities could be comfortably performed by the students. To explore the world outside the classroom, the teachers used "Expedition learning" as an instructional strategy in which a journey outside school was organized for the purpose of exploration. The students were supposed to do various tasks when they go for expeditions, so to prepare them for expeditions, separate classes were held for them which served as best examples of teaching science in an integrated manner e.g. for one of their expedition to Aravalies, students would have to make trail maps, so in the classes students learnt about the use of magnetic compass, orienteering the magnetic compass, finding directions etc. by performing different activities on their own in the class. In yet another class, students learnt about simple and compound leaves by going to the field and collecting samples of different leaves. The teachers shared with the researcher, "science is not about experimentations only, experiments are to be integrated with theory to make it meaningful through discussions"; so the concept of atom, which becomes a little abstract for students, was mainly dealt with through discussions and making use of various visual aids. According to the teachers, "most projects are interdisciplinary and provide a context, problem, or purpose that children can relate to. The projects help children to observe, analyze, reflect, synthesize, and understand from multiple perspectives. It empowers the child to think about problems, whether social, cultural, technological, or ecological, in a systemic manner and become an agent of societal change. It is a wholesome integrated approach that goes beyond the boundaries of subject curricula and provides multiple opportunities for the children to revisit and rework, thus creating an ethic of excellence through continuous planning, execution, and reflection." The teacher acted as a facilitator of learning for students and also helped them to develop their problem-solving ability.

Knowledge of Students' Understanding

The following three categories emerged:

i. The teachers understood and showed sensitivity towards students' needs, interests, problems, socioeconomic background, and special needs while planning the science lessons as well as while executing them.
ii. The teachers dealt with students' misconceptions, their skills and abilities as well as their previous knowledge as the requirements of learning science.
iii. The teachers were knowledgeable about areas of science that students find difficult and helped them overcome their difficulties.

The teachers shared "students learn most effectively when they are actively engaged in the learning process; they are curious by nature and want to explore the world around them, so we do a lot of hands-on activities, field trips, projects, and explorations with them". A healthy and congenial teacher student bond could be seen in the class. Students had no fear of asking even the small doubts, or doing the small mistake. They could freely discuss their ideas, views, experiences related to the concept. There was no need of controlling the class as the students were self disciplined. Special care was taken by the teachers not to introduce a concept directly in scientific vocabulary, students were allowed to be familiar with the concept first in their own language and vocabulary.

The classrooms were totally inclusive and the students were found sensitive towards the needs of special need learners and helped them in carrying out activities. The teachers also modified their plans and worksheets as per the special needs of the learners. The teachers' lesson plans on different concepts included common misconceptions held by the students and previous learning experiences related to the concept, about which teachers said: "understanding students' previous knowledge and their probable misconceptions is important because it is the base on which to build students' further understanding of science concepts".

Knowledge of Assessment

The following three categories emerged:

i. The teachers assessed cognitive, psychomotor, affective, and science process skills very efficiently in most of their classes.
ii. The teachers had clarity of the objectives of assessment and conveyed them in terms of learning targets to the students, and shared checklists and rubrics with the students, which contained the criteria of assessment.
iii. The teachers integrated all the assessment tasks with the teaching-learning process and used self-assessment and peer assessment as a way of assessment.

The teachers considered assessment to be an essential component. They shared "Assessment provides us with important information regarding the mastery of course content by students, both individually and collectively, and also provides information on the performance of the teacher. Assessment also provides the basis of reporting to parents regarding student progress". The students were made clear of "learning outcomes" or "targets".Their learning targets took care of all aspects of science learning, such as knowledge, reasoning, process skills, psychomotor skills, communication skills, creativity, etc. For example, in one of the classes on "plants" in sixth standard, the learning target was: "I can observe the leaf given to me minutely, and make a drawing that closely resembles the leaf".

In yet another class on the circulatory system in the seventh standard, the learning target was: "I can draw and explain the structure of heart." For expedition learning on "Orienteering," the long-term target was: "I can navigate unknown places using a compass and a map," followed by supporting targets:

- I can use a magnetic compass to find the reading of an object
- I can use a magnetic compass to follow a given reading to reach a landmark, etc.

For different learning targets, the teachers shared rubrics and checklists that contained the criteria of assessment of the task for self-assessment of students as well as for their peer assessment. The assessment of the students' learning was conveyed to the students as qualitative markers. Feedback was given in an organized, systematic way. Each student maintained a portfolio which was the collection of worksheets, peer assessment, self assessment, class records, surprise tests, solving problems , cross word puzzles and all the other work done.

The teachers shared “Assessment is an integral part of pedagogy; it does not start when teaching stops, rather it’s an ongoing process. The Formative Assessments informed students about their own progress, and enabled the teachers to ‘form’ effective instruction strategies while Summative Assessments measured individual achievement at a point in time, against standards and benchmarks.”

Knowledge of Resources

Following one category emerged:

i. The teachers didn’t refer to one particular textbook, used school resources, community resources, multimedia, and other types of resources.

The School resources included subject laboratories, technology laboratories, all the resource material for hands on activities, laboratories for carpentry, pottery, handicrafts etc., well equipped library , multimedia laboratories. Thus the school had all the resources required. The school considered community as one of the resource so field trips to science centers, museums, botanical gardens, national parks, etc. Were organised from time to time. Science talks were also held by the people specializing in areas of science and related to science.

Knowledge of Science Curriculum

Following one category emerged:

i. The teachers referred to the carefully designed, innovative science curriculum for all of their teaching practices.

The carefully designed science curriculum of the school in which the teachers taught was well documented and made the teacher knowledgeable about the objectives for teaching science, program and material that are relevant for science teaching. The science curriculum was divided into: Middle Programme-(GRADES 4-7) and Senior Programme-(Grades 8-12). According to the teachers, “Learning how to learn is a crucial aspect of the middle years. Children in our middle programme are curious, aware, self-motivated, and reflective learners. The teaching-learning experience is a balanced amalgamation of hands-on project work and analyses of experiences to construct concepts, knowledge, and skill sets modelled around project-based learning. The project-based learning provides the child with a real-life connection that is important for experiential learning. Most projects are interdisciplinary and provide a context, problem, or purpose that children can relate to". Dialogic, participative Pedagogy was at the very core of the Senior Programme learning processes.

Orientations toward Teaching Science

"An orientation represents a general way of viewing or conceptualizing science teaching. This component refers to teachers' knowledge and beliefs about the purposes and goals of science teaching at a particular grade level" (Magnusson, 1999, p. 97). The teachers viewed science beyond the textbooks. They believed in relating science to the child's experiences. Some of the purposes and goals of teaching science which teachers shared are as follows:

- "Nurturing the curiosity of a child".
- "Undertaking a continuous process of self-discovery, of seeking the truth about oneself and the world around, through a process of reflection."
- "Honing and nurturing the capacities of children to think independently, relate, act, and learn".
- "Enabling the children to grapple with a problem, issue, or concept using all his/her senses through learning by doing".
- "Helping children examine their learning critically and creatively. Through sustained inquiry, they can probe further into the problem, concept, or task at hand". ,
- "Helping the children think outside the box and engage collaboratively with others".

The science curriculum, instructional strategies, assessment tasks, and other educational decisions were mainly directed by these Orientations. Referring to Magnusson's table of orientations, the science teachers' orientations to science teaching represented multiple orientations which included 'Process', 'Activity-driven', 'Inquiry', 'discovery', 'Project-based science', 'conceptual change,' and 'Guided inquiry' orientations.

Contextual Factors Influencing Teachers' PCK

During interview, the teachers shared with the researcher, "We continuously reflect on our classroom practices, share our experiences with our colleagues and modify our teaching in the light of feedback given in group meetings, for example while dealing with the concept of heart, we used to show videos of functioning of heart first to the students and later on came to its theoretical understanding, but very soon we realized through observation and reflection that students are not able to relate to videos in the absence of any theoretical understanding, so we discussed in group meeting, modified our teaching and now we do theoretical understanding first and show videos later on and this is working" The teachers shared that when they joined the school, they had knowledge of the traditional system of teaching only, but through the school's innovative science program, Vision, and the continuous support of the school's head, the orientation program for the teachers, they were able to evolve new and better ways of reaching out to the children. To support the teachers in creating meaningful classroom experiences, an intervention program in the form of seminars, workshops, visits to innovative schools in India and abroad, and science lectures by eminent educationists was being organized from time to time. Besides this advanced infrastructure, availability of all types of resources, flexibility of curriculum, freedom to teachers to try out new ideas, collaborative planning, reflection, peer-learning, and group-learning helped the teachers in evolving child-centered teaching methodologies with the help of their mentors**.** One of the teachers shared with the researcher, "The teachers who believe in the child-centered learning work passionately, while those who don't believe work by compulsion and leave the school when they get the opportunity somewhere else". The teachers also shared that the practice of reflection during and after the class helped each teacher to make their own understanding of teaching.

Discussion

The findings of the study support the view that Pedagogical Content Knowledge is dynamic and practice-based. The teachers in the study were not simply applying fixed teaching methods. Their PCK developed through classroom experience, reflection, collaboration, mentoring and institutional support. This is consistent with the view that PCK grows through teaching practice and interaction with learners (Baxter & Lederman, 1999; Gess-Newsome, 1999; Van Driel et al., 2001). The study also shows that teachers' orientations toward science teaching influenced all other PCK components. Teachers who viewed science as inquiry and exploration were more likely to use questioning, activities, experiments, projects and reflective assessment. This supports Subramaniam's (2022) observation that orientation to teaching can influence other components of PCK. Another important finding is that PCK in an alternative school is not only an individual teacher's knowledge. It is also supported by school culture. The school's flexible curriculum, mentoring systems, collaborative planning, resources and reflective practices created conditions in which teachers could develop richer forms of PCK. This suggests that improving science teaching requires attention not only to teacher training, but also to the academic and professional environment in which teachers work. The study further shows that child-centred science teaching requires knowledge of students' understanding. Teachers must know students' misconceptions, prior experiences, interests, language needs, and learning differences. Without this knowledge, even strong content knowledge may not lead to meaningful learning. The teachers in this study used familiar examples, activities and differentiated support to make science accessible to learners. Overall, the study indicates that meaningful science teaching is created through the interaction of content knowledge, pedagogy, learner understanding, assessment, resources, curriculum, and teaching orientation. In the alternative school context, these components were strengthened by reflection, autonomy, and institutional support.

Conclusion

The study concludes that for meaningful science teaching, teachers need to engage with all the major components of Pedagogical Content Knowledge. These teachers require subject knowledge, understanding of student's level of understanding of the subject, instructional strategies, assessment, curriculum, resources and their own orientations toward teaching science. These components don't work in isolation, but rather interact with each other in the classroom setting. In the context of the alternative school studied for the study, it was visible that child-centred pedagogy, experiential learning, inquiry, project work, reflective assessment and meaningful use of resources contributed to the teachers' PCK. The teachers' created opportunities for students to observe, question, discuss, experiment safely and reflect meaningfully rather than focusing on textbook-based learning and teaching. These practices helped students connect science with their everyday experiences, and make the subject practical for them. The study also brought light to the role of school context in the development of teachers' PCK. Tools like mentoring, collaborative planning, peer learning, documentation, workshops, reflection, flexible curriculum and availability of resources act as catalysts as teachers evolve teaching of science from the traditional methods into a more innovative and meaningful practice. Teachers' willingness to change and belief in students' potential were also crucial. The findings suggest that teacher development programmes should not focus only on content knowledge or general pedagogy. They should help teachers connect content with learners, methods, assessment and context. They should also provide opportunities for reflection, collaboration and practice-based learning. Schools that wish to improve science teaching must therefore create professional environments that support teachers in developing and using PCK. The study finally argues that Pedagogical Content Knowledge is not fixed. It evolves through classroom experience, reflective practice and institutional support. In an alternative school, where teachers are given freedom, resources and collaborative support, PCK can become a powerful tool for making science education meaningful, inquiry-oriented and child-centred.

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