Science Education for the Future: Five Recommendations
A Policy Brief for Pakistan

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High quality education and particularly in the area of what is generally called STEM (Science, Technology, Engineering and Mathematics) is the greatest indicator of quality of life. Sustainable human development, eradication of poverty and removing unequal distribution of resources all depend on high quality education. High quality education in the area of science has been defined as far back as 1962 by Schwab and Brandwein as teaching through inquiry-based methods. Continuing to teach science content through rote memorization produces teachers who know of no better method to teach other than memorization. These teachers themselves lack conceptual understanding of science content and hence cannot help their students to understand science as they should or could (Halai, 2005). This cycle has to be broken. Science teachers need to be mentored into using more active methods of teaching and students need to be able to learn through innovative methods that are student-centric.

There are serious gaps in the science content knowledge of science teachers at all levels. In methods courses that I teach and the research-cum-development projects I have undertaken all indicate that a substantial amount of time is spent in helping the teachers to understand the content whether it is photosynthesis, acid bases or states of matter before the pedagogy can be discussed and implemented. In the Science Classroom Research for Inquiry Process in Teaching (SCRIPT) project the five-day workshop to help middle school science teachers understand inquiry as a method of teaching had to be extended by three days as teachers grappled with content. This is not surprising as the content and pedagogy have a deep connection. Because science teachers lack confidence in their understanding of science they are very hesitant to try new and innovative methods of teaching. The students of these teachers in their turn become teachers who have weak content knowledge and teach through rote memorization. Teachers with science degrees should be teaching science at all levels. In Pakistan it is only at the college level that experts are allocated for teaching science. It is time to allocate science specialists for teaching at all levels of school including at the primary stage. It is also time to revisit the lecture method of teaching science at our colleges and institutions of higher learning. In this case Problem-Based Learning (PBL) methods initiated by some medical colleges in Pakistan can serve as an example of student-centered undergraduate education.

Rote memorization is the most common method of science teaching in almost all rural and many urban areas of Pakistan. But even if science is taught for conceptual understanding it is not sufficient. Science should also be taught as a way of knowing. Learners from kindergarten onwards must learn how science knowledge is generated. That is why inquiry has acquired an iconic status in the current scenario of science education. In this method of teaching students individually or in groups are encouraged to raise questions and then develop a process to find answers to the questions. This process allows them to collect data and then make sense of the data to come to some conclusion about the questions raised. For instance if the question raised is, "Which of the two kinds of fertilizer helps the wheat plant to grow "better"?". The students have to unpack and define better, develop a fair test to see which fertilizer is better and draw conclusions from the data. However, the SCRIPT project provided conclusive evidence that teachers had difficulty in developing a process, had less difficulty in collecting data but had great difficulty in drawing conclusions from the data collected. And not surprisingly this gap was also seen in the students taught by them. Science teachers are keen to learn but they need mentors to help them to develop lesson plans that incorporate these new and innovative methods of teaching science.

Workshops are good ways to develop awareness of a new way of doing things. They can and sometimes do provide basic skills. However, often teachers are unable to implement new methods of teaching without direct and continuous support from mentors who help them develop lesson plans incorporating these new methods of teaching. Primary science teachers in remote areas of rural Sindh could and did teach excellent science lessons because mentors (developed from among them) supported their teaching for 2-3 years. This was the conclusion drawn from Mentoring Science Teachers in Rural Sindh (MSTARS) study conducted in rural Thatta and Sukkur districts of Sindh. The study demonstrated the power of sustained support and mentorship in enhancing teaching and learning in science. Mentors are teachers who have both good content knowledge and pedagogical knowledge. However, for a mentor to succeed he or she also needs skills in teacher development which includes ability to observe a lesson and give constructive feedback, peer coaching and learning to learn (to list a few skills). Without these attributes it is difficult for exemplary teachers to support other teachers. Hence, to develop the science content and pedagogical skills of science teachers a cadre of mentors are needed. This need not entail a whole new structure to be put in place. We can use the BEd teaching practice in schools as a place where mentors can support their teaching. At this point this important part of the BEd program is not optimally utilized.

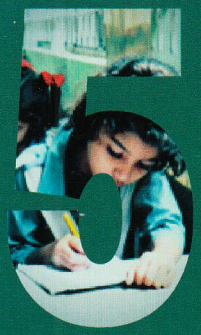
BEd as a professional degree for teaching has lost relevance in Pakistan because of lack of trained teacher educators. A cross provincial study in Sindh and Punjab carried out on teacher educators where 64 classroom observations were undertaken (only three were science and math) show that being a teacher educator is seen as a secondary profession. The findings show that teacher educators in the BEd program practice as content providers and not as skill or practice providers. This means that in a math class almost all of the time was spent in teaching logarithms and almost no time was spent on how to teach it. Nor was there a space in their program to practice teaching it in a real classroom. Teacher educators lecture to the prospective science teachers that active or discovery methods of teaching are most effective in teaching students. The pre-service teachers do not have a clue what that means. Unless this changes science teaching will not change.

Affected Population

The most affected are those who are studying science in school from grade 3 till grade 8 as they are taught science in a way that discourages interest in science. Most often they are taught by teachers who are themselves not conversant in science. Also affected are those who do "get" science in grade 9 and 10. They are taught science solely for the purpose of getting good grades in the high stake examination so that the students can obtain admission into colleges of their choice to go on to prestigious medical and engineering schools subsequently. However, equally affected are those who did not "get" to study science despite their interest. It would not be a cliché to say that everyone is affected.

What are the risks for teaching science in this way?

The greatest risk is that Pakistani citizenry is a consumer of science and technology but not a producer. Our young students think that science is only the forte of the people from the West (Halai, 2001). The general population lacks the skepticism that good teaching of science brings to everyday situations. It makes people gullible towards all claims made by politicians, religious scholars, media etc. Our television channels gave mega coverage to a person who alleged that he had invented a car that would run on water; when a basic knowledge of the laws of thermodynamics will show that it is not possible. A religious scholar attributed the 2008 earthquake to women who wear jeans. We are producing people who lack basic knowledge of science in an age of science and technology. The economic development of a society is dependent on its ability to create knowledge. If our student body thinks that knowledge creation is not possible and all that can and should be learnt is in textbooks then progress and development will be greatly hampered.



5 Recommendations

To help Pakistan become a science literate nation these five policy recommendations are made:

1. Every child has a right to quality science education in school.
2. Every child has a right to be taught by qualified science teachers from the primary to secondary and higher.
3. BEd and other teacher development programs for science teachers must demonstrate the use of inquiry and other active methods of teaching science.
4. BEd and other teacher development programs for science teachers should include a strong mentoring component.
5. A systematic process for induction of science teacher educators in colleges of education should be developed on a priority basis.

Normally, one of the best ways to bring about change in a profession is to bring about change in the licensure mechanisms and change in policies and hence the above recommendations. However, such changes affect only a part of the teaching profession in Pakistan. Here only government school teachers are required to have BEd before induction as a teacher. The fast developing and expanding private education sector does not require pre-service training; all of the training to teachers is provided while on the job. Hence to effect change in the private schools in Pakistan changes will have to be brought about in the manner in which teachers are trained or mentored on the job referred to as "other teacher development programs" in the recommendations.

Though I have stopped at five major recommendations, if truth be told there are many other issues that need to be dealt with if we want better science education for our children. One major issue is that of the language of instruction for science. While acknowledging that children learn best in their mother tongue the issue of the use of science terminology in languages other than English remains a tough challenge which is difficult to tackle. However, if these recommendations were implemented in true spirit over time a universally science literate body of school students would emerge who would understand their world better.

The policy brief and the five recommendations are based on my years of experience as a science teacher and a science teacher educator. They are also based on three large qualitative and mixed method studies undertaken in the area of science teacher development. Brief abstracts of the three studies are presented for the convenience of the readers.

Science Classroom Research for Inquiry Process in Teaching (SCRIPT)

This mixed method research and development study of 2-year duration was funded by HEC to enhance understanding of teaching science through inquiry in the context of middle grades. Five School-Based Mentors were trained in teaching through inquiry-based methods and mentoring process while they remained in their own schools but spent 50% of their time in mentoring 30 science teachers teaching 1500 students in the middle grades. More than 80 inquiry lessons were observed to see how inquiry was implemented in the "real" classrooms. The findings showed that the school management and teachers were more than willing to support inquiry in science if appropriate resources were provided. With support from mentors science teachers' demonstrated a gradual shift in their teaching from structured to guided inquiry. However, the science teachers as well as some mentors found it difficult to develop inquiry processes and draw conclusions from data once collected. The study has also highlighted gaps in science content knowledge of both teachers and mentors.

Mentoring Science Teachers in Rural Sindh (MSTARS)

This study focused on the ten science mentors in two districts of rural Sindh, i.e., Sukkur and Thatta. The mentors were developed through a Cluster Based Mentoring Program and had to undertake a year-long Diploma in Science Education as well as needs-based workshops. In return the science mentors supported the teaching of science in the project schools in the districts by offering both science content and pedagogy workshops and classroom support to science teacher in the field over a period of 2-3 years. Some of these were observed for the MSTARS study. The key findings were that the science mentors defined their professional knowledge in terms of knowledge of science and pedagogy but not in terms of knowledge required for teacher development such as peer coaching and class observation skill. Furthermore, mentors were able to demonstrate a variety of teaching methods like model-making, demonstrations, group work, discussion etc. in the workshop. Though the ability to critique their own methods (models for instance) and evaluate the best method to teach a particular content needed further development in the majority of cases.

Study on Teacher Educators' Role and Practice

This mixed method study first developed an overall picture of the role and practice of teacher educators by using a cross-sectional descriptive survey of all teacher educators (n=184, 71 % response rate) in the 16 selected BEd degree awarding institutions located in Karachi and Lahore (8 private & 8 public). Through the survey were identified 32 teacher educators who volunteered to be a part of the qualitative study where they were interviewed and at least two of their classes were observed making 64 classroom observations. The findings indicate that becoming teacher educators is a secondary profession; where educators spend substantial number of years teaching in schools/colleges before becoming teacher of teachers. The classroom observation data indicate that generally teacher educators practice as content providers and not as practice providers. Teacher educators consider themselves teachers/lecturers in higher education institutions and continue to lecture using traditional methods. Furthermore, institutions/policymakers do not consider them as teacher educators but as "lecturers". Institutional vision and mission makes a large difference in what teacher educators do, how they teach, what they think about their teaching and what they expect out of their student teachers. Need for relevant professional development opportunities (especially regarding pedagogy) for teacher educators, especially in Science and Mathematics is greatly needed.

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Author's Profile

Dr Nelofer Halai is a Professor at the Aga Khan University, Institute for Educational Development in Karachi, Pakistan. She has played a leadership role in developing the doctoral program in Education at AKU which has now graduated 10 PhDs. She is the founding and the current president of the Pakistan Association of Research in Education (PARE) which is playing a key role in fostering a research culture in education in Pakistan. She is the recipient of the coveted Anna Marie Schimmel Award for doctoral studies, and received the Blanche Snell Award twice for dissemination of outstanding research findings, and she also received the Phi Delta Kappan Academic Leadership Award. Dr. Halai is on the Editorial Board of many national and international journals and has played a key role in developing the quality of local education journals through her membership in the HEC Education Committee. She teaches science methods and qualitative research methods to graduate students in the MEd, MPhil. and PhD programs. Dr Halai is an active researcher with many national and international research projects to her credit with publications in international journals. She is the recipient of one of the first social science research grant from the Higher Education Commission (HEC) for her research on professional development of science teachers. Her work on teacher education has received national and international attention both through her publications and her invited presentations. Her latest book, Enhancing primary science through school-based mentors: A study from Pakistan will be launched by Oxford University Press in 2018. She can be contacted at nelofer.halai@aku.edu