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RESEARCH PAPER

Maximizing Subject Matter Knowledge of Science Teachers through Professional Development Plan and Training

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ABSTRACT

The study examined the effect of content-based professional development training in science subject on teachers' achievement in science at primary school level. Professional development trainings develop and improve the required abilities and skills essential to impart quality teaching. The study has been conceptualized on Knowles (1984) theory of adult learning that assumed that adults should be involved in the planning and evaluation of their learning as this experience provides them basis to teach the subject which is relevant to their lives. The study employed one group pre-test post-test experimental design. 140 primary school teachers from 5 clusters in Sheikhupura district were selected as a sample of the study. The teachers received 40 hours training during the span of one week. They were pre-tested and post-tested using researcher made test based on the content taken from grade 5 science textbook. Descriptive statistics and paired samples t-test were used to analyze the data. The study found a significant difference in achievement scores of teachers' pre-test and post-test i.e. posttest scores were better as compared to pre-test. The study concluded that the content-based professional development training of teachers in science subject at primary school level is significantly important. The researcher recommends improving subject matter knowledge of science teachers to achieve the targets about the provision of quality education.

Keywords: Content-Based Competency in Science, Professional Development Training, Quality Education

Introduction

Developing students' scientific and cognitive literacy, advancing scientific understanding, and preparing them for responsible citizenship are the main objectives of science education. To be the best teachers they can be, science instructors need to meet and exceed the standards set by their students. To guarantee that students are prepared for careers, universities, and the workforce, they must make a commitment to ongoing professional development to be knowledgeable about their subject areas and efficient teaching techniques (Muzaffar, et. al. 2021 & Fontila et al., 2022). As governments throughout the world have come to understand that having a workforce proficient in science, math, and engineering is essential to their economic future, they have made it a priority for all kids to succeed in science. Since elementary school is when children's early attitudes and orientations are formed, there is a special focus on science. However, scientific instruction presents unique challenges in elementary schools (Slavin et al., 2014).

Teachers are unable to teach students concepts they do not grasp. Subject matter knowledge has been emphasized by education regulations (such No Child Left Behind) and numerous teacher preparation programs, which mandate that teachers hold an undergraduate degree in education or a closely related field. One of the fundamental tenets

of education is that increased subject matter expertise on the part of teachers leads to increased student knowledge gains (Chen et al., 2020 & Muzaffar, 2016). The way teachers educate in the classroom has a big impact on the learning of the students. Teachers' content knowledge and ideas are intricately and powerfully tied to their practice. Many researchers think that because they lack the material and pedagogical competence to effectively teach science to young students, teachers may feel uncomfortable doing so, which lowers their motivation and capacity to provide engaging science experiences for students. These emotions deter individuals from instructing science since they make them feel inexperienced and unconfident (Drits-Esser et al., 2017; Mccormack, 2015; Slavin et al., 2014).

It is crucial to have a science subject knowledge foundation to encourage young scientists. It is often acknowledged that an effective teacher must possess "good" content understanding. Elementary education teachers' understanding of science and the problems associated with teaching science is one of the main determinants of how effectively and efficiently they teach science. Teachers' representation of the material to students is influenced by their content understanding (Mccormack, 2015). To develop the required skills in child, primary education has great importance and therefore governments of Pakistan have been making effort for ensuring the quality education to primary school students and helping them to achieve quality of education. There are various initiatives which have been taken by the government such as budget allocation, increasing enrollment number, enough teachers, and different other basic needs to improve the primary education. To enhance the success rate in Punjab Examination Commission (PEC) related exams, the Punjab Education Foundation (PEF) focused on improving the quality of primary schools through Public School Support Program (PSSP). Under that program, a public university in the Punjab province adopted some primary schools located in rural area of a district and set up a monitoring mechanism for their continuous supervision.

In that set up, the newly appointed teachers were less qualified and inexperienced and most importantly, they lacked in content-based competency in science subject. The research tells that the teachers with weaker knowledge in science are not suitable for improving students' success rate in high stakes tests (Kouser et al., 2011; Muhammad & Iqbal, 2015) and need professional development training on urgent basis to maintain minimum quality standards and enhance their content-based competency in science subject. Multiple studies emphasized the importance of professional development training to develop and update content-based knowledge especially in science teachers (Akerson & Hanuscin, 2007; Diamond et al., 2014; Duncan Seraphin et al., 2017; Heller et al., 2012; Hartshorne, 2005; Lakshmanan et al., 2011).Therefore, through employing an experimental approach, this study examined the effect of professional development training on the teachers' content-based competency in science subject which is highly needed to evaluate the effectiveness of professional development training programs in Pakistan.

Hypothesis

H.0: There is no significant difference in teachers' achievement scores in pretests and posttests in science.

Conceptual Framework

The study has been conceptualized on Knowles (1984) theory of adult learning that assumed that adults should be involved in the planning and evaluation of their learning as this experience provides them basis to teach the subject which is relevant to their lives. The study used an experimental approach which help the staff and head teachers for improving their approach.

Literature Review

Professional development Training and Content-Based Competency in Science Subject

At primary level, there are multiple issues involved such as less qualified teachers, use of poor teaching methods and assessment techniques, and lack of professional development training (Kouser et al., 2011; Ministry of Education, 2009; Muhammad & Iqbal, 2015), but most important teachers are lacking in their content knowledge especially in science subject which requires higher order competencies to teach the subject as compared to arts subjects (Ahmad et al., 2013; Lakshmanan et al., 2011). Memon (2007) criticized the low teaching quality and poor content knowledge as two wide-ranging problems of declining student performance. In Pakistan, Akram and Butt (2021) found that the several of reasons of failure for primary education system include memory-based assessment rather than testing analytical ability, poor content knowledge, and low teacher quality. Moreover, lack of financial resources, insufficient teaching staff and ineffective teachers' content knowledge are the important indicators of low-quality teaching in Pakistan at primary level (Ahmad et al., 2013). In certain situation, when the primary schools were failing and the Punjab government was paying billions of rupees to the caretakers of these failing schools, it was high time to provide trainings where possible, and suggest remedial actions so that the system could work effectively. This research was initiated to address these challenges properly and find out the proper solutions to maximizing teachers' knowledge in science.

Various studies have examined the effect of professional development programs on teachers' content-based competency in science subject at school level. Diamond et al. (2014) investigated the effect of professional development interventions on teachers' content knowledge in science subject through different tests, questionnaire and classroom observations. The study revealed that experimental group performed better as compared to control group which confirmed that professional development training contributed in the content-based competency of teachers in science subject at elementary school level. In another study, Heller et al. (2012) examined the effect of professional development models on teachers' knowledge in science subject and student achievement through using casual comparative approach. The study explored that teachers' knowledge gradually improved after providing trainings through different models of professional development that further enhance quality learning of students. Duncan Seraphin et al. (2017) investigated the effect of professional development through using inquiry based approach to teach science on student achievement and revealed through making teachers' competent in using the inquiry based teaching for science subject, quality education and student achievement can be maximized.

Akerson and Hanuscin (2007) investigated the effect of three years' professional development program on teachers' knowledge, practices and student engagement in science subject which revealed that professional development contributed to improve the teachers' knowledge and instructional practices in science subject at elementary school level. Another study examined the effect of standards-based professional development on the instructional practices and content-based knowledge about science subject and revealed the similar results that teachers' content knowledge and instructional practices in science subject can be maximized through the training on regular basis (Lakshmanan et al., 2011). Drits-Esser et al. (2017) examined the impact of a year-long professional development program on the patterns of change in primary school teachers' inquiry practices, beliefs, and science content knowledge. Fifteen teachers of grades four through six from three underperforming US schools participated in the study. The program's effectiveness in promoting teacher transformation was demonstrated by the results, which showed statistically significant increases in all three measures' scores during the program year. Scores for content knowledge rose dramatically in the year after the professional development.

Bennett et al. (2019) assessed the effects of a professional development program designed to raise the subject leadership capacity and subject and pedagogic content knowledge of primary school science teachers. The findings showed that a large number of teachers in the treatment group expressed greater confidence in their ability to teach science after their subject knowledge had improved. Kibona et al. (2020) conducted a study on content and pedagogy requirements for Professional Development (PD) aimed at enhancing science teachers' abilities in Mbeya, Tanzanian secondary schools. The findings showed that in order to be good scientific instructors, science teachers need Professional Development (PD) in Pedagogical Knowledge (PK), mastery of science subject contents, and technical skills of modern teaching.

Hanley et al., (2020) examined the effects of a professional development program for teachers that promotes more participatory, practical, and cognitively demanding science lessons. Through encouraging more discussion, more practical work, and less (but more concentrated) writing in scientific classes, the "Thinking, Doing, Talking Science" (TDTS) approach was created to improve teachers' abilities to provide conceptual challenge and improve students' higher order thinking. The results indicated that TDTS professional development program for teachers significantly improved primary science students' attainment and attitudes. Finally, Hartshorne (2005) found that content-based competency of teachers in science subject can be improved through providing professional development opportunities. In overall, all the provided studies concluded that content-based competency in science subject can be maximized through development trainings.

Material and Methods

For this experimental study, 140 primary school teachers were selected for intervention. Training was arranged after obtaining the achievement score of pre-tests to improve their weak areas. Teachers were given a separate training to develop their professional development plans so that the trainings could be more relevantly design for them. To develop the content-based competency in science, teacher training module was developed and training was given by high qualified teacher education faculty of a public university. After taking the post-test, effect of training was measured through the difference between pretests and posttests. The teachers were grouped into five clusters due to keeping the groups smaller.

Threats and Control

Numerous biases pose a threat to educational research studies that use the single group "pre- and post-test" design. This design usually involves the following steps: participant selection, pre-testing, exposure to an educational intervention, and post-testing (Marsden & Torgerson, 2012). The possible threats that typically occur during one group pre-test post-test design experiment are history, maturation, instrumentation and testing (Creswell, 2012).

The researcher made sure to control these threats so that the outcome of the experiment can be stated confidently. The threat of history is related to events may occur between the pre-test and post-test that influence the outcome of experiment. Maturation is related to participants becoming older, wiser, stronger, and more experienced during an experiment. This may result in changes in their scores between the pre-test and post-test. In this experiment, the training period was one week which minimize the chance of maturation and happening any event which can affect the results of training. Testing is another potential threat to internal validity which means participants may become familiar with the outcome measures and remember responses for later testing. The researcher carefully conducted the test and did not tell participants that same test will be used for post-test. To control the threat of instrumentation the researcher used standardize procedures throughout the experiment.

Table 1
Cluster-Wise Sample Distribution

S. No.	Name of Cluster	Participants (f)
1	Cluster 1	30
2	Cluster 2	27
3	Cluster 3	30
4	Cluster 4	30
5	Cluster 5	23
	Total	140

Testing

The major segment of the study was testing teachers' current knowledge in Science subject. To serve this purpose, one of the researchers developed the test of Science from the content and the questions were taken from the textbook of grade 5 approved by the Punjab Textbooks Board (PTB) Lahore. The *Science* test comprised 80 marks and included questions related to basic concepts of science such as living and nonliving things, plants, human body, anatomy of human body, and weather. The test comprised both objective and subjective type questions. The objective type part included fill in the blanks and short questions, while extended-response essay type questions were also included. Multiple Choice questions were not included in the test to minimize the guessing chance. The content validity of the test was ensured by the experts and practitioners. Five content experts with the background in teaching Science were requested to validate the content of the test. The corrections were made in the test according to the given feedback from the experts. After making proper seating arrangements, sampled teachers were pretested through ensuring strict invigilation and marking according to rubrics by the researcher.

Professional Development Plans, Module Development, and Intervention

Through providing training, professional development plan was developed which further provided assistance to achieve all targets of training. To support planning and implementation of professional development, Tucker (2013) Professional Development Taxonomy (PDT) framework was followed which is useful for planning professional learning, supporting implementation, measuring progress, and evaluating results. Going through this framework, the examinees were given training regarding how to develop objectives based on competencies they needed to enhance, discuss methods and strategies to achieve those objectives, mention the sources they needed to access, the timeframe they expect to accomplish the activities, the success indicators regarding achievement of the competencies, and the improvements if required. In the end, the teachers were given an assessment sheet regarding designing individual plan for their professional development. Responding to the assessment sheet, the trainees were able to describe objectives of their professional development and find out the gaps in their learning, and were much interested in developing their competencies in all the content of Science subject they were pretested in. They set almost similar objectives, and were ambitious to achieve objectives after receiving detailed training. The module for Science subject was developed based on the content from the textbooks of class 4 and 5.

The training related to *Science* teaching was conducted by the trainer. The *science* training included the explanation of the concepts related to vertebrates, invertebrates, embryo and sperms, decomposers and their works, the concepts of gases with bad smell, types of soil and seeds, the solar system and its functions, mass, weight, infection, and boiling and freezing points. The trainer used charts, power point, and textbook of class 5. Through lecture, discussion, and hands-on activities, the trainer involved the trainees in the concept development process. During the training, the trainees frequently asked questions, discussed the concepts is small groups, and used white board to demonstrate individual

understanding of the scientific concepts. Different pictures of things such as machines, the things and their level of friction, life under water, and life cycle were shown, through multimedia, to know their understanding of the concepts and information given in the pictures. Various concepts given in the textbook were practiced by the primary school teachers during the training.

Post-Testing

After one week training, examinees were post-tested through using the same procedure of the pre-test. The scores of each examinee were entered into SPSS for conducting relevant analyses and further data were made clean before making the analysis.

Results and Discussion

In the given study, descriptive statistics (Mean & SD) and paired sample t-test were used to analyze the data.

Table 2
Descriptive Statistics--Pre-Test and Post-Test Achievement Scores in Science Subject

Subject		N	Mean	SD
Science	Pre-test	140	15.49	12.487
	Post-test	140	51.55	15.048

Table 2 revealed that teachers achievement scores in post-test for Science subject (M=51.55, SD=15.048) was found better as compared to teacher achievement scores in pre-test for Science subject (M=15.49, SD=12.487).

Table 3
Paired Samples t-test for Content-based Comparison in Science Achievement

Subject		M	SD	t	df	Sig	Effect Size
Science	Pretest	15.49	12.487	27.834	139	.000	2.607
	Posttest	51.55	15.048				

Table 3 revealed the significant difference between mean score of the trainees in pre-test (M=15.49, SD=12.487) and post-test (M=51.55, SD=15.048), $t(139)=27.834$, p=.000. It means that trainees' performance was significantly better in post-test than their performance in pre-test. The effect size (d=2.607) showed the effect of the training was quite large.

Discussion

To find the effect of professional development training on the teachers' content-based competency in science subject, the study at hand used an experimental approach which revealed that there was significant difference in the achievement scores in pre-test and post-test for the science subject which endorsed the idea that professional development training significantly affected the teachers' content-based competency in science subject at primary school level. The results of the study are in line with multiple of previous research, theories and models that teachers' content-based competency in science subject might be improved through professional development trainings at school level (Akerson & Hanuscin, 2007; Diamond et al., 2014; Duncan Seraphin et al., 2017; Heller et al., 2012; Hartshorne, 2005).

There are various studies which confirmed the importance of professional development training to enhance the teachers' content-based competency in science subject and overall instructional process in education system. Diamond et al. (2014) revealed in their study that experimental group performed better as compared to control group which confirmed that professional development training contributed to the content-based

competency of teachers in science subject at elementary school level. In another study, Heller et al. (2012) also explored that teachers' knowledge gradually improved after providing trainings through different models of professional development that further enhance quality learning of students. Duncan Seraphin et al. (2017) revealed that through making teachers' competent in using the inquiry based teaching for science subject, quality education and student achievement can be maximized. All the provided studies are in line with the study which confirmed idea that both the variables which have great importance in education system are interlinked with each other.

Further, Akerson and Hanuscin (2007) also revealed that professional development contributed to improve the teachers' knowledge and instructional practices in science subject at elementary school level. Moreover, Lakshmanan et al. (2011) also found the similar results that teachers' content knowledge and instructional practices in science subject can be maximized through the training on regular basis. Similarly, in another study, Hartshorne (2005) also found the similar results that content-based competency of teachers in science subject can be improved through providing professional development opportunities. In overall, all the provided studies are in line with the study at hand and concluded that content-based competency in science subject can be maximized through development trainings.

Conclusion

The study examined the effect of professional development training on the teachers' content-based competency in science subject through using an experimental approach. The study revealed that achievement scores in post-test were better than pre-test for the teachers' content-based competency in science subject and significant difference in achievement scores of pre-test and post-test for teachers' content-based competency in science subject was also found which confirmed that professional development training affected the teachers' content-based competency in science subject at primary school level.

Recommendations

The study found the difference in achievement scores of pre-test and post-test in the teachers' content-based competency in science subject, therefore the study recommended to conduct professional development trainings for primary school teachers on regular basis to enhance and update teachers' content-based competency in science subject that are most required to achieve the targets about the provision of quality education. Further, the study also asked to district authorities and policy makers to make arrangements for these trainings of teachers to develop the skills about content-based in science subject at primary school level.

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