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Effectiveness of Science Inquiry with Six Major Instructional Tools for Diverse Learners of Middle Level in Public Schools

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Abstract

Science inquiry method with six major instructional tools/principles is an emerging strategy for diverse learners. This strategy was applied through two separate studies to teach Chemistry and General portions from the textbook of General Science at the upper middle school level in two Public Schools of Lahore. To conduct this experimental research, initially, 8 prospective science teachers were selected to get trained through two workshops of three days each. In the first workshop, collectively 40 lesson plans were prepared for both studies from the General Science by incorporating six major principles, such as Big ideas, Conspicuous strategies, Mediated scaffolding, Strategic integration, Prime background knowledge and Judicious review. Whereas in the second workshop, four prospective teachers who were willing for this experimental research, were invited to participate in the workshop divided into two teams (two teachers in each team). Both research teams conducted this research in separate schools at upper middle school level (8^{th} class) for 6 weeks. One team used this method to teach the Chemistry portion by selecting a random sample of 30 students of 8^{th} class from one public school, whereas, the second team conducted this experimental research to teach the General portion of the General Science textbook of 8^{th} class by selecting a random sample of 33 students from another public school of Lahore. The pretest and posttest were applied. Results of both research teams indicated that t-values 24.873 and 23.437 were significant at $p \leq 0.05$ level of significance. It shows that inquiry method with six major instructional tools for diverse learner of 8^{th} class was effective. This also proved that lesson planning and teachers' training was also successful in accommodating diverse learners at this level.

Keywords: Diverse learners, science inquiry, six instructional tools

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Introduction

Learner diversity is a prominent issue of probably every classroom, especially at the elementary school level. In Pakistan, apparently, the main issue is of teaching science for all learners (diversified) at upper elementary level. The previous review on effective teaching concluded that no single teaching strategy is effective all the time for all the learners (Killen, 2005). Therefore, the major concern is how to cope with this difficulty. How best to educate the students of the multi-cultural world of diverse backgrounds, values, customs and socio-economic status is a reasonable question of today's classroom. The curriculum of science at this level has been improved, but a question arises, whether the teachers are trained either academically or professionally, enough to effectively implement it. Thus, it is vital to understand the student diversity and developing awareness to avoid application of the teaching principles as 'recipes'. Elementary teachers need to know more to help every student succeed in the classroom through reaching their full potential. It demands that elementary teacher should understand the notion, 'what works for diverse/average students?' For this purpose, effective science teachers may adapt their teaching to address the learning needs of every student in the classroom (Lemlich, 1998). In reality, each student is proud to enter the classroom with his or her own unique identity which has been developed through his/her past experiences and use of various abilities in different circumstances. Similarly, the ethnicity, social class, gender and religion also have a significant effect on his attitudinal and motivational aspects of personality (Moreno, 2012). All these factors combine to signify his/ her individuality into a diverse learner in the science classroom. Diversity is a sweet feature of humanity because everyone is unique due to his or her own individual characteristics originated mostly from individual and group differences.

In this context of diversity, effective teachers serve as cultural mediators in today's classrooms. They are required to guide the learners to think critically about diversity, promote acceptance and reduce biases with their intentional efforts among diverse students (Banks, 2006; Redman, 2007). Reflective teachers also strive to work effectively for reducing their own biases or expectations and make sincere efforts to work with the diverse learners and accommodate them along with their individual/ group differences or even to their disability (Pang, 2005).

The concept of diversity is too much broad in its true sense but it can be grasped in the mind by considering its three categories which include, group differences, individual differences and exceptionalities (Moreno, 2012). With the help of these three facets of diversity, each learner can be easily tackled in science classrooms, particularly at an upper elementary level where students are mostly 12- 14 years of age. In this sense,

they are approaching formal operational stage according to Piaget's description of intellectual development. Educators must understand that schools need to go beyond data and information accumulation and move toward the generation of useful and applicable knowledge, a process supported by inquiry learning. In the past, perhaps a country's success depended on their supply of natural resources. Today, it depends on a workforce that "works smarter" (Banks, 2006). Through the process of inquiry, individuals construct much of their understanding of the natural and human-designed worlds. Inquiry implies a "needs or wants to know" premise. The inquiry is not so much seeking the right answer -- because often there is none -- but rather seeking appropriate resolutions to questions and issues. For educators, inquiry implies emphasis on the development of inquiry skills and the nurturing of inquiring attitudes or habits of mind that will enable individuals to continue the quest for knowledge throughout life (Martinello & Cook, 2008). Thus, it is very useful to apply inquiry learning approach along with six instructional tools for diverse learners because the students of 8th class are mostly assumed to be at the abstract stage. But due to their diversity, they may not learn science effectively. The teachers, administrators and textbook authors/publishers do not take their cognitive and emotional needs into account seriously. Our country is much populous and science education is mostly neglected by our authorities. 'Science for all' is a popular slogan of the advanced nations at middle school level but unfortunately, our young generation is deprived of effective science teaching. As a result, our schools cannot inculcate the vision of science learning and teaching at a broader scale (Coyne, Kawi, Enki & Carine, 2011).

The brief history of instructional methods reflects a swing between two approaches of either exclusive teacher-centred or principally student-directed. Similarly, content goals swing from a predominated emphasis on basics to ambitious goals emphasizing advanced applications and higher-order-thinking. But unfortunately, the consequences for diverse learners of such dichotomous thinking have not been addressed properly. For example, if diverse learners receive all or almost all of their instruction through teacher direction, they are unlikely to become independent and self-regulated learners. At the opposite extreme, the effects of purely child-centred discovery approaches have ranged in the form ineffective detrimental for less motivated and disabled students (Corno & Snow, 1986; Jeynes & Little, 2000).

As in most things, 'moderation' serves diverse learners best. Teacher direction can be very helpful during the initial phase of learning new content but students should purposefully weave from teacher direction to ensure that they become self-directed. Similarly, diverse learners have the right to a full complement of academic experience, including rigorous higher-order thinking. As to our knowledge, there is no single theory of cognition contends that higher order thinking may emerge automatically. However, a prominent model of six major principles of effective instructional tools which are Big

ideas, Conspicuous strategy, Mediated Scaffolding, Strategic Integration, Primed Background knowledge, and Judicious Review has been proposed as an effective teaching strategy that accommodates diverse learners (Coyne, Kame'enui & Carnine; 2012). The inquiry is a process by which children actively investigate their world through questioning and seeking answers to their questions. This process is characterized by actions such as probing, searching, exploring and investigating (Martinello & Cook 2008). The philosophy of inquiry-based learning finds its antecedents in constructivist learning theories, such as the work of Piaget, Dewey, Vygotsky, and Freire among others, and can be considered a constructivist philosophy, as cited by Alsop & Hicks (2013). Inquiry learning emphasizes constructivist ideas of learning, where knowledge is built from experience and process, especially socially based experience. Under this premise, learning develops best in group situations. Inquiry used within an educational setting is recognized as both a learning objective and a teaching methodology. Inquiry activities are developed to give students ample opportunity to explore, apply prior knowledge, examine, extend understanding toward new learning, and to evaluate their progress in developing new understandings. Inquiry education is most effective when students are able to recognize the importance or validity of their learning and how it can be applicable to their own lives. Banchi & Bell (2008) explain that teachers should begin their inquiry instruction at the lower levels and work their way to open inquiry in order to effectively develop students' inquiry skills. Open inquiry activities are only successful if students are motivated by intrinsic interests and if they are equipped with the skills to conduct their own research study. The teacher's responsibility during inquiry exercises is to support and facilitate student learning. A common mistake teachers make is lacking the vision to see where students' weaknesses lie. According to Bain, teachers cannot assume that students will hold the same assumptions and thinking processes as a professional within that discipline. Schwab (2004) recommended that students be taught to view science as 'enquiry' (a variation of the term 'inquiry') rather than a static body of information to be learned. He further recommended that students be taught the skills of inquiry and helped to apply them to conduct science investigations.

Therefore, it is need of time to train science teacher at a larger scale to teach science effectively and efficiently for developing the appropriate cognitive level of our diverse students. Science enquiry or discovery learning is very difficult to apply without proper training. Thus, six principles may be incorporated into science inquiry method to apply them in teaching science at middle school level particular for diverse learners at the public schools. In this way, this strategy will promote the higher level of thinking skills such as, problem solving, decision making, creativity and critical skills.

Methodology

This research study was carried out through two separate experimental groups by two separate research teams of teachers but both consisted of only one kind of experimental design i.e. Pre-test/ post-test of one experimental group was chosen to conduct this research study.

To conduct this research study, primarily eight female prospective science teachers who had recently completed their Master's degree in Science Education (M.S.Ed) with CGPA more than 3.00/4.00 in the session 2016-2017, were selected. They were divided into two groups (4 members in each team). From the content of entire textbook of 8th grade General Science, two portions were selected as follows:

1. Chemistry
2. General Science

Each research team was assigned one portion of the above-mentioned content of General Science. The validity was ensured in conducting two training workshops for the science teachers as research teams.

Training Workshop 1 - Lesson planning of inquiry for diverse learners

The principal researcher conducted two workshops.

1. In the first step, eight prospective Science teachers were invited to participate in this one day workshop. At the start of the workshop, all the participants were welcomed and informed about the goals of the workshop. In this workshop, three sessions were arranged. In the first session, the topic of applying six major principles of effective instructional tools in science inquiry for diverse learners at upper middle school was discussed by the principal researcher himself. The participants were given one topic initially, related to their area of interest such as, Physics, Chemistry, Biology and General portions from the General Science textbook. They were asked to prepare their lesson plans according to the teaching strategy of inquiry learning in groups. They were given common criteria to include six major principles of effective instructional tools/strategies such as:
   (i) Big ideas
   (ii) Conspicuous strategies
   (iii) Mediated scaffolding
   (iv) Strategic integration
   (v) Paired background knowledge
   (vi) Judicious review

2. In the second session, all the volunteers were trained to develop specific objectives which were discussed in the context of inquiry learning for diverse learning. All the participants were motivated to learn about the nature of developing specific objectives for diverse learners successfully.
3. In the third session, the two groups of four members each (according to their area of interest/specialization in M.S.Ed/B.Sc) were given the task to prepare two lesson plans by reviewing their mutual/individual inputs. All these lesson plans were prepared according to the criteria proposed by the principal researcher and then all these lesson plans were evaluated to ensure the unanimity among these lesson plans of the 8th grade General Science group. In this way, 'validity' was ensured for lesson planning in the first workshop and at the end of the workshop, participants were interviewed to obtain their willingness for conducting further research.

Training Workshop 2 - Teachers training

This workshop comprised of two sessions.

1. Reviewing of lesson planning

The content of entire textbook of 8th grade related to General Science was distributed among two teams with reference to their area of specialization (Chemistry or General Science). Each research team was required to prepare 20 lesson plans (40 in total) each according to the approved format in the workshops. In this validity was once again ensured to meet the important condition for conducting this particular experimental research.

2. Teachers' training (Teaching-learning methodology):

In this workshop, four prospective teachers were selected upon their willingness to conduct this research out of 8 participants. These selected research teams were required to deliver their lesson plans two times each with the help of low-cost materials for teaching to accommodate diverse learners. The principal researcher made his utmost effort to train all the teachers in the context of this science inquiry regarding learning and teaching for the diverse learners. Thus, it was ensured that the selected and trained teachers would apply six major principles of effective instructional tools in science inquiry to accommodate diverse learners for learning of general science at 8th grade.

Objectives

Following were objectives of both the studies:

i. To find out the learning outcomes of General science (Chemistry & General portion) for teaching diverse learners through the application of six major principles of inquiry at 8th class.
ii. To determine the effectiveness of the methodology of inquiry learning for the diverse learner at upper middle school by the teaching of trained prospective teachers.
iii. To find out the impact of lesson planning for applying six major principles of effective instructional tools in science inquiry for diverse learners at the upper middle school level.

Null Hypothesis

a) H_o1: There is no significant difference between the learning outcomes of diverse learners in pre-test and post-test of Chemistry/ General portion of upper middle school level (8th grade).
b) H_o2: There is no significant difference of teachers' training for applying six principles of effective inquiry method for diverse learners of 8th grade.
c) H_o3: There is no significant difference of lesson planning in the perspective of six principles of effective inquiry learning of Chemistry/General portion of the General science book of 8th grade.

The summary of both separate research studies (Chemistry & General Science) has been given below:

1. **Study-I (Chemistry Portion)**

   The research study-I for Chemistry portion was carried out through an experimental method. A sample of 30 students of 8th grade was randomly selected from a secondary school of Lahore district. Two equal tests were constructed as instruments for pre-test and post-test. Cronbach Alpha (SPSS, version VI) was used to check the reliability of the instruments which was obtained as 0.790. The validity of the instruments was ensured by the three experts after incorporating their opinions to improve it. Two trained prospective teachers taught the experimental group for 6 weeks. Three periods of 50 minutes each, per week, were allocated for interaction with the experimental group. . Initially, the time allocated for daily science class was 30 minutes; however, for the experimental research, the period duration was extended up to 50 minutes and reduced in number (from 6 to 3 times a week). Due to the time constraint of the

school and administrative problem, a team of two teachers were trained for the effective experimental treatment. This strategy was originally proposed by Coyne et al (2011). 20 lesson plans were prepared to teach Chemistry portion, consisting of three chapters of General Science of 8th class. These lesson plans were developed in the perspective of applying six major principles of effective instructional tools in science inquiry to accommodate diverse learners at the upper middle school level.

Table 1

Paired sample t-test for pre-score and post-score of students of 8th grade for chemistry portion

	M	*N*	*t*	*df*	*p*
Pre score	6.20	30	24.873	36	0.000
Post score	20.10	30			

Table 1 shows that t value (24.873) is significant at the $p \leq 0.05$ level of significance. So our null hypothesis (H_o1) that there is no significant difference between the results of pretest and posttest of Chemistry portion at 8th grade is rejected. Hence, it is concluded that there is a significant difference between the results of pretest and posttest of Chemistry portion at 8th grade. It means that applying six major principles of effective instructional tools to scientific inquiry to accommodate diverse learners at upper middle school level was effective. This also automatically verified that the second and third null hypotheses (H_o2 & H_o3) were also rejected, which indicates that teacher training and lesson planning for diverse learner was successful and effectively used for the teaching of the diverse learners. Inquiry method is more effective for diverse learners because the learning outcomes the chemistry portion of the general science of 8th class clearly indicated the effectiveness of this teaching methodology.

Table 2

A simple comparison between results of pretest and posttest of Chemistry portion of the general science of 8th grade is given as follows:

Pretest		Posttest	
M	6.20	M	20.10
Statements of pretest were 20		Statements of posttest were 20	
SD of pretest was 2.56		SD of posttest was 1.56	

Table 2 shows that mean and St. Deviation of pretest is 6.20& 2.56 while mean & St. Deviation of posttest is 20.10& 1.56 respectively. Here, it also verified that students perform better in posttest than that of pretest by using 6 teaching strategies for diverse learners.

2. **Study-II (General portion):**

This research study was also carried out through experimental methodology. Two equal tests were constructed as instruments for pre-test and post-test. Cronbach Alpha was used to check the reliability of the instruments which was obtained as 0.784. The validity of the instruments was ensured by the three experts after incorporating their opinions to improve it. Only one group of 33 diverse learners was randomly selected from 110 students of 8th grade from one school. Two trained prospective teachers taught the experimental group for 6 weeks. Three periods of 40 minutes each, per week, were allocated for treatment to the experimental group. 20 lessons plans were prepared to teach a General portion, consisting of 3 chapters of General Science. These lesson plans were developed especially applying six major principles of effective instructional tools in science inquiry to accommodate diverse learners at the upper middle school level.

Table 3

Paired sample t-test for pre-score and post-score of students of 8th grade in General/mixed portion

	M	*N*	*t*	*df*	*P*
Pre score	5.35	33	23.437	38	0.000
Post score	21.77	33			

Table 3 shows that t value (23.437) is significant at the $p \leq 0.05$ level of significance. So our null hypothesis (H_o1) that there is no significant difference between the results of pretest and posttest of General/mixed portion at 8th grade is rejected. Hence it is concluded that there is a significant difference between the results of pretest and posttest of General/mixed portion at 8th grade. It means that applying six major principles of effective instructional tools to scientific inquiry to accommodate diverse learners at upper middle school level was effective. The results of above table also verified that the second and third null hypotheses (H_o2 & H_o3) were also rejected, which showed that teacher training and lesson planning for diverse learner was successful and effectively used for the teaching of the diverse learners. Inquiry method is more effective for diverse learners because the learning outcomes in the Genera portion of the book of the General science of upper middle school level clearly indicated the effectiveness of this teaching methodology.

Table 4

A comparison between results of pre-test and post-test of General portion of the General science of 8th grade is given as follows:

Pretest		Posttest	
M	5.35	M	21.77
Statements of pretest: 20		Statements of posttest: 20	
SD	2.45	SD	1.37

Table 4 shows that mean and St. Deviation of pretest is 5.35 & 2.45 while mean & St. Deviation of posttest is 21.77 & 1.37. So it is concluded that students perform better in post-test than that of pre-test by using six major principles of effective instructional tools for diverse learners at upper-middle school level.

Discussion

Students make mistakes because they are often emotionally driven, thoughtless and make false decisions when feeling insecure. They need to be guarded against their carelessness and arrogance (Foresman, Fosl & Watson, 2017). Moreover, diverse learners need additional teaching and curricular requirements by virtue of their cultural linguistic and environmental backgrounds (Coyne, Kameiunni & Carinier; 2011). Science inquiry has been proved as a useful technique for developing the problem solving as well as creative skills. This strategy is effective at primary and secondary level when it is designed in the context of 5 E's model of learning science i.e. Engage, Explore, Explain, Expand and Evaluate. However, research indicates that this strategy is fruitful only for learners with high cognitive abilities or those who are motivated (Alsop & Hicks, 2013). Instead, learner diversity is not only a recent academic issue, rather a big challenge for the educators/ administrators particularly at elementary/ upper middle school level of public schools as well, because students with low socio-economic status are more emotional and create many classroom management problems for teachers (Goldston & Downey, 2013). To face this challenge, six tools or principles of science inquiry, i.e. big ideas, conspicuous strategies, mediated scaffolding, primed background knowledge, strategic integration and judicious review, provides a comprehensive evidence to accommodate diverse learners. However, the application of these tools/principles by everyone is not only difficult, but may not be applicable as such either. Therefore, the researchers designed two special workshops to train the four teachers and ensuring the same pattern of lesson planning for teaching General Science at upper middle level (8^{th} class). Although these teachers conducted their two separate researches at two different public schools for Chemistry portion and General portion of Science textbooks. But due to high validity and reliability, which was ensured in two workshops and through continuous monitoring by the researchers during the experimental treatment, the results of this research can be generalized regarding all the public schools of Lahore which is a populous city of Punjab, Pakistan. Therefore, the findings of the research study indicated that this strategy was very effective for diverse learner at upper middle school level. Researchers also recommend that this strategy may be applied at larger scale for teaching particularly all the science subjects at secondary level. Similarly, this strategy may be introduced for teacher training academies at all the provinces of Pakistan to raise the standards of education. The major contribution of this research study is to sensitize the

issue of diverse learning. This is because many students left their studies at elementary level, due to their teachers being unaware of the demands and needs of such children. By the addition of these six tools along with science inquiry, may resolve the issue of leaving school, as this strategy proposes many alternatives for different students of diverse backgrounds. When students will engage themselves in their learning process, it will not only motivate them for developing their critical thinking but also for attaining higher order thinking/ cognitive abilities (Awan, Perveen & Abiodullah; 2018).

Conclusion

The findings of the above mentioned both studies reflected that the students performed better in post-test than in the pre-test only due to the use of six tools as effective teaching tools/strategies along with science inquiry method for diverse learners. Hence, it can be concluded that science inquiry method was effective to accommodate diverse learners at upper middle school level in public schools only by applying the six major tools/principles. Similarly, the better achievement of diverse learners in the post-test verified that teachers training and lesson planning was also effective. Thus, Science inquiry method was an effective strategy to deal with the challenges in learning and teaching to the diverse learners at the upper middle level in public schools.

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