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Effectiveness of Argumentation based Instruction on Achievement in Physics of Higher Secondary School Students

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Abstract:
Background*: The way how science learn in schools is very much contradicted with the ethos of science. In schools, teachers present science as a readymade subject. This 'readymade' science in school ignores the contexts and situations in which concepts and theories in science are originally derived and used. Students get estranged from original scientific practices. Since the students are not expertise the epistemology of science, they failed to analyse the socio-scientific controversies they face in the modern technological world. Argumentation practices play a vital role in scientific epistemology. By integrating argumentation into science instructions, students can get a great opportunity to practice the language of science (Tippett, 2009).*
Materials and Methods*: In the present study, the investigator developed argumentation based instructional strategy to teach physics at higher secondary level. The investigator conducted a quasi-experimental research to validate effectiveness of Argumentation based Instruction on achievement in physics. For experimentation, the investigator selected students from two intact classes of grade 11 as sample of the study. From these, one class was randomly selected as control group and the other as experimental group. Then the investigator administered the pretests - Verbal Intelligence Test and Achievement Test in Physics for both groups. After the experimental treatment, the investigator administered the posttest- Achievement Test in Physics for both groups. The results of the tests were analysed statistically.*
Results*: The posttest and gain scores of achievement in physics of experimental and control group differ significantly at .01 level. Higher scores are associated with the experimental group. This points out that students who were taught through Argumentation based Instruction show significant enhancement in their achievement in physics than the students who received instruction through conventional method.*
Conclusion: *Argumentation based Instruction is more effective in enhancing Achievement in Physics of higher secondary school students than conventional method of teaching.*
Key Words*: Argumentation, Argumentation based Instruction and Achievement in Physics.*

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I. Introduction

One of the primary goals of education is to evolve people to advance personally fulfilling their responsible lives. In modern times, life is indubitably associated with science and technological advancements. Science education helps to foster understanding and habits of mind to face challenges of modern technological era. It trains students to nourish and advance a society which is open and righteous. In recent decades, science teaching is prevailed over the concepts of constructivism. Constructivist theories consider learning as modification of cognitive structures (Fosnot, 1996). It has both cognitive and social outlooks. The social outlook of constructivism is clearly pointed out in the works of Lev Vygotsky (1962). Social constructivism looks beyond individual mind of the learner and attributes how learners interact with world around them. The interaction and discourse with teachers, peers and environment are the fundamental things in the construction of knowledge (Pontecorvo, 1993). Consequently, discussions, debate and argumentation practices are considered to be most effective tools in modern science classrooms.

II. Need and Significance of the Study

Science is not an unquestionable collection of knowledge produced by reading the nature directly. Inquiry processes as well as examination by scientific community in specific and public in general are the two important features of scientific knowledge construction. Practices like checking alternatives, evaluation of evidences and examination of the authenticity of scientific conclusions are crucial elements in the advancement of scientific claims. Science education should give the same importance for the way of knowledge construction of science as that given for the products of science like theories and laws. Since argumentation is the

fundamental epistemic practice in science, the better way to engage student with the process of science is integrating scientific argumentation in their topics of study. The inculcation of argumentation is blooming area of interest among science educators (Erduran, Simon & Osborne, 2004).

Even though argumentation is an important aspect of science (Taylor, 1996), science education has not given much attention for argumentation practices. Current school science has not identified the pedagogical power of argumentation. Driver, Newton and Osborne (2000) describe "Science in schools is commonly portrayed from a 'positivist perspective' as a subject in which there are clear 'right answers' and where data lead uncontroversial to agreed conclusions". School science imparts a wrong idea that science is unproblematic and undisputable collection of laws and theories. This wrong notion will fail to improve learners' ability to critically examine scientific claims that confront in their day to day life. Students' scientific outlook may be affected many shortcomings through this notion. This leads to unscientific way of thinking and perceiving the universe.

Hence it is the need of the hour to develop an instructional strategy which integrates argumentation practices in science education scenario. The present investigation attempts to formulate an instructional design based on argumentation and to validate its effectiveness in terms of achievement in Physics.

III. Argumentation- Conceptual Frame Work

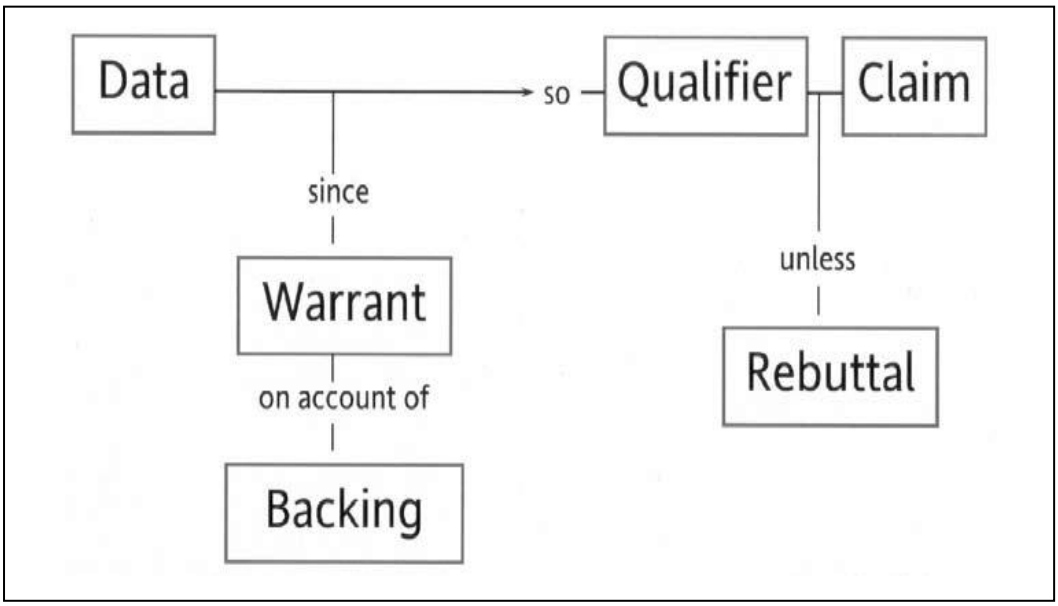
Discursive practices are vital elements of knowledge construction in science. Evaluating evidences, examining alternative conclusions and assessing feasibility of scientific conclusions are important aspects in the construction of scientific knowledge (Latour & Woolgar, 1986). Scientists engage in a process known as argumentation while they try to convince others for the validity of their claims and make consensus.

According to van Eemeren and Grootendorst (2004) "Argumentation is a verbal, social and rational activity aimed at convincing a reasonable critic of the acceptability of a standpoint by putting forward a constellation of propositions justifying or refuting the proposition expressed in the standpoint". To argue denotes to point out. Argumentation facilitates the interlocutor to make proper justifications. Argumentation can be considered as a special type of communicative technique where opinion is formed by scientific reasoning. Argumentation is used to convince someone for the validity of an opinion. One makes an argumentation when he/she wants to convince someone to decide in a specific manner on something that concerns him/her (Rigotti & Morasso, 2009).

Toulmin (1958) proposed a model on argumentation. The components of argumentation in Toulmin's model were (a) Claim, it is a conclusion (b) Data, they are the facts that support the claim; (c) Warrants denotes the explanation of how the data support the claim; (d) Backings, are the assumptions or theories that help to justify warrants; (e) Rebuttals, are related to the evidence to contradict others' opinion and (f) Qualifiers, are limitations or restrictions on a claim.

The argument model developed by Toulmin is presented as Figure no. 1.

Figure no. 1: Toulmin Argument Pattern (Toulmin, 1958)



IV. Argumentation and Science Education

Science has been revolutionizing people's view of nature and their ways of living. But there is a wrong understanding about science that, it is an empirical process to form claims, which are unproblematic inferences from observations (Driver, Newton & Osborne, 2000). There has been growing awareness of considering science knowledge construction as a social process. New scientific discoveries are evaluated by several establishments of science before it becomes a public knowledge. It is a regular practice that scientific discoveries are examined by experts before being published in academic journals, claims advanced by published articles are evaluated by peers, experiments may be repeated and alternative assumptions are forwarded and debated. In all these processes, argumentation practices play the central role.

Thus, for the significant perception of the processes of science, learning of science should be integrated with the practices of argumentation. While learning science, it is not worthy that the students just become passive receivers of the experts, rather they should practice raising and answering scientific questions. The students should be able to develop their own arguments and to critically evaluate alternative claims, so that they become dynamic contributor to the community of science. Students can able to get an insight into the epistemological practices of science by the process of argumentation.

Many educationists identified the importance of argumentation in science education.

Von Aufschnaiter, Erduran, Osborne and Simon (2008) investigated junior high school students' cognitive development and argumentation in science. The main purpose of the study was to examine how the content knowledge influences the quantity and quality of students' argumentation. The investigators found that argumentation facilitates students to improve their knowledge and understanding of science.

Kaya, Erduran and Cetin (2010) explored high school students' perception of argumentation in science classroom. The results showed that students exhibited positive attitude towards argumentation practices in science learning. Students claimed that their understandings of scientific endeavours were improved. The investigators suggested that teachers should modify themselves to integrate argumentation in science classrooms.

Lin (2013) investigated science undergraduate students' critical thinking ability and argumentation. The results revealed that quality of critical thinking is correlated with the strengths of arguments. The study pointed out the importance of argumentation in promoting critical thinking.

Cinar and Bayraktar (2014) examined the effectiveness of Argumentation Based Science Teaching on conceptual understanding of fifth grade students. The investigators found that students taught through argumentation based science teaching depicted significant improvement in conceptual understanding. Also, the students learned to produce arguments on scientific topics connected with everyday life.

Demirbag and Gunel (2014) studied the effect of Argument-Based Science Inquiry on science achievement and writing skills. The study was conducted on college students of the Central Anatolian Turkish University. Data analyzed qualitatively and quantitatively to explore the influence of Argument-Based Science Inquiry. The results of the investigation showed that the students received Argument-Based Science Inquiry approach performed better in achievement tests and writing skills.

Acar (2015) compared students' scientific reasoning in argumentation based approach and traditional approach. The sample of the study consisted of eighth grade students. Students' scientific reasoning was assessed before and after each instruction. Students taught through argumentation based approach showed significant improvement in scientific reasoning.

Demircioglua and Ucarb (2015) studied the effect of Argument Driven Inquiry based laboratory instruction on science process skills of pre-service science teachers in the General Physics Laboratory class. The sample of the study consisted of 79 pre-service teachers. They divided into two groups - control and experimental. The control group participated in traditional laboratory activities and the experimental group participated in laboratory activities based on Argument Driven Inquiry. The analysis of the data collected from the two groups showed that the science process skill of pre-service teachers participated in Argument Driven Inquiry improved significantly than those participated in rational laboratory activity.

In a study conducted by Songsil, W. et. al. (2019), the investigators developed a model which meets various important criteria for fostering argumentation in classrooms and named the model as Argument-Driven Inquiry (ADI) model. The investigators examined effectiveness of the model to increase students' scientific argumentation skills when learning about socio-scientific issues. A sample consists of 155 Grade 10 students was surveyed using a set of situational open-ended questions. The study found that most students could improve scientific argumentation skills and achievements while using the model.

Ural, E. and Gençoğlan, D. M. (2020) conducted a study to investigate effect of argumentation-based science teaching approach on 8th graders' learning of the science topics, their attitudes towards science class and their scientific process skills. The sample of the study consisted of 69 eighth grade students from two different classes attending Science and Technology course at a government school of Turkey. The design of the research was quasi experimental. The results of the study showed that the argumentation based science teaching

approach was more effective than the conventional teaching approach. The findings depicted that the academic achievement of the students taught with argumentation based approach was higher than the students taught with conventional approach. Also it was found that Argumentation Based Science Learning had no significant effect on students' attitudes towards science lesson. But the approach had a significant effect on students' science process skills.

From the analysis of the research reviews on argumentation, it is evident that the argumentation has been attaining too much significance in the field of science education and attracting the interest of educational practitioners all over the world. In this study, the investigator tried to develop an instructional strategy based on argumentation practices and validated its effectiveness on achievement in physics.

V. Argumentation based Instruction

According to Kuhn (1993), argumentation in science education includes process of proposing, supporting, criticizing, evaluating claims about science related topics. Current researches pointed out that the argumentation can be promoted through inquiry, discourse and collaborative based approach (e.g., Jimenez-Aleixandre, Pilar, Diaz de Bustamante, & Duschl, 1998; Kelly & Chen, 1999). Also socioscientific issues provide suitable context to stimulate argumentation practices in classrooms (e.g., Mason & Santi, 1994; Mortimer & Machado, 2000; Patronis & Spiliotopoulou, 1999). Therefore, the investigator developed a strategy by integrating socioscientific issues and inquiry and collaborative based approach to promote argumentation practices.

The investigator developed argumentation based instruction consisting of six phases. The instruction is based on Toulmin(1958) work on argumentation. The phases of the instruction are:

Phase I - Presentation of the Issue

Teacher introduces a socio-scientific issue related to the topic of study. The issues may be presented by exhibiting pictures, newspaper articles, videos or through any other media formats.

Phase I - Forwarding Questions

Teacher provides debatable questions. These questions should lead students into multiple responses and create an atmosphere for group discussion.

Phase III - Group Discourse

The students are directed to explore data and evidences related to the issue under investigation. This should be done in a collaborative manner. The students are grouped and start to investigate on the question forwarded.

Phase IV - Presentation of the Group Consciences

The students are asked to present their findings. The presentation should be in the following format:

- Claim: The conclusion reached
- Data: Facts that support the claim
- Warrant: Explanation of how the data support the claim
- Backings: Theories or laws that help to justify warrants
- Qualifiers: Limitations of the claim
- Rebuttals: Evidence to challenge the other claims

Phase V - Open Discussion

The class debates on the claims forwarded by each group and tries to reach a consensus.

Phase VI - Teacher Reiteration of the Topic

Teacher reviews the discourse processes and focuses students' attention into the topic of study.

VI. Objectives of the Study

The objectives of the study were presented below as general objectives and specific objectives:

General Objectives

1. To develop Argumentation based Instruction strategy on physics for higher secondary school students.

2. To find out the effect of Argumentation based Instruction on Achievement in physics of higher secondary school students

Specific Objectives

1. To compare the mean achievement scores in physics of Experimental group taught through Argumentation based Instruction and Control group taught through conventional method before experimental treatment.
2. To compare the mean achievement scores in physics of Experimental group taught through Argumentation based Instruction and Control group taught through conventional method after experimental treatment.
3. To compare the mean gain achievement scores in physics of Experimental group taught through Argumentation based Instruction and Control group taught through conventional method.

VII. Materials and Methods

Since the study was to find out effectiveness of argumentation based instruction on achievement in physics, experimental design was selected.

The experimental design selected for the study was quasi experimental pre-test post-test non-equivalent groups design. The design of the study is represented as

Experimental Group O1 X O2
Control Group O3 C O4

Where
O1& O3= Pre-tests
O2& O4 = Post-tests
X = Exposure to Experimental Treatment
C=Exposure to Control Treatment

The experiment was carried out in ten-week time period. Both groups were equated on the basis of verbal intelligence. Achievement test in Physics was administered to students as pretest and posttest.

Sample Selected for the study

For experimentation, the investigator selected students from two intact classes of grade 11 as sample of the study. From these, one class was randomly selected as control group and the other as experimental group. The number of students in the experimental and control groups were 56 and 59 respectively.

Tools Used

The tools and materials used for the present study were
1. Verbal intelligence test (Nasimudheen, 2019)
2. Achievement test in Physics (Nasimudheen, 2019)
3. Lesson transcripts based on Argumentation based Instruction (Nasimudheen, 2019)
4. Lesson transcripts based on conventional method of teaching (Nasimudheen, 2019)

Procedure for Data Collection

The experiment was conducted in the following three phases:
1. Pretest Phase
2. Treatment Phase
3. Posttest Phase

1) Pre-test Phase:

After getting consent for the experimentation from the authority of the school chose for the experimentation, two intact classes of grade 11 were selected. Among them, one class was randomly assigned as experimental group and the other as control group. Then the investigator administered the pretests - Verbal Intelligence Test and Achievement Test in Physics. Since argumentation may be influenced by the verbal intelligence of students, the investigator administered the verbal intelligence test before the treatment to check whether there exists any significance difference in verbal intelligence between the control and experimental groups. The rules and procedures of each test were strictly followed.

2) Treatment Phase:

In this phase, the experimental group was taught through Argumentation based Instruction and the control group was taught through conventional method of teaching. The conventional method was based on constructivist approach. Both the treatments were conducted in normal classroom setting. The units Mechanical Properties of Solids and Mechanical Properties of Fluids from grade 11 Physics text book published by NCERT, Government of India, were the selected as topics of the study.

3) Post-testing Phase:

After completion of the treatment, post-test was administered to both experimental and control groups. - Achievement Test in Physics was the post test. The response sheets were collected back after the completion of each test and were scored.

The three phases of experimentation were depicted in the Table 1.

Table no. 1: Phases of Experimentation

Phase	Experimental group	Control group
Pre-treatment phase	Administration of verbal intelligence test and achievement test in physics	Administration of verbal intelligence test and achievement test in physics
Treatment phase	Teaching physics through Argumentation based Instruction for 10 weeks	Teaching physics through conventional method for 10 weeks
Post treatment phase	Administration of achievement test in physics	Administration of achievement test in physics

VIII. Analysis and Interpretation of the Data

The present study was conducted to find the effectiveness of Argumentation based Instruction on achievement in physics of higher secondary school students. The objectives of the study were to compare the mean pre-test scores in achievement, mean post test scores in achievement and mean gain scores in achievement of experimental and control groups. t-test was administered on the scores and the results are presented in the following sections.

Comparison of Mean Pretest Scores of Verbal Intelligence and Achievement in Physics of Experimental and Control Groups

To compare the pre intervention status of the experimental and control groups with respect to the dependent variable verbal intelligence and Achievement in Physics, test of significance of difference between means of two independent groups was used. The data and results of the test of significance of difference between means presented in the Table 2

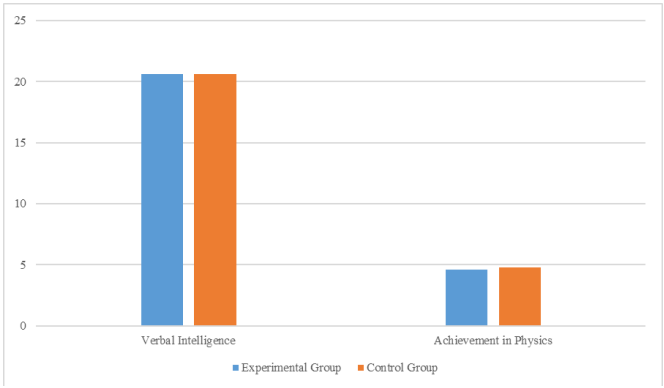
Table no. 2: Results of Test of Significance of Difference in Mean Pretest Scores of Verbal Intelligence and Achievement in Physics between Experimental and Control Groups

Variable	Experimental Group			Control Group			t
	N_1	M_1	SD_1	N_2	M_2	SD_2	
Verbal Intelligence	56	20.6	7.11	59	20.62	7.27	0.01
Achievement in Physics	56	4.59	2.02	59	4.77	1.85	0.61

It is evident from the Table 2 that the calculated t values of verbal intelligence and Achievement in Physics are not significant. This shows that the experimental and control groups do not differ significantly in their mean pre-test scores of verbal intelligence and Achievement in Physics. Thus the pre intervention status of the experimental and control groups on verbal intelligence and Achievement in Physics are same.

The results of the analysis are graphically represented in the Fig. 2

Figure no. 2: Graphical representation of Mean Pretest Scores of Verbal Intelligence and Achievement in Physics between Experimental and Control Groups



Comparison of Mean Posttest Scores of Achievement in Physics of Experimental and Control Groups

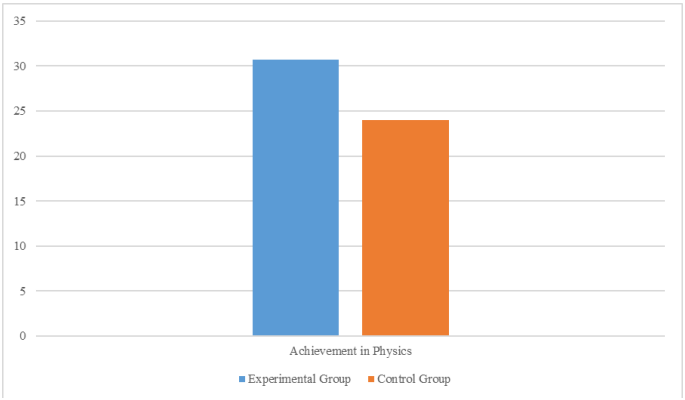
To compare the effectiveness of Argumentation based Instruction and conventional method of teaching in enhancing Achievement in Physics, comparisons of the mean post-test scores of Achievement in Physics of students in the experimental group and control group were done. Test of significance of difference between means of two independent groups was used for comparison of post-test scores. The means and standard deviations of post-test scores of Achievement in Physics of the two groups were subjected to mean difference analysis. The details are given in the Table 3

Table no.3: Results of Test of Significance of Difference in Mean Post Scores of Achievement in Physics between Experimental and Control Groups

Variable	Experimental Group			Control Group			t
	N_1	M_1	SD_1	N_2	M_2	SD_2	
Achievement in Physics	56	30.7	7.4	59	24.02	4.6	7.2

Table no. 3 shows that the calculated t value for Achievement in Physics is significant at .01 level. So the experimental and control groups differ significantly in the mean scores of Achievement in Physics after intervention and higher mean values are seen to associate with experimental group. Hence Argumentation based Instruction is more effective in enhancing Achievement in Physics of higher secondary school students than conventional method of teaching.
The results of the analysis are graphically represented in the figure no. 3

Figure no.3: Graphical representation of Mean post test scores of achievement in physics of experimental and control groups



Comparison of Mean Gain Scores of Achievement in Physics of Experimental and Control Groups

To test whether significant difference exists between mean gain scores of Achievement in Physics of experimental and control groups, comparison of mean gain scores was done using test of significance of difference between means. The means and standard deviations of gain scores of Achievement in Physics of experimental and control groups were subjected to mean difference analysis. The data and results of the test of significance of difference between means presented in the Table no. 4

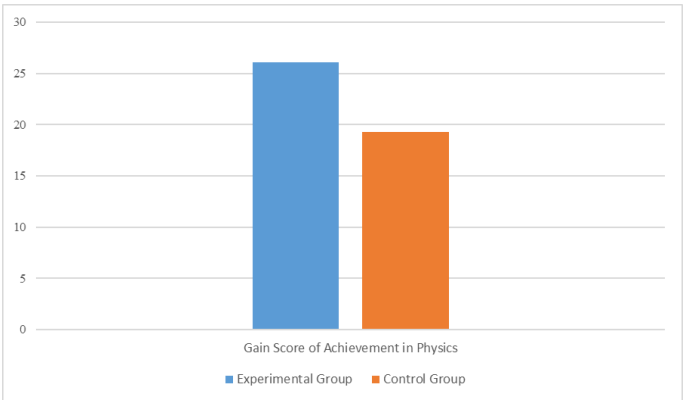
Table no. 4: Results of Test of Significance of Difference in Mean Gain Scores of Achievement in Physics between Experimental and Control Groups

Variable	Experimental Group			Control Group			t
	N_1	M_1	SD_1	N_2	M_2	SD_2	
Achievement in Physics	56	26.10	7.31	59	19.26	4.85	7.35

It is clear from the Table no. 4 shows that the calculated t value for Achievement in Physics is significant at .01 level. Hence there is significant difference between mean gain scores of Achievement in Physics of experimental and control groups. The mean gain score of the experimental group is significantly greater than that of the control group. Therefore, Argumentation based Instruction is more effective in enhancing Achievement in Physics of higher secondary school students than conventional method of teaching.

The results of the analysis are graphically represented in the Figure no. 4

Figure no. 4: Graphical representation of Mean gain scores of achievement in physics of experimental and control groups



IX. Major Findings of the Study

1. No significant difference was found in the pretest scores of experimental and control group on achievement in physics of higher secondary school students.
2. The post test scores of achievement in physics of experimental and control group differ significantly in favor of experimental group. This points out that students who are taught through Argumentation based Instruction show significant enhancement in their achievement in physics than the students who received instruction through conventional method.
3. The mean gain scores of achievement in physics of experimental and control group differ significantly in favor of experimental group. This shows that students who are taught through Argumentation based Instruction improved more in their achievement in physics than the students who received instruction through conventional method.

X. Educational Implications of the Study

1. The present study tried to develop an instructional design based on argumentation for enhancing Achievement in Physics. The study has confirmed that the developed strategy has promising effect on Achievement.
2. The study, through the effectiveness of argumentation based instruction, proved that if the instruction is personally significant and meaningful, students can acquire more scientific appreciations. Argumentation based instruction offers an effective platform to enhance argumentation practices thereby familiarizing the methods of scientific inquiry.
3. The developed instructional strategy suggests a real model which accentuates both scientific inquiry and achievement of the learner. Curriculum developers have to make use of the findings of the study and provide opportunity to link the content of the syllabus of science courses with argumentation practices.
4. Argumentation based instruction approach provides interdisciplinary connections. It promotes linking science contents with social studies, environmental studies, mathematics, civics, commerce etc. Argumentation based instruction gives an opportunity to bring real life into classrooms through peer-discussion and moral reasoning.

XI. Conclusion

Argumentation based Instruction is an effective technique in teaching physics at higher secondary level because there was enhancement in the achievement of students. Instead of promoting rote learning of scientific concepts, argumentation based instruction broadens students' understanding of science by providing opportunity to argue on science related issues. It is a student centred approach which impedes the teacher dominant one-way approach in traditional classrooms and initiate a platform where students can share different ideas, confront upon it and reach a conclusion based on accurate scientific norms. The shift from poker-faced reception to active participation and exploration make learning of physics joyful. Through argumentation practices, students can become acquainted with epistemology of science. Thus, it is strongly recommended that the inclusion of argumentation based instruction in the transaction of physics should be highly appreciated.

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