

Improving Science Process Skills among Science Teachers through Hands-on Experiments

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ABSTRACT

Science process skills are essential for effective science teaching and learning, as they enable teachers and learners to engage in scientific inquiry, observation, experimentation, reasoning, and communication. However, classroom observations indicate that science teachers often face difficulties in translating theoretical concepts into meaningful practical experiences. Limited exposure to experiential and activity-based teaching methods may also affect their competence in conducting hands-on experiments. The present Study was undertaken to examine the effectiveness of hands-on experiments in improving the science process skills of science teachers. A sample of 20 science teachers from government schools in the Perambalur Block was selected using purposive sampling. A single-group pre-test and post-test design was adopted.

The intervention consisted of training sessions and hands-on experimental activities designed to develop six core science process skills: observing, classifying, measuring, inferring, experimenting, and communicating. Data were collected through a science process skills assessment tool administered before and after the intervention. The results showed a clear improvement in all six skills. The overall average score increased from 50% in the pre-test to 90% in the post-test. The highest improvement was observed in observing (+43%), followed by classifying (+44%), measuring (+41%), inferring (+41%), experimenting (+34%), and communicating (+37%). The findings indicate that hands-on experimental activities can provide science teachers with practical opportunities to strengthen their science process skills and enhance their ability to integrate experiential learning into classroom practice. The study suggests that regular hands-on training and activity-based professional development may help teachers bridge the gap between theoretical knowledge and practical science teaching.

Keywords: Science Process Skills, Hands-on Experiments, Science Teachers, Experiential Learning, Science Education.

INTRODUCTION

Science education plays an important role in developing scientific thinking, curiosity, problem-solving ability, and an understanding of the world around us. The purpose of science teaching is not limited to providing information about scientific facts and concepts; it also involves developing the ability to observe, investigate, question, experiment, interpret, and communicate scientific ideas. These abilities are commonly referred to as science process skills. They help learners actively participate in the process of scientific inquiry and apply their knowledge to real-life situations.

Science process skills such as observing, classifying, measuring, inferring, experimenting, and communicating are closely associated with effective science learning. These skills cannot be developed adequately through theoretical instruction alone. Learners need opportunities to handle materials, perform

experiments, make observations, record findings, compare results, draw conclusions, and communicate their understanding. Therefore, hands-on experimental activities have an important place in science education.

The teacher plays a central role in providing such learning experiences. However, classroom observations suggest that many science teachers continue to depend largely on traditional methods of teaching, particularly when dealing with scientific concepts that require practical demonstration and investigation. Teachers may also have limited opportunities to experience and practise activity-based and experiential approaches. As a result, there can be a gap between theoretical understanding and the practical application of science in the classroom.

Hands-on experiments provide teachers with opportunities to experience science as an active process rather than simply as a body of knowledge. Through practical activities, teachers can develop their ability to observe carefully, classify objects or phenomena, make accurate measurements, draw reasonable inferences, conduct experiments systematically, and communicate scientific findings. These experiences can subsequently be transferred to their classroom teaching practices.

In this context, the present Study was undertaken to examine the effectiveness of hands-on experiments in improving science process skills among science teachers in the Perambalur Block. The study focused on six core science process skills—observing, classifying, measuring, inferring, experimenting, and communicating. A single-group pre-test and post-test design was used to examine changes in teachers' science process skills following the intervention. The study therefore seeks to explore whether structured hands-on experimental activities can contribute to the professional development of science teachers and strengthen their capacity to promote process-oriented science learning in their classrooms.

REVIEW OF RELATED LITERATURE

Science education aims to develop not only conceptual understanding but also the skills required to investigate scientific phenomena. Science process skills are fundamental to scientific inquiry because they enable learners to collect information, analyse evidence, draw conclusions, and communicate findings.

Padilla (1990) explained that science process skills involve abilities used by scientists when conducting investigations and solving scientific problems. These skills include observing, classifying, measuring, communicating, inferring, predicting, and experimenting. Developing these skills helps learners become active participants in the learning process rather than passive recipients of information. Hands-on learning has been widely recognised as an important approach for developing science process skills.

Hofstein and Lunetta (2004) stated that laboratory and practical experiences can provide learners with opportunities to investigate scientific questions, manipulate materials, collect evidence, and develop scientific reasoning. Practical activities can also help learners connect theoretical concepts with observable phenomena. Such experiences are particularly valuable in science because many concepts become more meaningful when learners are given opportunities to investigate them directly.

Abrahams and Millar (2008) examined the effectiveness of practical work in school science and highlighted the importance of designing practical activities that connect what students do with the scientific ideas they are expected to learn. Their work suggests that merely performing an experiment does not automatically result in conceptual or process-skill development. Practical activities need to be appropriately structured and linked with learning objectives. This is relevant to the present Study because hands-on experiments were organised with specific science process skills as the focus.

National Research Council (2000) emphasised that inquiry involves asking questions, gathering evidence, developing explanations, and communicating conclusions. Science teaching that provides opportunities for investigation can therefore support the development of observation, measurement, inference, experimentation, and communication. Teachers require appropriate knowledge and pedagogical strategies to create such inquiry-oriented learning experiences in their classrooms.

Kolb (1984) proposed that learning develops through a cycle involving concrete experience, reflective observation, abstract conceptualisation, and active experimentation. Hands-on experimental activities provide concrete experiences through which teachers can reflect on their own learning and subsequently apply similar approaches in their classrooms. This framework provides a useful theoretical basis for using practical experiences as part of teacher professional development.

The literature therefore indicates that science process skills are closely related to scientific inquiry and that practical experiences can provide meaningful opportunities for their development. At the same time, effective hands-on learning depends on appropriate planning, teacher preparation, and purposeful integration of activities with learning objectives. The present study builds on these ideas by providing structured hands-on experimental experiences to science teachers and examining changes in six core science process skills—observing, classifying, measuring, inferring, experimenting, and communicating—through a pre-test and post-test approach.

Objectives

1. To identify the needed science process skills.
2. To develop the science process skills among science teachers
3. To assess the science process skills among science teachers

Hypotheses

1. There is no significant difference between the pre-test and post-test scores of science teachers in their overall science process skills in hands-on experimental activities.
2. There is no significant difference between the pre-test and post-test scores of science teachers in observing, classifying, measuring, inferring, experimenting, and communicating skills.

METHODOLOGY

Research Method

The study employed an experimental research method with a single -group pre and Post test design to examine the effectiveness of hands-on experiments in improving Science Process Skills among science teachers. The independent variable was the hands-on experimental training, while the dependent variable was the Science Process Skills of science teachers.

The hands-on experimental intervention was designed to provide science teachers with opportunities to actively engage in practical scientific activities and develop key Science Process Skills such as observing, classifying, measuring, inferring, experimenting, and communicating. The study involved assessing the teachers' Science Process Skills before and after the intervention to determine the changes associated with participation in the hands-on experimental activities.

Sample:

A sample of 20 science teachers were selected from the Perambalur block. These teachers represent a cross-section of upper primary and secondary level educators working in government schools. The selection was done using purposive sampling,

Study Phases

The study was conducted in a systematic manner through different phases. Initially, the science teachers were selected as the participants for the study. A pre-test was then administered to understand their existing level of Science Process Skills before the intervention.

Based on the identified needs, suitable hands-on experiments were planned and organized. The selected experiments were then carried out with the participating science teachers as part of the intervention. The activities provided opportunities for the teachers to actively participate in practical scientific work and develop their Science Process Skills through direct experimentation.

After completing the intervention, a post-test was administered to assess the changes in the Science Process Skills of the teachers. The pre-test and post-test data were subsequently analysed using appropriate statistical techniques to determine the changes following the intervention.

The findings were then interpreted in terms of their educational implications, particularly for science teacher education and the effective use of hands-on experiments in science teaching. Finally, the study concluded with a summary of the major findings and suggestions for further research.

Research Design

Single group of participants was observed before (pre-test) and after (post-test) . The intervention in this case involves training sessions and practical activities designed to enhance science process skills using hands-on experimental methods.

Description of the Tool

A Science Process Skills Assessment Tool was developed by the investigator to assess the science process skills of science teachers before and after the hands-on experimental intervention. The tool consisted of 30 multiple-choice questions, designed in accordance with the objectives of the study and the six selected science process skills, namely observing, classifying, measuring, inferring, experimenting, and communicating.

Item Construction Procedure

The items were constructed by the investigator after reviewing relevant literature and considering the objectives of the study and the content of the hands-on experimental activities. The items were framed to assess the participating teachers' understanding and application of the selected science process skills. Care was taken to ensure clarity, relevance, appropriateness of difficulty level, and alignment of each item with the intended skill.

Content Validity

The content validity of the assessment tool was established through expert validation. The preliminary version of the tool was submitted to five teacher educators from District Institutes of Education and Training (DIETs) for expert review. The experts examined the items with respect to their relevance to the objectives of the study, clarity of language, appropriateness of content, and representation of the selected science process skills. Based on the suggestions and recommendations of the experts, necessary modifications were made to the items, and the final version of the assessment tool was prepared.

Number and Expertise of Validators

The content validity of the tool was reviewed by five teacher educators from DIET, who had expertise in teacher education, science education, and educational assessment. Their professional judgments were used to improve the relevance, clarity, and suitability of the items included in the final assessment tool.

Face Validity

The developed Science Experiments Questionnaire was given to a few subject experts in the field of Science Education and Science Experiments for Classes VI–VIII to obtain their opinions regarding the relevance, clarity, appropriateness, and suitability of the items. Based on the experts' suggestions, necessary

modifications were made to the questionnaire. Thus, the face validity of the developed questionnaire was established.

Scoring Procedure

The final assessment tool consisted of 30 multiple-choice questions, with one mark assigned to each correct response. Thus, the maximum possible raw score was 30 marks. Each correct answer was awarded one mark, while an incorrect or unanswered item received zero marks. The same scoring procedure was followed for both the pre-test and post-test to facilitate comparison of the participants' Science Process Skills before and after the intervention. Finally the score converted to 10 marks for calculation purpose.

Intervention Duration

The hands-on experimental intervention was conducted with the selected science teachers for a period of three months. The intervention involved structured practical activities designed to provide teachers with opportunities to actively participate in science experiments and develop their Science Process Skills.

Intervention Content

The intervention consisted of selected hands-on experiments from Physics, Chemistry, and Biology appropriate for the study from class VI-VIII. The experiments included activities such as measuring the focal length of a lens, studying the refraction of light, investigating the properties of acids and bases, observing yeast cells under a microscope and observing plant cells and so on. Through these activities, the teachers were provided opportunities to practise Science Process Skills such as observing, classifying, measuring, inferring, experimenting, and communicating.

Results

S. No	SAMPLE	Pre test scores Converted to 10	Post test scores Converted to 10
1.	SAMPLE 1	5	9
2.	SAMPLE 2	6	10
3.	SAMPLE 3	4	9
4.	SAMPLE 4	5	9
5.	SAMPLE 5	4	8
6.	SAMPLE 6	5	9
7.	SAMPLE 7	4	7
8.	SAMPLE 8	5	10
9.	SAMPLE 9	5	9
10.	SAMPLE 10	4	9
11.	SAMPLE 11	5	9
12.	SAMPLE 12	6	10
13.	SAMPLE 13	5	9
14.	SAMPLE 14	5	9
15.	SAMPLE 15	4	8
16.	SAMPLE 16	6	9

17.	SAMPLE 17	6	10
18.	SAMPLE 18	5	9
19.	SAMPLE 19	5	9
20.	SAMPLE 20	6	10

Hypothesis:1

There is no significant difference between the pre-test and post-test scores of science teachers in their overall science process skills in hands-on experimental activities.

The table shows mean standard Deviation values of pre and post test

Test	N	M	SD	t	Level of significance
Pre test	20	5.0	0.73	16.98	S (2)
Post test	20	9.0	0.76		

P value and statistical significance

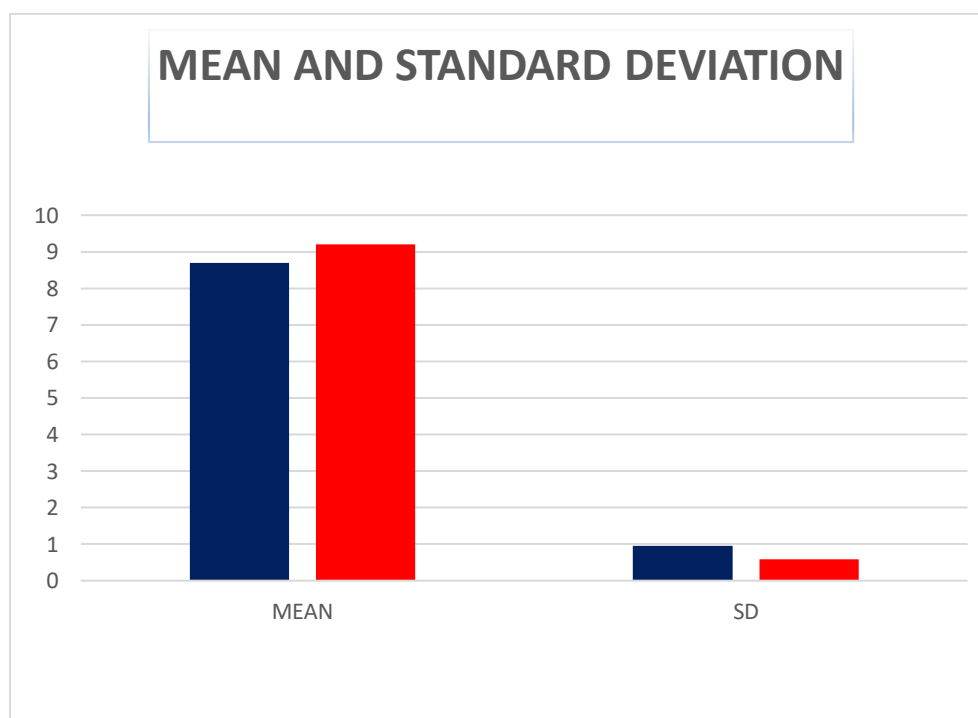
The two-tailed P value is less than 0.0001

By conventional criteria, this difference is considered to be extremely statistically significant.

N- No of participants

M — Mean Value

SD - Standard Deviation



The above table infers that the post test mean score is 9.0 higher than the pretest mean score 5.0. It clearly shows that the performance of science teachers in science process skills was increased. The 't' value 16.98 is

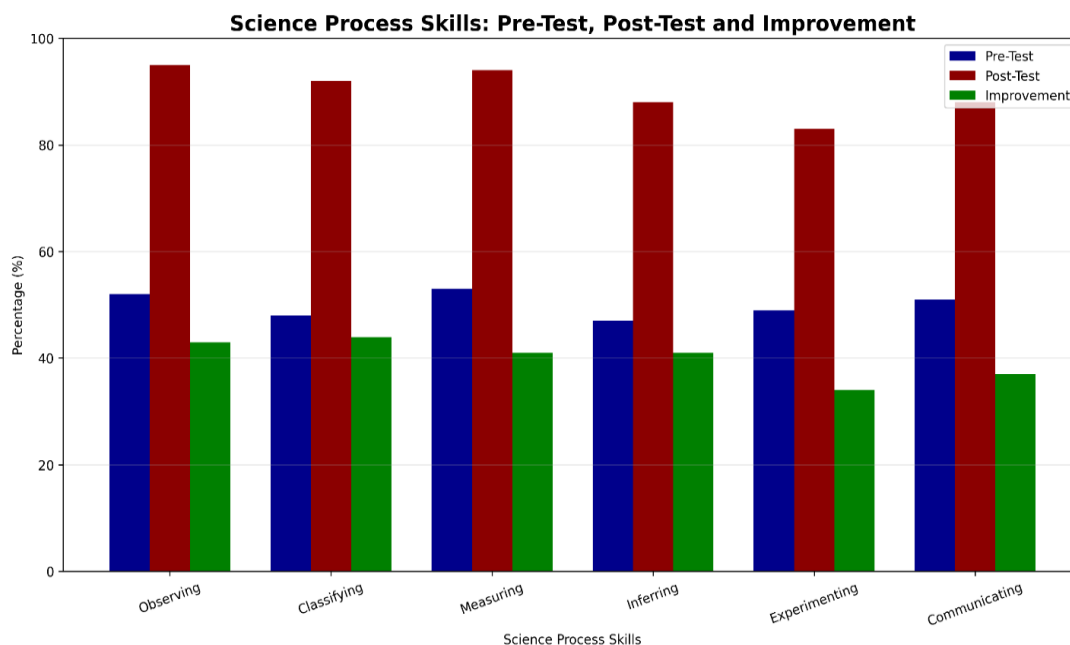
higher than the table value 2 at 0.05 level. Hence there is significant difference between pre and post test performance of science teachers.

2. There is no significant difference between the pre-test and post-test scores of science teachers in observing, classifying, measuring, inferring, experimenting, and communicating skills.

Hypothesis:2

There is no significant difference between the pre-test and post-test scores of science teachers in observing, classifying, measuring, inferring, experimenting, and communicating skills.

Science Process Skill	Pre-Test (%)	Post-Test (%)	Improvement (%)
Observing	52	95	+43
Classifying	48	92	+44
Measuring	53	94	+41
Inferring	47	88	+41
Experimenting	49	83	+34
Communicating	51	88	+37



The table and bar diagram clearly show that all six science process skills improved after the hands-on experimental intervention. The highest improvement was observed in Observing (43%), followed by Classifying (44%) and Measuring (41%). Inferring (41%), Experimenting (34%), and Communicating (37%) also showed improvement. The overall average increased from 50% in the pre-test to 90% in the post-test based on the six skill percentages provided. Therefore, the descriptive findings indicate a substantial improvement in science process skills following the intervention.

Gain Ratio

Since the maximum possible score is **10**, the normalized gain can be calculated as:

$$g = \frac{\text{Post} - \text{Pre}}{\text{Maximum} - \text{Pre}}$$

Using the group means:

$$g = \frac{9.0 - 5.0}{10 - 5.0}$$

$$g = \frac{4.0}{5.0} = 0.80$$

Thus, the normalized gain ratio = 0.80, or 80%.

FINDINGS

Pre-Test and Post-Test Performance

The pre-test and post-test scores of the 20 science teachers were analysed to determine the effectiveness of the hands-on experimental intervention in improving their Science Process Skills. The results show that the pre-test mean score was 5.00 (SD = 0.73), whereas the post-test mean score was 9.00 (SD = 0.76). Thus, there was an increase of 4.00 points in the mean score following the intervention.

The reported paired t-value was 16.98, with the reported two-tailed p-value being less than 0.0001. Based on these reported values, the difference between the pre-test and post-test performance was statistically significant. Therefore, the findings indicate that the science teachers demonstrated substantially higher Science Process Skills in the post-test than in the pre-test.

“The overall average score increased from 50% in the pre-test to 90% in the post-test.”

Skill wise Findings

The skill-wise analysis shows that all six selected Science Process Skills improved following the hands-on experimental intervention. The Observing skill increased from 52% in the pre-test to 95% in the post-test, showing an improvement of 43 percentage points. Similarly, Classifying improved from 48% to 92%, representing a gain of 44 percentage points, which was the highest improvement among the six skills.

The Measuring skill increased from 53% to 94%, showing an improvement of 41 percentage points. Inferring also demonstrated a substantial improvement, increasing from 47% in the pre-test to 88% in the post-test, with a gain of 41 percentage points. The Experimenting skill increased from 49% to 83%, representing an improvement of 34 percentage points. Communicating improved from 51% to 88%, showing a gain of 37 percentage points.

Overall, the findings indicate improvement in all six Science Process Skills after the hands-on experimental intervention. The highest improvement was observed in Classifying (44 percentage points), followed by Observing (43 percentage points), while the lowest improvement was observed in Experimenting (34 percentage points). The results suggest that the intervention was associated with considerable improvement across the selected Science Process Skills.

“The present study examined changes in science process skills following participation in hands-on experimental activities.”

Gain Ratio

The normalized gain ratio was calculated using the maximum possible score of 10.

$$g = \frac{\text{Post - test Mean} - \text{Pre - test Mean}}{\text{Maximum Possible Score} - \text{Pre - test Mean}}$$

$$g = \frac{9.00 - 5.00}{10 - 5.00}$$

$$g = \frac{4.00}{5.00} = 0.80$$

Thus, the normalized gain ratio was 0.80 (80%). This indicates that the participants achieved 80% of the possible improvement between their initial performance and the maximum attainable score.

DISCUSSION

The findings of the present study indicate that the hands-on experimental intervention was associated with a substantial improvement in the Science Process Skills of the participating science teachers. The mean score increased from 5.00 in the pre-test to 9.00 in the post-test, showing a gain of 4.00 points. The reported t-value of 16.98 with a two-tailed p-value of less than 0.0001 indicates a statistically significant difference between the pre-test and post-test performances.

This suggests that the teachers demonstrated higher levels of Science Process Skills after participating in the hands-on experimental activities.

The skill-wise findings provide further evidence of improvement across all six selected Science Process Skills. Classifying showed the highest improvement, increasing by 44 percentage points, followed by Observing, which increased by 43 percentage points. Measuring and Inferring each showed an improvement of 41 percentage points, while communicating improved by 37 percentage points. Experimenting showed an improvement of 34 percentage points, which was the lowest among the six skills, although it still demonstrated a clear increase from the pre-test to the post-test.

The normalized gain ratio of 0.80 (80%) further indicates a substantial gain between the initial performance and the maximum possible score. The teachers achieved a considerable proportion of the possible improvement following the intervention. When considered together with the increase in mean scores and the skill-wise percentage gains, the findings provide consistent descriptive evidence of improvement in Science Process Skills after the hands-on experimental intervention.

The findings also have implications for science teacher education. Providing teachers with opportunities to perform experiments themselves may help them experience the processes involved in scientific inquiry and subsequently use similar approaches in their own science classrooms. Hands-on activities can therefore be incorporated into teacher training programmes to provide practical opportunities for developing and applying Science Process Skills.

Overall, the findings of the present study indicate that participation in hands-on experimental activities was associated with improvement in the Science Process Skills of the science teachers. However, the findings should be interpreted in relation to the study design and sample size. The observed pre-test–post-test improvement demonstrates change over the intervention period, but without an appropriate comparison group, other factors that may have contributed to the change cannot be completely ruled out.

AI Use Statement

The Authors Used Grammarly and ChatGPT for grammar checking, improving sentence clarity and language improvement.

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