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An Exploratory Study on the Levels and Dimensions of Science Process Skills Among Undergraduate Students in Higher Education Institutions

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Abstract: *Science process skills play an important role in increasing scientific literacy and students' critical thinking skills. The purpose of this study is to explore and evaluate the levels and dimensions of science process skills of undergraduate students at the Higher Education level. The recent study was based on quantitative in nature following a descriptive approach. Population of the current study was all the second semester undergraduate students of University of Malakand, Pakistan. A sample of 177 students was drawn using stratified sampling technique from seven departments which included three students from Pure Sciences, two students from Social Sciences and two students from Arts. After ensuring reliability and validity of the data, science process skill data were obtained using a questionnaire with a standardized form. The result showed that the level of science process skills that were possessed by undergraduate students was moderate (Grand Mean = 17.68). The results of Independent samples t-test showed that the difference in science process skills achievement between boys and girls was not statistically significant, t(175) = 0.956, p = 0.29. A one-way ANOVA analysis however revealed that there was a statistically significant difference between the academic disciplines, F(2, 174) = 5.48, p = 0.006. Students who were from Social Sciences had the highest marks (M = 18.66), students from Pure Science had the second highest marks (M = 17.41) and students from Arts had the lowest marks (M = 17.05). The study findings are that academic discipline has significant impact on science process skills, but there is no significant impact of gender on science process skills. The results of this study underscore the importance of inquiry teaching in all subjects of higher education and process-oriented teaching. This study serves as baseline data for the improvement of science education in the Pakistani Universities and also supplements the researcher's study on science process skills and academic achievement.*

Introduction

Science process skills (SPS) are the basic mental and handling skills needed to think and act like scientist. The skills were first systematically introduced in the 1960s, through a program called the Science. A

Process Approach (SAPA) (National Association for Research in Science Teaching [NARST], along with; Gizaw & Sota, 2023). The development of science process skills has been considered as one of the most crucial part of scientific literacy, critical thinking and problem solving in the learner. Process skills-based learning is more effective than the traditional content approach that fosters rote memorization in actively building students' knowledge, allowing them to pursue scientific inquiry and apply learning to real-life situations (Ekici, 2020; Gizaw & Sota, 2023). The scientific skills listed above have been consistently found to have a positive impact on students' conceptual development and scientific competencies.

The development of science process skills assumes even greater importance at the under-graduate level. The purpose of university education is to make students independent thinkers and future scientists and technologists who can be the part of scientific and technological progress. But there were some indications that in relatively many undergraduate students, including in developing countries, the level of development of these skills was relatively low, which could be attributed to the teacher-centered teaching approach, too small laboratory space and results, and too few hands-on lab experiences (Rusmini et al., 2021; Deta et al., 2020). This is a very critical question in the Pakistani scenario of higher education. At the same time that the nation is working to improve STEM education, many undergraduate science programs are dealing with issues that impede more effective teaching and learning, including traditional teaching models that do not allow for inquiry-based learning and a shortage of resources. Hence, it is necessary to know the situation of science process skills possessed by the undergraduate students to support curriculum modification and improvement of the instruction (Ahmed, 2023).

Despite the considerable research efforts on science process skills at school level, limited efforts have been made to explore and investigate the levels and dimensions of these skills in the context of undergraduate students from higher education institutions especially in the context of Pakistan. Previously, there is a lack of research on the baseline level of process skills in the undergraduate level, while the majority of the studies were on secondary education or the relationship of process skills and academic achievement.

Literature Review

Conceptual Framework of Science Process Skills

Science process skills (SPS) are set of psychomotor and cognitive skills which allow one to carry out scientific inquiry and to build scientific knowledge. The American Association for the Advancement of Science (AAAS) during the time period of 1960s developed the Science- A Process Approach (SAPA) curriculum project which popularized these skills systematically NARST, 2026.; Gizaw & Sota, 2023). The science process skills used in this activity were categorized as basic process skills, comprised of observations, classifying, measuring, inferring, predicting, and communicating, and integrated process skills, comprising of formulating hypotheses, controlling variables, interpreting data, experimenting, and defining operationally (Padilla, 1990; Rusmini et al., 2021). The building blocks for developing more complex integrated skills are basic skills, which are necessary for conducting scientific investigations. These skills are said to be transferable across science disciplines and represent the real activities of working scientists (NARST, 2026).

Importance of Science Process Skills in Science Education

The teaching and learning of science process skills are considered crucial to attain scientific literacy and 21st century skills. With strong SPS, students will not be satisfied with just memorizing facts but will be able to grasp the concepts, think critically and solve problems (Ekici, 2020; Gizaw & Sota, 2023). It has

been shown that students who had good process skills showed good conceptual understanding, they were more active in learning and they could use the acquired knowledge in new situations (Feyzioğlu, 2012; Maranan, 2017). For higher education, mastery of SPS is especially significant when students graduate as undergraduates are expected to move into independent research as researchers and critical thinkers. The goal of a university is to create students with the ability to design experiments, analyses data and help science progress (Fugarasti et al., 2019).

Science Process Skills at the Undergraduate Level

The science process skills of undergraduates have been investigated in several studies, especially science education programs. Deta et al. (2020) examined students from non-science undergraduate of Universitas Negeri Surabaya and determined that the SPS range of students was moderate to low in controlling variables and formulating hypothesis skills. Likewise, Rusmini et al. (2021) studied students in chemistry education and found that students' performance in determining tools and materials was relatively good, whereas in interpreting and concluding data was less good. Based on the systematic review conducted by Fugarasti et al. (2019) on SPS at the undergraduate level, most studies on SPS at university level are found in Asian contexts, with interventions carried out in the forms of project-based learning, inquiry-based approach, and technology integration. In general, the studies showed that undergraduate students' SPS is not fully developed when the learning model used is traditional with lecturing and traditional teaching (Kurniawan et al., 2023).

Science Process Skills in Developing Countries and Pakistan

The development of science process skills in developing countries has additionally encountered challenges, such as teachers' teacher-centered teaching style, lack of laboratory facilities, few resources, and large classes (Kurniawan et al., 2023). Research conducted in Indonesia, Malaysia and the Philippines has consistently found that undergraduate students' SPS levels at low to medium level. The research on science process skills is still in its initial stages in the Pakistani context, especially at undergraduate level. The current studies have been conducted mostly with secondary school students. For example, Ahmed (2023) has discovered that at higher secondary level students of private school have performed better in fundamental science process skills than students of public school. Yet, there is a significant lack of empirical evidence in terms of the extent and scope of SPS among the undergraduate students of the higher education institutions in Pakistan. This deficit is quite noteworthy as the base of scientists, teachers and researchers of the future in the country is the undergraduate course.

Measurement of Science Process Skills

A multitude of tools have been created to assess SPS, such as paper-and-pencil tests, performance-based assessments, and rubrics (Feyzioğlu, 2012). Many researchers, such as Rusmini et al. (2021), prefer using multiple methods that consist of both test and observation checklist and laboratory report to assess basic skills and integrated skills accurately.

Research Gap

Although, there is significant literature about science process skills at the school level and there are many intervention studies on increasing SPS, but there is little exploratory research that extensively examines the current level and dimensions of SPS of undergraduate students in higher education institutions particularly in Pakistan context. Most of the previous studies have concentrated on the school level student or studied the relationship between SPS and academic achievement, but not detailed profile of skill possession. The current study is designed to address this issue, explore and evaluate the dimensions and levels of science process skills of undergraduate students.

Research Objective

- To explore and evaluate the level and aspect of Science Process Skills possessed by the students of undergraduate level in Higher Education Institutions.

Research Hypotheses

The following null hypotheses were formulated to investigate dimensions of science process skills in relation to the following key demographic variables:

Ho1: Science process skills of undergraduate students are not significantly different based on gender.

Ho2: Academic discipline (Pure Sciences, Social Sciences and Arts) does not significantly differ in the science process skills of the undergraduate students.

Nature of the Research

The study used descriptive survey research design. The survey design was deemed suitable for the study since it was intended to investigate and evaluate the science process skills of the undergraduate students.

Population of the Study

The population of the study was all 2nd semester undergraduate students of different Departments University of Malakand.

Sampling Procedure

Stratified sampling technique was used in the study. The first was the selection of seven department's purposive sampling to represent various field of study. These comprised three departments of pure sciences, two of social sciences and two of arts. The three categories (pure sciences, social sciences, arts) of students constituted strata. 20% of the second semester students were randomly selected in each of the selected departments. The stratified sampling method provided proportional representation from various academic disciplines and expanded the representativeness of the sampling.

Research Instrument

This data was obtained from a standardized questionnaire regarding science process skills, which had been developed by Rauf et al. (2013). This has been obtained from the original author's permission. The instrument was modified to the context and has been content validated by the field experts. A pilot study was carried out with a sample of students other than the actual sample to establish clarity, relevance and cultural appropriateness. Cronbach's alpha coefficient was used to measure the reliability of the instrument.

Data Collection Procedure

The researcher personally gave this questionnaire to the selected second semester undergraduate students of seven departments (pure sciences, social sciences and arts) of University of Malakand. Time was allowed for students to answer the items. Ambiguities, if any, were resolved on the spot to provide accurate and reliable responses. Data collection was done in an ethical manner, with the principles of confidentiality and consensual participation.

Data Analysis

Descriptive statistics were used to analyze the collected data with the aid of Statistical Package for Social Sciences (SPSS) version 26. The levels and dimensions of the science process skill among undergraduate students were explored and described by using frequency, percentage, mean and standard deviation.

Ho1: Science process skills of undergraduate students are not significantly different based on gender.

Gender	N	Mean	T	df	Mean difference	Sig.
Male	79	17.8987	.956	175	.378	.29
Sum of science process skills female	98	17.5204				

A t-test for independent samples was performed to compare the difference in science process skills between males and females in the undergraduate level. The results indicated a slight difference in means between male (M = 17.90) and female (M = 17.52) students. This difference, however, was not found to be statistically significant (t(175) = 0.956, p = 0.29). The result of the p value (0.29) is greater than 0.05, thus the null hypothesis (Ho1) which is there is no significant difference in science process skill on the basis of gender is not rejected. This means that there is no significant difference between undergraduate students on the science process skills based on gender.

Ho2: Academic discipline (Pure Sciences, Social Sciences and Arts) does not significantly differ in the science process skills of the undergraduate students.

Sum of science process skills	N	Mean	F	df	Sig.
Pure science	90	17.41	5.48	2,174	.006
Social science	50	18.66			
Arts	37	17.05			

The results of the one-way ANOVA showed that the mean scores of undergraduate students from various academic disciplines in science process skills were significantly different, F(2, 174) = 5.48, p = 0.006. The mean score of students from the Social Sciences was the highest (M = 18.66), followed by the Pure Science (M = 17.41), and the lowest mean score was for the Arts students (M = 17.05). The null hypothesis (Ho2) is rejected as a result of this finding and it shows that academic discipline can significantly affect science process skills of the undergraduate students.

Findings

The present study was undertaken to explore and evaluate the level and size of science process skills of undergraduate students at the University of Malakand. The main outcomes of the study are as follows:

1. The overall level of science process skills among undergraduate student was obtained that moderate with grand mean score of 17.68.
2. Male and female undergraduate students did not show a statistically significant difference in their science process skills, t(175) = 0.956, p = 0.29. The average for male (M = 17.90) and female (M = 17.52) students in science process skills were almost identical.
3. The students who are in different academic disciplines showed a statistically significant difference in science process skills, F(2, 174) = 5.48, p = 0.006. The students from Social Sciences showed the highest score of science process skills (M = 18.66), followed by the Pure Science students (M = 17.41) and the lowest score was shown by the Arts students (M = 17.05).
4. Academic discipline was found to be one of the factors that significantly influenced the science process skills of the undergraduate students, while the gender factor did not show any significant influence.
5.

Discussion

The study was conducted to explore and evaluate the level and dimensions of science process skills of undergraduate students of University of Malakand. The main findings are presented below and discussed against the background of the existing literature. It was observed that the overall level of science process skills of undergraduate students was in the moderate category (Grand Mean = 17.68). The findings are consistent with some previous studies conducted in the developing countries which found that science process skill of university students was moderate (Deta et al., 2020; Rusmini et al., 2021). The medium indicates that the students have some basic process skills but require significant development in integrated skills (hypothesis formulation, control of variables, and interpretation of data). In terms of gender, there was no statistically significant difference in science process skills between the male and female ($p = 0.29$). This result is similar to previous studies showing that gender has no significant effect on science process skills development in the students' educational environments are the same (Feyzioğlu, 2012; Gizaw & Sota, 2023). It adds to the conviction that science process skills are more a function of instructional practices and learning opportunities than of gender. The main result obtained from the study was that science process skills were significantly different among science disciplines ($p = 0.006$). The highest mean score was obtained by Social Science students, followed by students of pure Science and the lowest was obtained by Arts students. This finding is significant in that it is in contrast to the general belief that students in Pure Science would do better than others in process skills. Social Science curricula may have more critical thinking, inquiry based activities, and analytical activities in the assignments, which could indirectly increase process skills. This pattern has also been found in other Asian settings, such as others where discipline-related pedagogical practices affect skills (Kurniawan et al., 2023). Findings from this study emphasize the need for curriculum reform with the implementation of inquiry and process-based learning in all curricula, especially in Arts and Pure Science programs.

Conclusion

This study aimed to explore and evaluate the amount and forms of science process skills of the undergraduate students of the University of Malakand. The study offers an insightful analysis of the status of these key skills in the context of Higher Education in Pakistan. The results showed that the science process skills (SPSS) possessed by undergraduate students were in a moderate category (Grand Mean = 17.68). Students' performance on basic science process skills was at a reasonable level, with plenty of room for improvement, especially with regard to integrated and higher-order process skills. The study did not reveal any significant differences between the male and female students in science process skills. This indicates that there is no influence of gender on the development of science process skills in this context. A significant difference was found between the academic disciplines, however. The science process skills of the students in Social Sciences were the highest followed by that of the students from Pure Science and the lowest for Arts students. Based on these results, it can be concluded that academic disciplines have a significant effect on science process skills development.

Implications of the Study

The results of this study have significant implications for curriculum developers, teachers, and higher education policy makers. They recommend shifting from content-oriented teaching to more inquiry and process-oriented teaching in all subjects.

Recommendations

1. Higher education institutions should explicitly incorporate training of science process skills in all undergraduate programs, particularly in disciplines in Arts.

2. Improve the process skills of students by increasing the number of practical, hands-on, project-based learning activities in the curriculum design.
3. Faculty should participate in professional development programmers relating to effective strategies in developing science process skills.
4. Undergraduate assessment system should include regular assessment of science process skills. The limitations and suggestions for future research are presented below.

Future Research

The study was conducted with second semester undergraduate students of one public university (University of Malakand). Samples from more universities from other parts of Pakistan can be included in future research. Furthermore, long-term studies and intervention studies are suggested to address how science process skills can be effectively fostered in the long term.

In summary, the cultivation of good science process skills will be important for creating scientifically literate science graduates who are competent. This study will serve as a strong base for the future work needed to enhance the quality of science teaching in HEIs in Pakistan.

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