Available Online
Journal of Education and Social Studies
ISSN: 2789-8075 (Online), 2789-8067 (Print)
http://www.scienceimpactpub.com/jess

DEVELOPMENT AND VALIDATION OF WORKSHEETS IN PHYSICS BASED ON SCIENCE PROCESS SKILLS AT HSSC LEVEL

Farkhunda Choudhary and Masood Ahmed

Allama Iqbal Open University (AIOU), Islamabad, Pakistan

ABSTRACT

Science process skills (SPS) are necessary skills that should be acquired in the 21st century. Assessment of student's competency level in science process skills is a major challenge for teachers. It is necessary to have a validated science process skills instrument that could measure the level of competency for science process skills among science students. This study focused on developing a valid and reliable instrument to measure students' competency level in science process skills. This research study is based on the research and development process. The researcher followed a systematic method based on the 4D instructional development model used by Thiagarajan et al. (1974). This model splits the instructional development process into four phases: define, design, develop, and disseminate. In the first phase, the physics curriculum was critically analyzed at the higher secondary school certificate level to select the four experiments in the subject of physics that were based on science process skills. The construction of item indicators, i.e., the aspects of SPS, were selected in this phase. The second stage was designed in which the researcher developed four worksheets for four experiments. In this stage, items were constructed. In the third stage, items were revised in the light of the expert's judgment. In the fourth stage, the research instruments passed through a field trial after validation. The subject of the field trial was 60 Physics students of grade XII of two top-level colleges in the city of Rawalpindi. The third phase was the evaluation phase, in which scoring rubrics for worksheets were developed. The validation yielded 22 items for the worksheet of Experiment I, 22 items for the worksheet of Experiment II, 19 items for the worksheet of Experiment III, and 15 items for the worksheet of Experiment IV. The reliability coefficient of Worksheet I is 0.79; it was 0.88 for Worksheet II. For worksheet III, it was 0.71, and 0.82 for worksheet IV. The statistical values confirmed that all four worksheets were empirically valid and reliable for assessing science process skills.

Keywords: Science process skills; Scoring rubrics; Item development.
** Email: farkhunda.rasheed@aiou.edu.pk*

https://doi.org/10.52223/jess.2023.4215
Received: May 24, 2023; Revised: July 15, 2023; Accepted: July 22, 2023

INTRODUCTION

Science process skills are needed in Physics learning in the 21st century. Science process skills play a pivotal role in a scientific investigation. SPS is very important to be developed in science learning because, with the help of SPS, students develop their thoughts to make discoveries using scientific investigation. The purpose of teaching physics is to increase students' expertise in the subject by imparting them the required information and abilities. According to Maison et al. (2019), SPS forms the foundation of the scientific method. The abilities scientists employ when conducting scientific research are known as SPS. SPS are subdivided into two categories: basic and integrated science process skills. Basic science process skills include observation, questioning, communication, counting number relations, and measuring skills. According to Chiappetta and Koballa (2002), integrated Science process skills include defining operationally, formulating hypotheses, controlling variables, interpreting data, hypothesizing, and experimenting or designing investigation. BSPS provides the basis for the ISPS. So basic science process skills and integrated science process skills come under the large umbrella of SPS. (Rambuda & Fraser, 2004).

Performance-based assessment is one method to assess the science process skills of students. According to David and Zimmermann (1992), "performance assessment" is a type of assessment where students are required to perform a task or an activity instead of choosing an answer from a list of choices. Performance-based assessment requires students to formulate a scientific hypothesis, solve problems, converse in a foreign language, or conduct research on an assigned topic. Another way to assess SPS is the direct assessment method. In this method, students' skills are determined in the presence of an observer or examiner who is awarding marks (Reiss et al., 2012). The examiner or teacher awards the students marks when they are manipulating the objects in science or undertaking a piece of practical work. Direct assessment of practical skills has high validity. It motivates scientific teachers to make sure that pupils become proficient in real-world abilities that will be evaluated.

Jalil et al. (2018) found that the assessment of the science process skills is not being carried out in schools in a comprehensive way. Even the instruments to assess SPS were not available in some schools. The traditional ways, such as practical work, of assessing SPS have a number of constraints. For example, for a large class size and under-resourced science lab, assessing students' performance in SPS was not easy. It is more appropriate to measure science process skills through hands-on activity procedures, but large class sizes and under-resourced science labs in public as well as private schools, pose enormous practical assessment problems in Pakistan.

In Pakistan, the SPS acquisition level of the students is assessed through practical exams. Students are required to perform certain experiments by following some given instructions. Practical Examiners observe the students' performance and also evaluate their answer sheets according to the marking scheme provided by the boards. The scores of students obtained through the marking of their practical work indicate the students' performance level in science process skills.

The most common way used to assess science process skills in science class was the paper-pencil test. However, it was considered unsuitable as it was developed by science class teachers who were not properly trained in the context of SPS. The majority of science teachers of science classes only focused on observation and measurement aspects of SPS and completely ignored other aspects of basic and integrated science process skills. So, there is a question mark on the validity of paper-pencil tests developed by science class teachers in Pakistan.

Research Objectives

This research study intends to achieve the following objectives:

1. To develop standardized worksheets of science process skills that could measure the science process skills level of students in the subject of Physics at the HSSC level.
2. To construct valid and reliable worksheet items based on physics experiments at the HSSC level.

LITERATURE REVIEW

Science learning outcomes related to skill are measured through traditional, alternative, authentic, and performance assessments. These methods were considered appropriate for assessing students' science process skills. Traditional assessments are tests that are usually comprised of true /false, matching, and multiple-choice items. In alternative assessment, students create responses to short questions or essay-type questions, whereas in authentic assessment, students are required to perform real-world tasks that exhibit meaningful application of essential knowledge and skills. In this type of assessment, students are engaged to apply knowledge and skills in the same way they are used in real-world situations. Performance assessment is a type of test that requires students to perform a task instead of choosing an answer from a list of choices (Oloruntegbe, 2010).

To assess science process skills, many instruments have been developed and used by various researchers. Ozgelen (2012) used the Integrated Process Skill Test (SPST) to measure primary students' SPS in a research study. Akani (2015) used the Science Process Skill Test (SPST) and Assessment Format for Science Process Skills (AFSPS) to determine the SPS of 200 senior students. These instruments were validated by five validators who have expertise in their subjects. Bassey and Amanso (2017) employed a 32-item instrument titled: "Science Students Process Skills Acquisition Test" for data collection. In his action research study, Karsli and Shain (2009) developed a worksheet based on SPS to support awareness and knowledge about SPS in prospective science teachers.

Safitri et al. (2020) used an observation sheet to measure student's SPS. The observation sheet was in the form of statements. Statements were related to formulating questions, measuring, conducting experiments, interpreting data, concluding, and communicating. Raj and Devi (2014) constructed an SPS inventory to investigate the SPS of students. This tool was comprised of 51 multiple-choice questions and four options for each statement. A research study conducted by Widdina et al. (2018) used three types of instruments for data collection. They were observation sheets, performance assessments, and rubrics. An observation sheet was used to measure each student's process skills when they were doing an experiment. Performance assessment was used to assess how the students were handling and using the apparatus during the experiment. In comparison, the rubric was used as a guidance tool to give a desirable score in the observation sheet during experimental activity.

A study conducted by Widanti and Aloysius (2020) used an observation sheet for analyzing the content of the student worksheet based on science process skills. A research study was conducted by Nugraha et al. (2018) to develop a basic physics experiment to improve the mastery concept in Meld's Law. During the researchers developed a worksheet using the SPS approach, which include almost all aspects of science process skills.

Kurniawan et al. (2023) used observation sheets and essay tests to investigate the effect of science process skills on critical thinking skills. Jalil et al. (2018) developed a valid and reliable Science process skills instrument (I-KPS). I-KPS was a paper test for assessing six indicators of science process skills. The type of items in this test was essay type completed with scoring rubrics. The average item difficulty level of I-KPS was 0.38, the content validity of I-KPS was 0.96, and the reliability coefficient was 0.935. Mohamad and Ong (2013) developed a psychometrically- supported 60 multiple-choice item test of basic and integrated science process skills (T-BISPS). T-BISPS has 28 items for basic SPS with a reliability coefficient of 0.86 and 32 items for integrated science process skills with a reliability coefficient of 0.89. The mean item difficulty index for T-BISPS was 0.60, while the mean item discrimination index was 0.52. Tilakaratne and Ekanayake (2017) developed two science process skills achievement tests (SPSAT 1 & SPAST 2) to assess the understanding of science process skills for sixth-grade students and to assess the understanding level of SPS of seventh-grade students. Both tests consisted of multiple-choice questions. Zeidan & Jayosi (2015) developed a science process skills test consisting of 18 items; the reliability of this instrument was found to be 0.95.

METHODOLOGY

This research used the system approach of the 4D instructional development model used by Thiagarajan et al. (1974). The 4D model divides the instructional development process into four stages: Define, Design, Develop, and Disseminate. In this research study, the researcher used these four stages to develop and validate the science process skill worksheet. In the first stage, through analysis, the researcher described the objectives and constraints of the worksheet. In the second stage, the researcher designs the worksheet's format and constructs the worksheet's initial design. In the third stage, the researcher took expert appraisal and developmental testing of worksheets for the finalized selection of items for all four worksheets. In the last stage, a summative evaluation of the worksheet was undertaken, and the reliability of the instrument was ensured. The instruments used in this study were the validation sheet and scoring rubrics for the worksheet.

RESULTS AND DISCUSSION

Stage I: Define

According to Thiagarajan et al. (1974), the defining phase is mainly analytical. Through analysis, objectives and constraints for the instructional materials were prescribed. The researcher followed the first stage of the 4D model. In the first stage, the researcher analyzed the lists of experiments of the national curriculum for Physics grades XI and XII 2006. Analysis of experiments revealed that there was a total of 46 experiments in the Physics syllabus. Out of 46 experiments, there were only five experiments in which both basic and integrated aspects of science process skills were present. The researcher selected 4 out of 5 experiments for the present study in which students could gain both basic and integrated science process skills.

Stage II: Design

At this stage, the researcher designs the activities for the worksheet. A draft of the worksheet was prepared, which is composed of seven parts. A detailed description of each part is given below.

Part I

This part of the worksheet was related to observation skills. In this part, different situations/ Physical phenomena were shown through diagrams, and students were asked to observe the physical quantities involved in the situation.

Part II

This part of the worksheet was related to communication skills. In this part, students were asked to draw the diagram of the experiments and write the names of certain equipment. In this part, questions such as design an experiment, description of associating physical phenomena of the experiment, and basic ideas about experiments were also asked to determine the communication skill level of students.

Part II

This part of the worksheet was related to measurement skills. In this part, different stages of the experiment were shown through diagrams, and students were asked to measure the physical quantities.

Part IV

This part of the worksheet was related to relationship skills. Questions such as determine

Relationships between different physical quantities were developed to determine the communication skill level of students.

Part V

In the fifth part of the worksheet, activities for Physics students include formulating hypotheses about the experiment.

Part VI

This part of the worksheet was related to controlling variables skills. In this part, questions related to the identification of dependent, independent, and controlling variables were asked from the Physics Students.

Part VII

This part is related to students' interpreting data skills. In the seventh part of the worksheet, activities include making or completing a data table, drawing a graph by using data and interpreting the results obtained from the data table and graph.

To find the different aspects of SPS, the researcher prepared four worksheets for four experiments.

Stage III: Develop

In this stage, the researcher found the content validity of the instrument and ensured the feasibility of the instrument. For the validation of the worksheet, the researcher developed a validation sheet to take expert opinions from five subject experts of Physics. The validation sheet was a list of Likert–scale questions. The expert team was asked to read the items of the worksheet carefully and complete the validation sheet by rating each item according to their opinion.

The validation sheet consisted of three parts. A detailed description of each part is given below.

Part I

This part of the validation sheet is related to content validity. In this part, validators were asked to rate each item of the worksheet according to the rubrics given in Table 1.

Table 1. Rubrics for content validity of worksheet.

Criteria	Rating of Worksheet item
Very relevant to the specific aspect of SPS	4
Quite relevant to the specific aspect of SPS	3
Somewhat relevant to the specific aspect of SPS	2
Not relevant to the specific aspect of SPS	1

Table 1 shows the criteria for rating items of the worksheet to determine the content validity of the worksheet. Very relevant items of the worksheet were rated as 4, quite relevant items were rated as 3, somewhat relevant items were rated as 2 and non-relevant items were rated as 1 by the validator.

The validation data obtained through this part was tabulated and content validity index was calculated by the researcher using the following formula (Kamba etal., 2018)

$$\mathrm{CVI} = \frac{\text{Items rated as relevant and very relevant (3 and 4)}}{\text{Total number of items}} \qquad (1)$$

Table 2. Content validity index for worksheet.

Instrument	CVI
Worksheet for Experiment 1	0.781
Worksheet for Experiment 2	0.836
Worksheet for Experiment 3	0.768
Worksheet for Experiment 4	0.826

Table 2 shows the details of the content validity index calculated by the researcher for worksheets of four experiments. For the worksheet of experiment 1, the value of CVI was calculated to be 0.781; for the worksheet of experiment 2 it was 0.836; for the worksheet of experiment 3, it was 0.768; and for the worksheet of experiment 4, it was 0.826.

Part II

In this part of the validation sheet, expert opinion was taken about the worksheet's construction, clarity, comprehensiveness, and language. This part of the validation sheet consists of a statement prepared on the Likert -scale. The expert team was asked to give an opinion about each item of the worksheet. Expert opinion was recorded by the researcher according to the criteria given in Table 3. In this part, data was collected to ensure the feasibility of the worksheet.

Table 3. Rubric for the feasibility of the worksheet.

Criteria	Score
highly feasible to use	4
Feasible to use	3
Feasible to use with improvement	2
Not feasible	1

Table 3 shows the rubric's criteria to determine the feasibility of the worksheet. A highly feasible item was rated as 4, a feasible item was rated as 3, a feasible item after improvement was rated 2, and a non-feasible item was rated 1 by the validator.

Validation data was analyzed, and the average score was calculated by using the formula.

$$\text{Average Score} = \frac{\text{Total mean score obtained for items from validators}}{\text{No of validators}} \quad (2)$$

After calculating the average score, the researcher interpreted the validity of the worksheet according to the criteria (Hariapsari & Sudibyo, 2018) given in Table 4.

Table 4. Interpretation criteria for validation.

Average Score	Criteria	Interpretation
1-1.49	Invalid	Not Applicable
1.50-2.49	Less valid	It can be used with large revision
2.50-3.49	Valid	It can be used with small revision
3.50-4.0	Very valid	It can be used without revision

Table 4 shows the interpretation criteria for validation of the worksheet. The researcher decided that the worksheet can only be used without revision if the average score lies within the range of 3.50 to 4.0

Table 5. Validation results of Worksheets.

Instrument	Average Score	Validity Status
Worksheet for Experiment 1	3.65	Very valid
Worksheet for Experiment 2	3.76	Very valid
Worksheet for Experiment 3	3.59	Very valid
Worksheet for Experiment 4	3.69	Very valid

Table 5 shows the validation results of worksheets for four experiments; from the interpretation of results, it was found that worksheets for all four experiments were very valid.

Stage IV: Disseminate

In this stage, the researcher administered the instrument to 60 Physics students from two top-level colleges in the city of Rawalpindi. After administering worksheets, the researcher used scoring rubrics to grade worksheet items. Table 6 shows the scoring rubrics for the evaluation of worksheets.

Table 6 Rubrics criteria for scoring worksheet.

Criteria	Score	Skill level
Below 10% correct answer of an item	1	Very low
10 to 30 % correct answer of an item	2	Low
31 to 60% correct answer of an item	3	Fair
61 to 80% correct answer of an item	4	Good
Above 80% correct answer of an item	5	Excellent

Table 6 shows the rubric criteria for scoring worksheets. Below 10% of correct answer of an item was awarded one mark, 10 to 30 % correct answer of an item was awarded 2 marks, 31 to 60 % correct answer of an item was awarded 3 marks, 61 to 80% correct answer of an item was awarded 4 marks and above

80% correct answer of an item awarded 5 marks by the researcher. After grading all four worksheets, the data obtained was tabulated on SPSS, and the reliability coefficient for each worksheet was calculated by using Cronbach's Alpha Coefficient formula.

Table 7. Reliability statistics of worksheet.

Instrument	No of Items/ Activities	Cronbach's Alpha (α)
Worksheet for Experiment 1	22	0.79
Worksheet for Experiment 2	22	0.88
Worksheet for Experiment 3	19	0.71
Worksheet for Experiment 4	15	0.82
Overall Reliability	78	0.927

Table 7 shows the detail of the reliability coefficient calculated by the researcher for worksheets of four experiments. For the worksheet of experiment 1, the value of α was calculated to be 0.79; for the worksheet of experiment 2, it was 0.88; for the worksheet of experiment 3, it was 0.71; and for the worksheet of experiment 4, it was 0.82.

CONCLUSIONS AND RECOMMENDATIONS

Science process skills worksheets measure students' science process skills in four different physics experiments at higher secondary school certificate level. The specification of worksheets is: (1) The aspects of science process skills assessed are observation, communication, measurement, the relationship between variables, formulating hypotheses, controlling variables, and interpreting data. (2) The worksheet format is Constructed response questions and completed with scoring rubrics. (3) The reliability coefficient for worksheets is greater than 0.7, which ensures their reliability. (4) The content validity index is also greater than 0.7, ensuring the instrument's content validity. Science Process skill worksheets based on seven aspects of science process skills were found valid based on the interpretation of five validators. It was also concluded that all four worksheets based on four experiments in Physics were reliable. This research study concluded that all four worksheets based on physics experiments are valid and reliable for measuring science process skills at the HSSC level. For future study, it is suggested that theoretical reliability of worksheets may also be ensured by using item response theory.

REFERENCES

Akani, O. (2015). Levels of profession of science process skills by final year students of college of education in southern state of Nigeria. Journal of Education & Practices, 6(27), 94-102.

Bassey, B. A., & Amanso, E. O. (2017). Assessing students' gender, school type and science process skills acquisation of senior secondary school students in Calabar education Zone, Cross River State, Nigeria. International Journal of Education and Evaluation, 3(4), 19-25.

Chiappetta, E. L., & Koballa, T. R. (2002). Science instruction in the middle and secondary school (5th Ed). Upper Saddle River: NJ: Merrill Prentice Hall.

David, s., & Zimmermann, J. (1992). Performance assessment. educational research consumer guide. No.2, 1-5. Office of Educational Research and Improvement (ED), Washington, DC.

Hariapsari, K. W., & Sudibyo, E. (2018). Validity of teaching materials based on socio-scientific issues approach on the topic of vibration, waves, and sound. In Journal of Physics: Conference Series (Vol. 1108, No. 1, p. 012034). IOP Publishing.

Jalil, S., Ali, M. S., & Haris, A. (2018). Development and validation of science process skills instrument in physics. In Journal of Physics: Conference Series (Vol. 1028, No. 1, p. 012203). IOP Publishing.

Kamba, H. A., Giwa, A. A., Libata, A. I., & Wakkala, T. G. (2018). The relationship between science process skills and students attitude towards physics in senior secondary school in Aliero metropolis. African Educational Research Journal Vol6(3), 107-113.

Karsli, F., & Şahin, Ç. (2009). Developing worksheet based on science process skills: Factors affecting solubility. In Asia-Pacific Forum on Science Learning and Teaching (Vol. 10, No. 1, pp. 1-12). The Education University of Hong Kong, Department of Science and Environmental Studies.

Maison, M., Darmaji, D., Astalini, A., Kurniawan, D. A., & Indrawati, P. S. (2019). Science process skills and motivation. Humanities & Social Sciences Reviews, 7 (5), 48–56.

Mohamad, M. A. J., & Ong, E. T. E. T. (2013). Test of basic and integrated science process skills (T-BISPS): How do form four students in Kelantan FARE?. Asian Journal of Assessment in Teaching and Learning, 3, 15-30.

Nugraha, M. G., Utari, S., Saepuzaman, D., Solihat, F. N., & Kirana, K. H. (2019). Development of basic physics experiments based on science process skills (SPS) to enhance mastery concepts of physics pre-service teachers in Melde's law. In Journal of Physics: Conference Series (Vol. 1280, No. 5, p. 052075). IOP Publishing.

Oloruntegbe, K. O. (2010). Approaches to the assessment of science process skills: a reconceptualist view and option. Journal of College Teaching & Learning, 7(6), 11-18.

Özgelen, S. (2012). Students' science process skills within a cognitive domain framework. Eurasia Journal of Mathematics, Science and Technology Education, 8(4), 283-292.

Panday, A., & Sthapak, S. (2021). Science process skill among secondary school students. Edutracks Journal, 20 (11), 39-43.

Raj, R. G., & Devi, S. N. (2014). Science process skills and achievement in science among high school students. Scholarly Research Journal for Interdisciplinary Studies, 2(15), 2435-2443.

Rambuda, A. M., & Fraser, W. J. (2004). Perceptions of teachers of the application of science process skills in the teaching of Geography in secondary schools in the Free State province. South African Journal of Education, 24(1), 10-17.

Reiss, M., Abrahams, I., & Sharpe, R. (2012). Improving the assessment of practical work in school science Leading Education and Social Research. London: Institute of Education University of London and The University of York.

Safitri, L. N. (2020). Comparison of students science process skills after using learning an experimental and virtual laboratory on Archimedes Laws. In Journal of Physics: Conference Series (Vol. 1440, No. 1, p. 012079). IOP Publishing.

Thiagarajan, S., semmel, D. S., & Sommel, M. I. (1974). Development for training teachers of expectacional children: a source book. Washington, D. C.: Center for Innovation in Teaching the Handicapped Indiana University Bloomington, Indiana.

Tilakaratne, C. T. K., & Ekanayake, T. M. S. S. K. Y. (2017). Achievement level of science process skills of junior secondary students: Based on a sample of grade six and seven students from Sri Lanka. International Journal of Environmental & Science Education, 12(9), 2089-2108.

Widanti, Y. B. R., & Aloysius, S. (2020). Analysis of science process skills in student worksheet on microorganism topics for senior high school. In Journal of Physics: Conference Series (Vol. 1440, No. 1, p. 012069). IOP Publishing.

Widdina, S., Rochintaniawati, D., & Rusyati, L. (2018). The profile of students' science process skill in learning human muscle tissue experiment at secondary school. Journal of Science Learning, 1(2), 53-59.

Zeidan, A. H., & Jayosi, M. R. (2015). Science process skills and attitudes toward science among Palestinian secondary school students. World Journal of Education, 5(1), 13-24.

Kurniawan, D. A., Darmaji, D., Astalini, A., & Husna, S. M. (2023). A study of critical thinking skills, science process skills and digital literacy: reviewed based on the gender. Jurnal Penelitian Pendidikan Ipa, 9(4), 1741-1752.