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Examining Science Process Skills Among Select High School Students

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***Abstract*—** *The development of science process skills (SPS) plays a crucial role in improving learners' intelligence, hands-on abilities, and social skills. Acquired SPS allows learning in a more constructive and effective way improving learners' cognitive and mental capabilities. This study assessed the process of development of SPS among select learners in a lab activity on density and looked into their attitude towards chemistry and their ability to practice SPS via case study approach through classroom observations using an SPS and chemistry attitude inventory and an expert-validated SPSPA to determine the SPS exhibited. Based on the results, learners have a positive attitude towards chemistry (μ=4.0492, SD=1.5566) and sometimes practice SPS (μ=2.41, SD=0.81) in class such as communicating, interpreting, and questioning. However, Case A (high-performing student) has the most exhibited SPS which has an average level of proficiency while cases B and C have an approaching proficiency level and developing level for case D (student at-risk). Overall, the study illustrated that SPS can be examined which can then be an onset for strategies to optimize learning, as evidence is clearly exhibited that there exist varying degrees of proficiency across cases.*

***Keywords*—** *Chemistry Attitude, SPS Proficiency Assessment, SPS Proficiency Level, High-performing Student, Student At-risk.*

I. INTRODUCTION

The Program for International Student Assessment (PISA) 2022 results have shown a significantly low rating in science and mathematics. In science, the Philippines ranked the third lowest, unlike the results in 2018 that ranked second-lowest (Servallos, 2023). Research showed that students have difficulty understanding essential concepts in chemistry (Nakhleh M B 1992; Atagana, et al., 2014). In this rapidly evolving landscape of the 21st century, the importance of science process skills has become increasingly evident. These skills lay the foundation of scientific inquiry and discovery playing a key role in understanding the modern world (Kalogiannakis et al., 2021; Taştan et al., 2018).

The development of SPS plays a crucial role in improving learners' intelligence, hands-on abilities, and social skills. Engaging in science learning is intricately linked to achieving scientific proficiency, which is gained through hands-on experiences in both direct and indirect experiments and investigations. These activities serve as valuable training grounds for acquiring essential science process skills (Yusuf, S., Hasan, A. M., & Ahmad, J., 2023).

To learn chemistry, the quality of the learning process and the achievement of learning objectives are strongly influenced by several factors, including their attitudes. The main objective of this study was to assess exhibited SPS among learners.

II. REVIEW OF RELATED LITERATURE

A. Importance of Science Process Skills

Science process skills (SPS) are the procedural skills that involve experimentation and investigation that are ingrained as habits in one's mind fostering a continuous and intrinsic commitment to these processes. Also, SPS are scientific inquiry and inquiry process skills (Harlen, 1999; Chakraborty and Gillian, 2021). Finley (1983) characterized SPS as not only transferable but also as a set of versatile, generalized skills that find practical utility in everyday life.

B. Factors that Affect the Development of SPS

The development of SPS is a multifaceted journey influenced by a diverse array of factors. Numerous studies and literature have provided insights into the key components of this developmental process. Several factors and strategies were identified which include, scientific attitude and motivation, integration of SPS in curricular materials, classroom lessons, the use of instructional strategies and methods, and providing explicit teaching or training of SPS. The identified instructional strategies include student-centered teaching methods and multiple representations approaches. (Gizaw, Gidele & Sorsa, Solomon. 2023).

C. Science Attitude and Motivation Towards Chemistry

In our fast-paced and ever-changing world, education extends beyond acquiring knowledge and skills; it places significant emphasis on developing students' attitudes, behaviors, and motivation. This holistic approach aims to prepare individuals for the challenges and issues that the future holds (Miller, 2017). Opulencia (2011) stated that the goal of science education is to cultivate in students the ability to both think and act like scientists. This emphasis sheds light on the formation of the scientific attitudes that characterize a scientist's approach to their work.

D. Curriculum and Instructional Materials

Both materials are connected as it contributes to the efficiency of teachers and it also plays a vital role in facilitating effective learning for students. Moreover, curriculum materials can help teachers to select and integrate teaching methods, use of instructional materials or aids, guiding and supporting activities for students, and the preparation of lesson plans for the development of SPS among students (Abdu-Raheem, 2016; Lane, S. 2022; Gizaw, Gidele & Sorsa, Solomon. 2023). In the study of Ajidagba, et al., (2010) and Akinleye (2010), they believed that instructional materials can benefit teachers and students. Teachers can teach conveniently using the integrated materials and practical activities to make the learning process more rational, authentic, and practical. Moreover, students can grasp quickly without having any problems.

III. METHODOLOGY

The study used a case study approach which was done through classroom observations focusing on both teachers' and students' teaching and learning process respectively (Cresswell, 2013; Cresswell & Clark, 2018). The SPS inventory and attitude inventory was administered to determine the selected students to be focused. In addition, to assess the exhibited SPS among learners, a science proficiency assessment tool was used. Purposive sampling technique was utilized, which is a nonrandom method that involves deliberate selection of participants based on specific qualities they possess. The entire section of Grade 7 learners in MSU-IIT Integrated Developmental School taking up the chemistry subject served as the respondents for this study. Selection criteria for case study candidates focused on identifying students with the target attitudes towards chemistry (positive and negative) and the ability to practice science process skills (highly exhibiting and minimal to none). By employing purposive sampling, the researcher aimed to include students who are most likely to demonstrate the desired qualities and provide valuable insights relevant to the research objectives.

A. Quantitative Analysis

Among the quantitative data gathered were from the instrument validation, SPSPA, ASCIv2 and SPSI which are tools used to verify validity, assess SPS proficiency, identify attitudes towards the subject and look into their self-report SPS, respectively. The SPSPA tool was validated using the V-aiken index shown in Table I.

TABLE I. Instrument Validity Level Category

V-Aiken Index	Validity Level
V< 0.4	Low
0.4 0,4 ≤ V < 0,8	Medium
V ≥ 0,8	High

B. Quantitative Analysis

The qualitative data were generated from SPSPA during classroom observations and interviews. To assess thoroughly the process of development of learner's SPS, the researcher observed the classes during the entire duration of the discussion of the topic of interest using an observation sheet and researcher's log. The SPSs observed were analyzed and organized per criteria per topic. Descriptive analysis, emergence of findings, coding system, and comparative analysis was implemented (Patton, 2002).

IV. RESULTS

A. Science Process Skills Proficiency Assessment

The items 1, 2, 7, and 9 in Table II demonstrate moderate validity while 3, 4, 5, 6, and 8 demonstrate high validity. Based on the results of the expert's validation, the SPSPA instrument, with an average score of 0.795 (SD= 1.28) gained the medium category which stated that the assessment instrument was declared valid and suitable.

TABLE II. Summary of SPSPA Validation Results

Item Number	V-aiken	SD	Category
1	0.75	1.73	Medium
2	0.66	1.53	Medium
3	0.83	0.58	High
4	0.92	0.58	High
5	0.83	0.58	High
6	0.83	1.53	High
7	0.75	1.73	Medium
8	0.83	1.53	High
9	0.75	1.73	Medium
Mean	**0.795**	**1.28**	**Medium**

B. Science Process Skills Inventory

The 11-item SPSI each represents a different skill in the science inquiry process. The recommended SPSI score is based on the SPS composite score, which is calculated by summing the individual scores for each item.

TABLE III. Summary of SPSI of the respondents

Criterion no.	Mean	SD	Interpretation
1	2.59	0.74	Usually
2	2.71	0.80	Usually
3	2.06	0.78	Sometimes
4	2.24	0.82	Sometimes
5	2.41	0.66	Sometimes
6	2.41	0.86	Sometimes
7	2.41	0.82	Sometimes
8	2.50	0.90	Sometimes
9	2.26	0.93	Sometimes
10	1.94	0.79	Never
11	3.03	0.77	Always
Average	**2.41**	**0.81**	**Sometimes**

Table III shows the composite SPS scores which indicates that the learners (n=34) sometimes practice SPS (μ=2.41, SD=0.81). This depicts that based on their self-report, the learners usually use scientific knowledge to form a question and usually ask a question that can be answered by collecting data. Also, they can sometimes design a scientific procedure to answer a question, sometimes communicate a scientific procedure to others, record data accurately, use data to create a graph of presentation to others, create a display to communicate data and observations, analyze the results of a scientific investigation and use science terms to share the results. In contrast, the learners never used models to explain results but always use the results of their investigation to answer the question.

C. Chemistry Attitude

ASCIv2 is the shortened version from its original 20-item form with two subscales: intellectual accessibility (IA) and emotional satisfaction (ES) which has internal consistency by Cronbach alpha of 0.82 and 0.79, respectively. The instrument was found to detect small attitude differences (Bauer, 2008; Brandriet, et al., 2011; Xu & Lewis, 2011).

TABLE IV. Summary of ASCIv2 of the learners (n = 34)

Scale	Item No.	Mean	SD	Interpretation
Intellectual Accessibility (IA)	1	3.8182	1.336	Negative
	2	3.8182	1.2614	Negative
	3	3.7273	1.4202	Negative
	4	5.3333	1.2162	Weakly Positive
	Average	*4.1742*	*1.30789*	*Positive*
Emotional Satisfaction (ES)	5	4.0909	1.6079	Positive
	6	3.3939	1.7667	Negative
	7	4.3333	1.5943	Positive
	8	3.8788	1.9326	Negative
	Average	*3.9242*	*1.7253*	*Negative*
Overall		**4.0492**	**1.5566**	**Positive**

Table IV shows that in terms of IA the learners have a positive attitude (μ=4.1742, SD=1.30789) which indicates that they believe that chemistry is slightly hard, a bit complicated, a little confusing and slightly unchallenging. In terms of ES, the learners have a negative attitude (μ=3.9242, SD=1.7253) which indicates that they feel that chemistry as a subject is slightly comfortable and a bit pleasant but at the same time slightly frustrating and a little chaotic. Overall, though, the learners have a positive attitude (μ=4.0492, SD=1.5566) towards the subject.

D. Development of Learner's SPS

The purpose of this study is to describe the process of the development of the learners' SPS. The researcher chose the case study candidates based on their abilities to practice SPS as well as their attitudes towards chemistry. The mean scores from the SPSI and ASCiV2 were the basis for the selection of case study candidates.

TABLE V. Case Study Candidates

Cases	SPSI	ASCv2
Cases A	2.55 (Usually)	5.25 (Weakly Positive)
Cases B	2.73 (Usually)	4.38 (Positive)
Cases C	2.00 (Sometimes)	3.63 (Negative)
Cases D	1.90 (Sometimes)	3.75 (Negative)

As per result in Table V, Cases A and B are identified as high-performing students while cases C and D are at-risk students for the subject. This classification was also confirmed by the subject teacher.

Table VI shows the summarized count of SPS exhibited in each case. Case A, the highest attitude score among cases (5.25, Table V), demonstrated strong observation skills (6), and his in-depth knowledge of scientific concepts allowed him to predict objectives (5) and provide explanations (6) for results and efficiently organize and carry out investigations (6). He shows consistency and clear identification of variables and employs systematic approach for the collection of data. Moreover, case A demonstrated a systematic and analytical approach in drawing meaningful interpretation of results and conclusions (6) noting relationships among variables. Lastly, he displayed the ability to ask meaningful questions (3) and communicate effectively with the groupmates (4).

TABLE VI. SPS Exhibited during a Lab Activity on Density

Measuring and Comparing Densities Experiment				
SPS	**Score (Number of Counts)**			
	Case A	**Case B**	**Case C**	**Case D**
Observing	6	4	4	2
Predicting	5	4	5	2
Explaining	6	4	3	1
Planning and Conducting Investigations	6	4	4	4
Interpreting	6	2	3	0
Raising Questions	3	2	3	2
Communicating	4	3	4	4
Total	5.1	3.3	3.7	2.1
Interpretation	*P*	*AP*	*AP*	*D*

Legend: P = Proficient, AP = Approaching Proficiency, D = Developing

On the other hand, Case B, though the highest self-reported SPSI composite score (2,73, Table V), displayed lesser observation skills (4) than Case A. Lack of accuracy and depth is evident although she exhibited the ability to predict (4) and formulate explanations (4). Moreover, case B demonstrated a systematic approach that utilized realistic methods in measuring (4), but lacked accuracy in getting lab results leading to errors during interpretation (2). However, Case B exhibited the ability to formulate questions relevant to the experiment (2) but rarely listens to others' suggestions and feedback, which impacts the collaborative effort and her ability to communicate (1). Case B varied a bit from Case A in terms of SPS exhibited despite being both classified as high-performing, probably because the nature of Case B prefers less engagement and teamwork among group members and less focus on relevant observations needed for the experiment instead focused more on individualization and menial interaction. Whereas, Case A showed active participation and engagement in group activities plus has prior ability in utilizing laboratory equipment to gather accurate data.

In addition, Case C with lowest attitude score among cases (5.25, Table V), displays his ability to conduct and perform investigations with the guidance of his group members. He exhibited the ability to observe (4) using the senses which allowed him to distinguish relevant information needed for the experiment, and utilized laboratory equipment in gathering data. He made use of evidence in formulating predictions (5), however, he provided explanations based on his own understanding (3). Case C demonstrated his ability to formulate questions and participate effectively in answering those questions (3), which allowed him to communicate effectively during the experiment through active listening and discussions among peers (4). Case C and D were both assessed approaching proficiency in terms of exhibited SPS though they belong to different categories: C (at-risk) and B(high-performing) probably because B prefers to learn-work alone rather than in groups. It seems learning with others enhances the display of SPS. In addition, Case C and D belong to at-

risk however, Case D belongs to the developing level, lower than case C. This might be due to Case C's demonstrated balanced and active participation in group discussions effectively engaging in teamwork.

Lastly, Case D with the lowest self-reported SPSI composite score (1.90, Table V) has demonstrated a passive approach with little participation in group activities and fewer precise explanations (2). For observing, he utilized his senses of vision and touch while carrying out the experiment (2). He formulated predictions about the objectives of the experiment (2) but provided inaccurate explanations based on his own understanding (1). However, he actively participated in conducting and planning investigations through evaluating results, sought proper measurement techniques which demonstrate his willingness to learn (4). Additionally, he did not display any interpretation skills (0). Despite this, he could potentially improve his understanding because he asks relevant questions during the activity (2) and actively listens to both his classmates and teacher (4).

As a result of observed SPS exhibited during the lab activity in density, Case A is in proficient level while Cases B and C approaches proficiency, and Case D is still developing in terms of their level of SPS. A comparison between the level of SPS exhibited by high-performing learners (Case A & B) and at-risk group (Case C & D) is still inconclusive for only a topic in chemistry. However, enough and notable evidence shows that there exist differences among groups that could be starting points for crafting instructional materials and methods that could optimize the teaching-learning process.

V. Conclusion and Recommendations

The developed SPSPA which was used for assessing the learners' SPS has been declared valid and reliable. This suggests that the instrument effectively measures what it intends to measure and produces consistent results over time.

The finding of the SPSI suggests that the learners (n=34) sometimes practice SPS inside the classroom. ASCIv2 results suggest students have an overall positive attitude towards the subject (μ=4.0492, SD=1.5566), though negative (μ=3.9242, SD=) on ES but positive (μ=4.1742, SD=) on IA subscale. This suggests that learners think that chemistry as a subject is slightly hard, a bit complicated, a little confusing and slightly unchallenging and feel slightly comfortable and a bit pleasant but at the same time slightly frustrating and a little chaotic.

The development of SPS among the learners included in the case study suggests that they exhibited the essential features of effective scientific inquiry and learning. Case A exhibited most of the SPS while Case D had the least exhibited SPS. Overall, the study provided evidence that SPS can be examined and there exist distinct differences exhibited among high-performing and at-risk learners.

For the enhancement of the learners' SPS, the teacher may utilize various methods including assessment and reflection. This encourages learners to reflect on what they have learned, the processes they have used, and how they could improve.

For more beneficial aspects, further studies can improve the SPS among learners through developing interventions and employing evidence-based strategies.

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