The level of scientific research skills of the biology students in the Philippines

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ABSTRACT

Scientific research is essential in advancing human knowledge and in driving technological advancements. Students in the bachelor of science in biology program are expected to accomplish scientific research as a curriculum requirement. Possessing scientific research skills is essential for producing high-quality research outputs. A scale for assessing scientific research skills among senior high school students is available, however, there is an instrumentation gap in evaluating these skills at the tertiary level. In this regard, a research gap also exists in the assessment of students' scientific research skills. Confirmatory factor analysis (CFA) using the JAMOVI software was utilized to establish the validity and reliability of the scientific research skill scale. The study included 133 officially enrolled biology students who voluntarily agreed to participate. The results provided compelling evidence that the tool effectively assesses scientific research skills in three key areas: scientific information development skills, scientific research management skills, and scientific research processing skills. This also affirmed the relevance of the three key areas in the biology program. The results also revealed that the level of scientific research skills of the students is on the average level across all three areas. This reflected an existing issue in the field of scientific research as mastery of skills is crucial in producing quality output, hence the study has significant implications for curriculum developers and policymakers of higher education institutions. There is a need to revisit the curriculum and to incorporate opportunities to enhance scientific research skills across various science subjects.

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1. INTRODUCTION

Scientific research has a significant role in advancing knowledge and in driving technological innovations [1]. Scientific results provide a meaningful contribution to society [2]. The application of systematic and rigorous method through scientific research can result in solving problems that exist in a society such as in addressing different environmental threats [3]. Scientific research involves studies in natural sciences that include studies in the field of biology, which commonly requires a detailed examination of subjects as well as an exploration of interrelations and interdependencies [4].

In the Philippines, scientific research has been inculcated in basic education by engaging students in the development of science investigatory projects [5]. Students from elementary to high school level conduct scientific research to be presented at the science fair [5]. In terms of the senior high school, Santiago and Soliven [6] indicated that scientific research is gaining increased attention evident by studies reflecting scientific research productivity and influencing factors. In tertiary education, the bachelor of science in biology program is guided by the Commission on Higher Education (CHED) memorandum order No. 49, series of 2017 that outlines the mandated policies, standards, and minimum requirement in the program [7]. As stipulated in the memorandum, the minimum standard of the program concerning scientific research mandates students to utilize techniques in conducting biological research work in laboratory and field settings that may be acquired through fieldwork and research projects.

To successfully accomplish the tasks required in the program and to produce quality research output, students must be equipped with scientific research skills. The development of research skills is essential in graduate and undergraduate programs as it promotes enhanced research performance [8]. Moreover, success in research endeavors is strongly linked to proficiency in academic research skills [9]. Study by Diocos [10] specifically discovered that graduate students face significant hurdles in scientific research, with notable issues stemming from an insufficient mastery of essential research methodology and data analysis skills—components of practical scientific knowledge—thus emphasizing the critical need to better provide these skills. Moreover, Park and Ha [11] indicated that various obstacles were experienced in the conduct of scientific research in the post-graduate program including scientific uncertainty that can be addressed through the acquisition of technical skills in performing experimental procedures in scientific studies.

These issues about the skills in scientific research were also identified in basic education. Fernández *et al.* [12] found out that students in secondary high school have underdeveloped scientific research skills. The students exhibit difficulties in conducting scientific research due to inadequate skills in identifying research problems, constructing hypotheses, establishing an experimental design and drawing conclusions. This aligns with the findings of Tonzon [13] who also targeted to identify the level of scientific research skills of the secondary students. It was shown that the secondary students were found to have underdeveloped skills in terms of causal explanation and in generating hypotheses. The students were also found to be moderately skilled in terms of interpreting data, recognizing experimental variables, and in analyzing and interpreting the results of an experiment. Conversely, Servado [14] discovered that the students in senior high school science, technology, engineering, and mathematics (STEM) education are progressing toward mastery in terms of their scientific research skills. However, it was also indicated in the study of Servado [14] that grade level is not directly associated with the research skills of the students. It means that advancing to a higher grade level does not equate to a more enhanced scientific research skill and the developed skills in senior high school STEM education cannot serve as a basis of more developed skills in tertiary education.

The novelty of the study lies in addressing two critical research gaps. It is important to point out that a research gap exists in the assessment of scientific research skills of students in tertiary education, specifically in the biology program where these skills are integral to the curriculum. The skills of the students in this program warrant proper assessment to objectively establish if scientific research skills are also lacking among the students at the tertiary level. In addition to addressing the recognized research gap in the assessment of scientific research skills, the current study also seeks to address the lack of a validated instrument specifically designed to measure scientific research skills at the tertiary level. Santiago and Valtoribio [15], as cited by Servado [14] developed a tool in gauging the scientific research skills of the students, which focuses on three factors that include skills in processing, managing, and developing scientific information [16]. However, this scale is intended to measure the scientific research skills of senior high school students. Therefore, establishing the reliability and validity of the scientific research questionnaire can address the identified instrumentation gap.

To attain the objectives, the researchers grounded the current study with the self-efficacy theory of Bandura. According to Bhati and Sethy [16], the self-efficacy theory of Bandura has gained significant attention regarding its impact on the academic achievement of students. It was further emphasized that students with higher self-efficacy are more likely to accomplish difficult tasks and challenges compared to students with lower self-efficacy [16]. The theory of Iso-Aholo further justifies the foundation of the study as the theory posits that skills serve as mental and physical tools in carrying out effective motor and cognitive performance in different domains [17]. The theory put emphasis that the extent of skills can enable an individual to perform at a certain level [17]. These theories offer rationale for the attainment of the study's objectives because once skills are properly assessed, steps can be taken to further improve them, resulting in better performance and greater success. Tsintsadze *et al.* [18] have proven that self-assessment has a significant influence on the academic and personal growth of students as assessment can lead to the recognition of strengths and weaknesses leading to the development of autonomy in completing tasks.

Therefore, the researchers argue that self-assessment of the students' levels of scientific research skills is crucial in the identification of areas that need improvement. Such evaluation can serve as a foundation for implementing suitable actions that enhance scientific research skills, leading to improved research outcomes. The current study aims to assess the scientific research skills of the students in the bachelor of science in biology program. The study seeks to answer research questions that explore if the self-assessment scientific research skills scale that includes three factors namely scientific information development skill, scientific research managing skill, and scientific research processing skill is valid and reliable for the students in the biology program. Lastly, the current study aims to determine the level of scientific research skills of the students.

2. METHOD

A quantitative approach was employed in the form of a descriptive research design. The purpose of the descriptive research design is to describe individuals, conditions, or events without manipulation of variables. Moreover, this design also reflects the characteristics of a population along with the identification of trends or problems that exist within a unit [19]. The respondents of the study were composed of 133 officially enrolled first-year students in the program bachelor of science in biology at a university in the Philippines. All the respondents from the program voluntarily agreed to participate in the study.

The study utilized a self-assessment questionnaire developed by Santiago and Valtoribio [15] and utilized by Servado [14] in assessing the scientific research skills of senior high school students. The 20-item scientific research skills questionnaire was divided into three factors: 5 for scientific information development skills, 8 for scientific research managing skills, and 7 for scientific research processing skills. The adopted questionnaire was subjected to content validity by 3 experts in the field of scientific research to ensure the suitability, adequateness, objectivity, relevance, and appropriateness of the questionnaire to biology students. The questionnaire that utilized a 7-point Likert scale was further subjected to confirmatory factor analysis (CFA) using the JAMOVI software. CFA is a statistical method used to assess how well a proposed model fits the observed data [20]. It aids in verifying the underlying factor structure that is presumed to represent the targeted construct or phenomenon [20].

Using g power, an initial power analysis suggests that n=105 is minimum sample size with large effect size (f2=0.35), α=0.05, 95% power, with 20 observable variables. We obtained n=135 sample which yields 99% statistical power using α=0.05 with large effect size (f2=0.35) in the post hoc analysis [21]. The psychometric properties were established with construct, convergent, discriminant validity, and internal consistency, as seen in Table 1. Construct validity was established using CFA, and convergent and discriminant validity with the maximum shared variance (MSV), average variance extracted (AVE), and composite reliability (CR). In terms of reliability, Cronbach's alpha was used for the internal consistency of the scale. The psychometrics properties are presented in the results section.

All participants are first year biology students in a state university. Comparisons using independent t-test in terms of scientific information development skills (t(131)=-1.71, p=09), scientific research managing skills (t(131)=0.41, p=68), and scientific research process (t(131)=-0.38, p=70) between gender at birth (i.e., male and female) do not show significant differences.

Table 1. Factor structure

Scientific research skills	T	df	p
Scientific information development skills	-1.71	131	0.09
Scientific research managing skills	-0.41	131	0.68
Scientific research processing	-0.38	131	0.70

Note: two-tailed test, $p<0.05$

3. RESULTS AND DISCUSSION

3.1. Results

There is no missing information in the data set. JAMOVI was utilized in the validation of the research instrument. Table 2 includes CFA used to establish the construct validity of the instrument. In addition, Table 3 is composed of the CR, AVE, and MSV to establish the discriminant and convergent validity. Furthermore, Table 4 shows the descriptive statistics of the demographic profile and Table 5 shows the factor loadings and descriptive statistics of the items.

Table 2. Factor structure

Factors	CFI	TLI	SRMR	RMSEA	90% CI Lower	90% CI Upper	X^2	Df	P
The 3-factor	0.84	0.82	0.07	0.11	0.09	0.12	427	167	<0.001
Modified 3-factor	0.95	0.93	0.05	0.06	0.05	0.08	226	138	<0.001
One-factor	0.79	0.77	0.07	0.12	0.11	0.14	513	170	<0.001

Note: CFI=comparative fit index; TLI=Tucker-Lewis index; SRMR=standardized root mean square residual; RMSEA=root mean square error approximation

Table 3. Discriminant and convergent validity

Variables	CR	AVE	MSV
Scientific information development skills	0.96	1.37	0.525
Scientific research managing skill	0.92	1.71	0.525
Scientific research processing	0.95	4.11	0.638

Table 4. Descriptive statistics, bivariate correlation, and internal reliability

No.	Variables	1	2	3	M	SD	A	VD
1.	Scientific information development skills	-			4.43	0.94	0.87	Average
2.	Scientific research managing skills	0.72	-		4.17	0.99	0.89	Average
3.	Scientific research processing	0.72	0.80	-	4.38	0.98	0.86	Average

Note: 1-1.9=absolutely no mastery; 1.91-2.81=very low; 2.82-3.71=low; 3.72-4.61=average; 4.62-5.51=moving towards mastery; 5.52-6.41=closely approximating mastery; 6.42-7=mastered

Table 5. Factor loadings

Factor	Items	B	SE	M	SD
Scientific information development skills	1. I can develop my own scientific inquiry or question based on data available at hand that are scientifically correct.	0.74	0.09	3.99	1.20
	2. I can prepare an abstract of a research topic.	0.94	0.09	4.40	1.31
	3. I can bring my ideas in developing a research topic.	0.93	0.11	4.71	1.25
	4. I can create my own hypothesis.	0.94	0.09	4.38	1.30
	5. I can create correct recommendations based on the result of my own study.	0.97	0.09	4.53	1.25
	6. I can create appropriate rationale of my study.	0.87	0.09	4.14	1.19
	7. I can correctly create my own conclusions.	0.79	0.10	4.83	1.29
Scientific research managing skill	8. I can manage research articles of a theme drawn from scientific journals, and databases.	0.86	0.10	4.19	1.33
	9. I can recognize a scientific paper in reputable resources.	1.09	0.09	4.22	1.37
	10. I can communicate orally or through written the results of a review of scientific literature.	0.79	0.09	4.21	1.27
	11. I can identify gaps in the articles I read from literatures and related studies.	0.97	0.09	4.15	1.40
	12. I can systematically plan research and its implementation based on scientific rules.	0.93	0.11	4.05	1.23
	13. I can appropriately organize the structure of data analysis based on scientific rules.	0.84	0.09	4.07	1.18
	14. I can systematically manage the actual study or experimentation implementation.	0.84	0.09	4.16	1.32
	15. I can systematically manage the actual research writing.	1.03	0.09	4.29	1.28
Scientific research processing	16. I can appropriately analyze main ideas of a varied data source such as literature and my own experiment.	0.91	0.10	4.32	1.16
	17. I can discuss data interpretation from different data sources such as literature and my own experiment.	0.89	0.10	4.23	1.17
	18. I can appropriately use statistical procedures in my analysis.	0.86	0.09	4.05	1.30
	19. I can choose reliable information from varied data sources.	0.88	0.09	4.94	1.32
	20. I can appropriately use scientific procedures in implementing experiments.	0.98	0.09	4.35	1.20

3.1.1. Validity and factor structure of scientific research skills scale

The three confirmatory tests were used to test the models of the scientific research scale: i) the 3-factor structure with all 20 items; ii) modified 3-factor structure with covaried items of all 20 items; and iii) single-factor model with all 20 items. Hu and Bentler guide [22] was used to interpret the model-fit index. Root mean square error approximation (RMSEA) and standardized root mean square residual (SRMR) of less than 0.07 and 0.00 indicate an excellent and perfect fit of the models. For the comparative fit index (CFI) and Tucker-Lewis index (TLI), indexes greater than 0.90 and 0.95 suggest adequate and excellent fit. Lastly, a non-significant Chi-square, however, the Chi-square findings were no longer accounted for in the interpretation since it tends to favor a larger sample size as specified by Tanaka [23].

The 3-factor structure obtained a poor model-fit index, the CFI and TLI are both lower than 0.9, and SRMR and RMSEA are higher than 0.07 (CFI=0.84, TLI=0.82, SRMR=0.07, RMSEA=0.108). The modified 3-factor structure obtained adequate fit index, CFI and TLI are higher than 0.90, SRMR and RMSEA are both less than 0.70 (CFI=0.95, TLI=0.93, SRMR=0.05, RMSEA=0.06). The items were covaried based on the modification fit suggestions (1-2, 1-7, 1-5, 4-7, 8-9, 8-10, 10-11, 12-13, 13-14, 8-14, 9-14, 10-14, 9-13, 2-5, 3-5, 11-12, 3-6, 5-6, 5-7, 11-14, 12-14, 9-12, 14-15, 16-17, 16-19, 11-13, 15-16, 8-13) within the respective factor structures (i.e., scientific information development skills, scientific research managing skills, and scientific research processing). Lastly, the single-factor model obtained poor model-fit, the CFI and TLI are both lower than 0.9, and SRMR and RMSEA are higher than 0.07 (CFI=0.79, TLI=0.77, SRMR=0.07. RMSEA=0.12).

Figure 1 reflects the 3-factor structure of scientific research skills. Items within the sub-components were covaried. Item 1 to item 7 obtained adequate fit in the scientific information development skills; item 8 to item 15 with the scientific research management skills; and item 16 to item 20 with the scientific research processing skills. Lastly, the adequate model fit suggests that scientific research skills are composed of scientific information development skills, scientific research management skills, and scientific research processing skills.

Upon establishing the factor structure, the convergent and discriminant validity was tested as reflected in Table 3. CR was used to establish the reliability of the study since CR analyzes the reliability of each subtest of a construct. All components of scientific research skills obtained a CR higher than 0.70 suggesting excellent reliability. The AVE should be higher than 0.50 to establish the convergent validity. All components of the scale obtained an AVE higher than 0.50. Lastly, the MSV of all the components is lower than the AVE supporting a good discriminant validity.

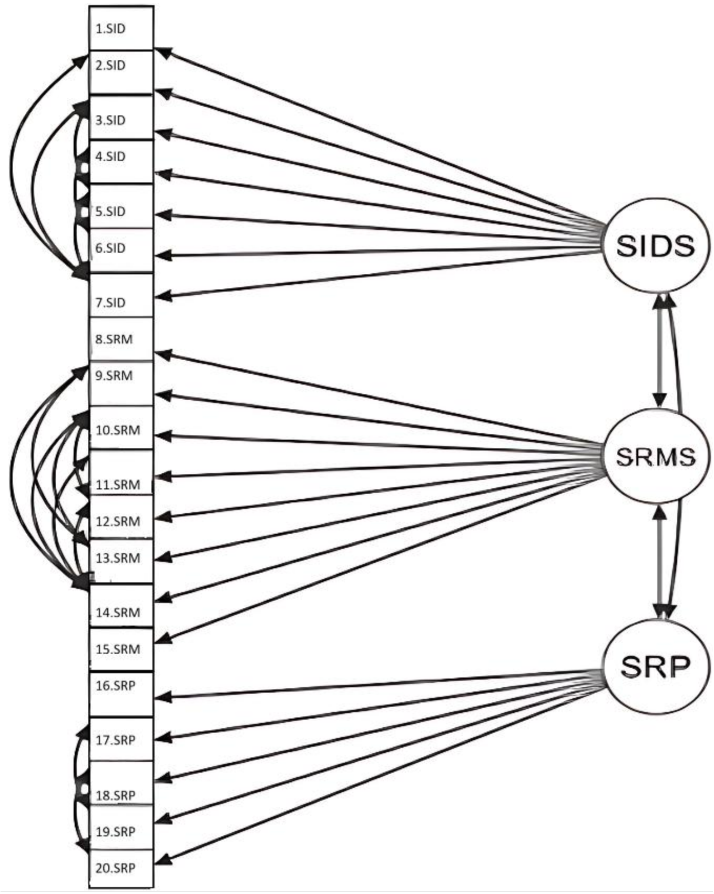

Figure 1. The 3-factor structure with maximum likelihood estimation

3.1.2. The level of scientific research skills

Table 4 reflects the overall mean score of 4.43 for factor 1, 4.17 for factor 2, and 4.38 for factor 3 which revealed that the level of scientific research skills of the students under the bachelor of science in biology program is on the average level across all three factors. Table 5 further shows that under scientific information development, the students exhibit average proficiency in developing scientific inquiry, preparing abstract, creating hypothesis, rationale, and recommendations. The least developed skill in this area is the skill in developing scientific inquiry with a total mean score of 3.99. In addition, Table 4 also showed that under the scientific research management, the students have average skills in recognizing scientific papers from credible sources, identifying gaps, communicating the study both orally and in writing, and in systematically planning and managing scientific-based implementation, data analysis, experimentation and in actual research writing. The identified least developed scientific research management skills is the skill in the implementation of the study. Furthermore, it is also reflected that the students have average skills in analyzing sources, interpreting data, utilizing statistical procedure, and implementing experiments. The identified least developed skill is the skill in using statistical procedure.

3.2. Discussion

3.2.1. The scientific research skill scale

The results provided compelling evidence that the self-assessment tool effectively measures the scientific research skills of the students in the bachelor of science in biology program. The effectiveness of the tool in measuring the scientific research skills of senior high school students was previously established while the current study confirms its relevance for tertiary education students particularly those in the biology program. Grounded by the self-efficacy theory of Bandura, this study successfully validated a self-assessment scale that measures the students' scientific research skills. Vasileiadou and Karadimitriou [24] confirmed that self-assessment has a positive influence with students' academic performance. Hence, this finding is significant as the tool can help in the identification of the strengths and weaknesses of the students enabling the provision of targeted interventions. Moreover, since the validity and reliability of the tool is already established in the biology program, this has opened an opportunity for future researchers to establish its suitability to other tertiary education programs. Critically, the validated tool can also be used in the identification of the relationship of various factors on the level of scientific research skills of the students. This is one of the limitations of the study that can be addressed in the future with the use of the validated tool. Establishing the factors that influence the level of scientific research skills of the students can significantly contribute to achieving high-quality research output.

The results also confirm the relevance of the three key areas in the biology program: scientific information development skills, scientific research managing skills, and scientific research processing skills. One of the identified key areas in scientific research is the scientific information development skill that pertains to the ability of the researcher to formulate scientific information across various aspects of the study including its implementation [14]. This area covers the skills in developing inquiry from scientifically correct data and skills in developing an abstract, rationale research topic, hypothesis, recommendation, and conclusion [14]. Hosseini *et al.* [25] highlight the importance of formulating clear research questions as a critical step in evidence-based studies which emphasize that well-defined questions underpin the construction of problem statements and hypotheses and ensure rigorous and effective scientific research. The accomplishment of these key steps requires skills defined in factor 1 (scientific information development skills). Additionally, this skill is relevant in the biology program as it allows students and researchers to generate new information and address relevant issues. This skill aligns with one of the biology program outcomes in the Philippines, where students are expected to contribute to the advancement of knowledge in biological sciences.

The ability to manage scientific research is another essential skill that students in biology program are expected to acquire. Scientific research managing skills focus on the ability to search, manage, organize, and systematically arrange scientific information and the different research components. This area covers the skill of recognizing scientific papers from credible sources, the skill in communicating the study both orally and in writing, the skill in identifying research gaps, and the skill in systematically planning and managing scientific-based implementation and experimentation [14]. Birney *et al.* [26] emphasized that management of research data had become a priority as researchers seek to increase the reproducibility of findings, and in promoting the reuse of data. This is also anchored in the biology program's objective as students are expected to acquire skills in effectively communicating research outputs both orally and in writing.

Another important factor to be emphasized in this program is the development of scientific research processing skills that cover the ability to process and analyze scientific information effectively. This skill focuses on the capability to comprehend, process and analyze various aspects of the study covering the planning, implementation, and writing of the scientific paper. It also includes the ability to analyze data from both literature and experimental results, as well as the proficiency in applying appropriate statistical methods [20]. The processing and analyzing of data are necessary in organizing the findings from varied data collection methods and in extracting meaningful insights from large datasets [27]. According to Olaitan [28], data collected from studies are unstructured facts that become meaningful when these are subjected to correct processing. The scientific method is fundamentally grounded in the collection and analysis of data to validate theories and hypotheses and to draw empirical conclusions [29].

3.2.2. The level of scientific research skills

The current study successfully bridged the identified research gap and attained the objective of assessing the scientific research skills of students in the biology program. Using the validated questionnaire, it was determined that the students possessed an average level of scientific research skills. The results reflect a continuing challenge in the field of scientific research evident by the underdeveloped skills of the students. There is a clear need to enhance the average skill level of the students, as the biology curriculum demands proficiency necessary for roles in government and private institutions, along with competencies relevant to research activities. Mastering research skills is critical for undergraduate students throughout their academic journey and remains valuable in their future careers [8].

In comparison to the data obtained by Servado [14] using the same instrument, the senior high school STEM students were on moving towards the mastery level compared to the average level of students in biology program. The result supported the claim of Servado [14], that a higher grade level is not a guarantee of enhanced research skills. It is also noteworthy to indicate that the respondents from the university are composed of students with STEM and non-STEM backgrounds in their senior high school years as the CHED permits state universities and colleges (SUCs) in the Philippines to admit students irrespective of the senior high school track or strand they have completed, as outlined in CMO 105, series of 2017 [30]. The senior high school strand is a factor to be considered in understanding the scientific research skills of the students. According to Birney *et al.* [26], STEM students are provided with research opportunities that the students develop engagement and enthusiasm towards the research process. This factor serves as another limitation of the study, hence further studies are needed to determine if the senior high school strand of a student influences their level of scientific research skill.

To further examine three key areas, the results revealed that under the skill in developing scientific information, the students possess average skills in developing scientific inquiry, abstract, hypothesis, rationale, and recommendations. In connection, difficulties were observed among secondary students pertaining to skills in identifying problems and in establishing hypotheses [12]. This means that difficulties in scientific research may also be present in tertiary education as mastery of scientific research skills was not achieved by the students. As stated by Hashmi [31], students struggle with research writing due to low level of writing skills.

Hence, these average skills may lead to difficulties in the future research endeavors of the students. Furthermore, the identified least-developed skill in this area is the skill in developing scientific inquiry. Enhancing scientific inquiry is beneficial as this process counters the tendency to treat science as a fixed body of knowledge [32]. Moreover, Zompero *et al.* [33] emphasized the need of equipping the students with inquiry practices for them to build confidence.

The results also revealed that all areas under scientific research management are at an average level, with study implementation being the least developed skill. The result aligns with the findings obtained by Servado [14] that revealed that the least developed scientific research managing skill of the senior high school STEM students pertains to the skill in the implementation of the study. In terms of the scientific research processing skills, the students were found to have average skills in analyzing sources, interpreting data, and implementing experiments with the skill in using statistical procedure as the least developed skill. Fernández *et al.* [12] highlighted that the secondary students also have difficulty with the skill in designing experimental procedures. Problems related to the skills in utilizing proper statistical procedures among senior high school were also reflected in the study of Servado [14]. These difficulties extend into the postgraduate education as challenges were identified in the key aspects of the research process [34]. This is alarming given the fact that underdeveloped skills extend to the post-graduate level. The processing and analyzing of data are commonly seen as the most complex phase in a research project that demands a systematic and analytic approach to ensure that the data is properly processed from the point of collection to the analysis stage [35]. A study by Hashmi [31] revealed that the student researchers faced difficulties in analyzing and interpreting research data and clamored for training that can improve these abilities.

Given the critical role of scientific research in higher education, the necessity of enhancing these skills is well established in this study. Actions are warranted to enhance the scientific research skills of the students to address the existing challenges in this field and to produce better research output. Mastering scientific research is essential for university students to advance their academic development and to contribute to the progress of society [36]. Moreover, higher self-assessment can result in a greater chance in achieving academic goals [37]. The theory of Bandura suggests that exposure to safe yet challenging tasks can foster mastery and lead to the further enhancement of skills. Hence, the results confirm the importance of implementing targeted educational strategies to develop these essential competencies in higher education.

The cultivation of scientific research skills at the tertiary level is highly beneficial as it opens opportunities to be exposed to an engaging learning environment that sparks students' interest and enhances students' innovative and practical capabilities [38]. The enhancement of students' scientific research skills is closely tied to the structure and opportunities provided within the curriculum. Tonzon [13] emphasized that scientific research skills are best acquired when incorporated into subjects being taken by the students as isolated programs that target scientific research skills unlikely to enhance the students' scientific research capabilities. Establishing and maintaining sustainable research initiatives can yield significant advantages to both academic institutions and notably to the students [39].

4. CONCLUSION

The study successfully bridged identified research gaps in the field of scientific research. Guided by the self-efficacy theory, the instrumentation gap was addressed through the validation of the self-assessment tool that gauges the level of scientific research skills of the students in the biology program. The three key skills recognized as valuable in the program include scientific information development skills, scientific research managing skills, and scientific research processing skills. Future studies may be done to identify if these skills are also relevant to other science-related courses that require completion of scientific research. Moreover, similar studies may focus on including a larger number of respondents since the validity and reliability of the questionnaire are already established. The study further revealed that the scientific research skills of the students in the bachelor of science in biology program were underdeveloped indicated by the average skill level obtained by the students. The findings have significant implications for curriculum developers and policymakers in higher education institutions. There is a need to assess and revisit the curriculum to ensure that the opportunity to engage in scientific research is integrated across various subjects as scientific research skills are most effectively developed when integrated into subjects. Future studies may also focus on identifying effective capacity enhancement programs that target the enhancement of scientific research skills. Future training programs may be adjusted and may also include the development of the identified three key areas in scientific research.

It is also important to highlight that the university students in the biology program exhibit lower levels of scientific research skills compared to the results gathered by other researchers in the assessment of senior high school STEM students. This limitation of the study regarding the exploration of the senior high school strand of the students may be considered to fully understand the scientific research skills of the students. Future studies may focus on identifying the correlation between senior high school strands and the scientific research skills of students in science-related courses.

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AUTHOR CONTRIBUTIONS STATEMENT

The chart presents the contributions of all the authors. The checkmark indicates the specific contributions of each author.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Chillet G. Credo	✓	✓		✓	✓	✓		✓	✓	✓		✓	✓	
Justin Vianey M. Embalsado	✓	✓	✓	✓		✓		✓	✓	✓	✓			
Jed V. Madlambayan	✓		✓	✓	✓			✓		✓	✓			
Rich Paulo S. Lim	✓	✓	✓		✓					✓			✓	
Maica S. Pineda		✓			✓	✓	✓		✓	✓		✓		
Ricardo C. Salunga		✓	✓			✓	✓			✓			✓	
Arnel A. Diego		✓		✓		✓	✓		✓	✓	✓	✓		
Tracy John A. Credo	✓				✓		✓		✓	✓	✓	✓		

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors state no conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author [CGC], upon reasonable request.

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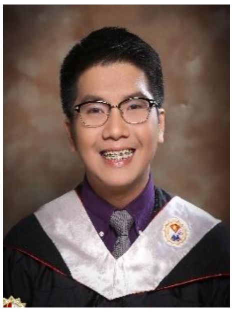

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