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Students' Conceptual Understanding, Self-Efficacy and Scientific Creativity in Science Learning: A Multivariate Analysis

Albert Andry E. Panergayo

Abstract

This paper examined the conceptual understanding, self-efficacy, and scientific creativity of the students in Physics. The study further investigated the significant difference observed in the study variables according to sex and grade level using multivariate analysis. Using descriptive model of research design, the 125 Senior High School (SHS) students were asked to fill out the Physics Conceptual Understanding (PCU) test, Science Learning Self-Efficacy Scale (SLSE), and Scientific Creativity (SC) test. After the score were tallied and organized, two-way MANOVA was administered to determine the difference in the outcome variables when grouped according to sex and grade level. Based on Pillai's Trace as revealed, there was a statistically significant difference in independent variables based on grade level. The analysis further revealed that PCU (p=0.675) and SLSE (p=0.101) are unaffected, while SC (p=0.010) is influenced by the grade level. This study uncovered that there is no sex difference observed, while statistical variation exists in terms of grade level specifically to SC. This concludes that PCU, SLES, and SC is not affected by their sex identity but are associated on their academic level. Implications for practice into classroom are discussed and further suggestions of future research are provided.

Keywords: *conceptual understanding, multivariate analysis, science learning self-efficacy, scientific creativity, self-efficacy*

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About the author:
College of Teacher Education, Laguna State Polytechnic University, San Pablo City, Laguna 4000, Philippines. Email: albertandry.panergayo@lspu.edu.ph

1. Introduction

In the recent years, science education has undergone various educational reforms in order to respond to the evolving knowledge-based society and to the rising global demands for workforce equipped with scientific literacy and skills. This was further fuelled by the emergence of COVID-19 pandemic coupled with industrialization which created a double-disruption effect on the way education is delivered to the learners (Schwab & Zahidi, 2020). The increasing adoption of technology paved greater gaps in the in-demand skills over the next five years (Whiting, 2020). Consequently, educators and policy makers were prompted to reinvent curriculum to address the rising mismatch with the acquired competencies in schools to the required skills in the global market. In fact, science education takes no exception from the impacts of these educational reforms and transition. The current reforms directed science education to gradually place Science, Technology, Engineering, and Mathematics (STEM) education at the center of the curricular development. STEM, as an academic field, has been recognized both locally and globally to be a powerful vehicle for economic and social development (Panergayo et al., 2021). This can be attributed to the fact that STEM education equips students with skills that make them more employable and prepared to fulfil current and future labor demands, from a wide range of experiences to abilities (Partnership for 21st Century Skills, 2017).

STEM-skilled workforce is a focal element to meet economic challenges and sustainability in the 21st Century. In defining STEM skills, Siekmann and Korbel (2016) argued these skills are difficult to describe since they do not exist in isolation; they are directing, enabling, or facilitating abilities that derive content from other skill areas, comparable to innovation skills. According to Sen et al. (2018), however, STEM skills are seen to emerge from problem solving skill, association skill, engineering-based design skills, innovation, digital competence, creativity, and communication and collaboration. Skills necessary to carry out STEM-related tasks involved cognitive, manipulative, technological as well as collaboration and communication skills. In an effort to respond to the advancement of industries, both STEM and non-STEM tasks are demanding young people who have developed and developing the broad-set of skills. In fact, STEM skills are in great demand from employers and will remain so in the future. Currently, 75% of jobs in the fastest growing industries require manpower with STEM skills (Deming & Noray, 2019). Hence, STEM learners are encouraged to engage in continuing professional development and actively enhance their competencies to meet the increasing demands of the workplace (UNESCO, 2019).

Gender disparity has been well documented for decades in most OECD countries (OECD, 2012). Gender differences and its influence to career paths have been long documented in the literature and is still evident nowadays as revealed by the current Global Gender Gap Report of the World Economic Forum (WEF). It states that on average men are underrepresented in the fields of education, health and welfare while women are underrepresented in the STEM fields (WEF, 2017, p. 31). Gender gaps research in science has been investigated multiple times in the literature (i.e. Makarova, 2019; Charlesworth & Banaji, 2019; Huang et al., 2020; Sá et al., 2020; Al-Balushi et al., 2022; Cimpian et al., 2020; Meinck & Brese, 2019; Nygaard et al., 2022; Frandsen et al., 2020; Gupta, 2019; Reinking & Martin, 2018; Kiran et al., 2023; Marescotti et al., 2022). Makarova et al. (2019) contended that gender-science stereotypes of math and science can possibly impact young women and men's goals to register in a STEM major at university by showing that a less definite masculine image of science has the potential to increase the probability of STEM career aspirations. In spite of the fact that gender gap is evident in STEM disciplines such as physics and engineering, there is a numerical dominance of female students in biology area suggesting no disparities exists in undergraduate life sciences (Eddy et al., 2017). In view of these, the study aimed to examine and compare the conceptual understanding, science learning self-efficacy, and scientific creativity in Physics across sex and grade level of SHS STEM learners in a state university in the Philippines. The result of this study would provide valuable inputs in enhancing the teaching and learning process in STEM education considering the gender difference and academic level. Likewise, the findings may serve as a groundwork for developing lesson exemplars, instructional materials, and learning environment directed towards enhancement of students' performance in terms of conceptual understanding, science learning self-efficacy, and scientific creativity. This study posits the following hypotheses:

H1: There is a significant difference on students' conceptual understanding, science learning self-efficacy, and scientific creativity when grouped according sex and grade level.

H2: Sex and grade level significantly determine the students' conceptual understanding, science learning self-efficacy, and scientific creativity?

2. Literature Review

2.1. Conceptual understanding

The literature has revealed that students come to their science classrooms with a range of different conceptions about the natural world surrounding them (Pfundt & Duit, 1991; Carmichael et al., 1990). David Ausubel (1963), an American psychologist who is famous for his researches in advanced organizers, argued that the most vital single factor prompting learning is what the learner already knows. When a student interprets, relates, and merges new information with current knowledge, and then applies the new information to solve unique challenges, they are engaging in meaningful learning (Gonzalez et al., 2008). Pines (1985) defines concept as "packages of meaning [that] capture regularities [similarities and differences], patterns or relationships among objects [and] events, p. 108." Similarly, according to Joseph Novak, who is recognized for his concept mapping study, concept is "a perceived pattern in events or objects, or recordings of events or objects, identified by a seal of approval. Most of these concepts have a label in word or in the form of symbol (Novak & Canas 2008). A concept is further defined as a tool constructed for the purpose of organizing observations and used for the prediction of actions and classification. In science, the fundamental building blocks of thought that have depth referred to concepts (Moran & Keely, 2016).

2.2. Science learning self-efficacy

Students have ideas about their capacities for learning science. It has been demonstrated that these self-perceptions about their individual capacities to promote science learning directly influence success through motivation and their capacity to function in a certain science learning environment (Evans, 2014). These self-efficacy attitudes are crucial for enhancing science education. Similar to this, learning content has an impact on how self-efficacy develops (Zhu, 2007). When faced with challenges and learning material, students who lack self-efficacy for learning may exhibit task avoidance and self-doubt. Researchers are prompted to investigate the motivating processes in teaching and learning by the perspective of conceptual transformation (Barros et al., 2010). Education academics are therefore drawn to the application of the self-efficacy notion in understanding scientific learning to ascertain its effects on the teaching and learning process. This motivates experts in science education to investigate how to gauge students' levels of self-efficacy in relation to science learning, which leads to the creation of several scales in science education.

2.3. Scientific Creativity

Scientific creativity (SC) is another important skill needed to be developed among STEM students. SC is one of the context-specific forms of creativity. It is defined as the capacity to have a novel-original and useful-adaptive ideas in the domain of natural and social science (Guilford, 1956). Scholars generally agree that diverse thinking and scientific inventiveness go hand in hand. Creativity includes both the act of coming up with an idea or a solution and the method by which those ideas are generated. In light of this, learning science necessitates a significant engagement with a wealth of knowledge, creativity, and creative thoughts. The history of science is full of momentous discoveries, innovations, and breakthroughs that were made possible by the emergence of spontaneous, useful knowledge. In the rapid changing environment due to industrialization, the society offers new problem that requires new forms of solutions. In this regard, creativity has become a necessity at this age of innovation and invention. Developing the students' conceptual understanding, self-efficacy, and creativity in science learning should be place at top priority in the STEM educative process.

3. Methodology

3.1. Research design

This study used the descriptive model, that is comparative and cross-sectional in nature, as a research design. Gall et al. (2007) argued that this research design allows to collect data in a methodical way to characterize the study variables. In the present study, the study variables are the conceptual understanding, science learning self-efficacy, scientific creativity, and the preferred learning style of SHS STEM learners. Dullock (1993) further contended that descriptive research also allows comparison of different criterion variables from different demographics. Hence, this research design was deemed utilized to address the research problems.

3.2. Participants

The main participants of this study are 125 SHS students. The participants were students who were officially enrolled in STEM Track during the academic year 2022 to 2023. Table 1 shows the profile of the respondents according to sex, age, and grade level. The table clearly shows that majority of the respondent were female (64.8%), while the remaining percentage are male (35.2%). It also presents that a large fraction of the respondents was 16 and 17 years old with percentage distribution of 39.2% and 56.0%. It can further be gleaned from table 1 that Grade 11 (54.4%) dominated the Grade 12 (45.6%) students.

Table 1

Profile of the respondents (n=125)

Demographics		**f**	**%**
Sex	Female	81	64.8
	Male	44	35.2
Age	16	49	39.2
	17	70	56.0
	18	1	0.8
	19	4	3.2
	20	1	0.8
Grade level	Grade 11	68	54.4
	Grade 12	57	45.6

3.3. Instruments

This study utilized the following research instruments to collect the needed data to answer the research objectives:

Physics Conceptual Understanding Test (PCUT). This instrument is a researcher-made test composed of conceptual questions adapted from California Standardized Test and Massachusetts Comprehensive Assessment System released test questions for Physics. The test is composed of 50 items divided into knowledge (20%), comprehension (40%), and application (40%) type of questions. It further underwent expert validation from three Physics professors from a state university in Manila, Philippines which made the test constructions deemed appropriate to the nature of the target respondents.

Scientific Creativity Test (SCT). The SCT was adapted from the study of Hu and Addey (2002) and was validated for the purpose of the study. This scale was used to assess the scientific creativity of the students based on the Scientific Creativity Structure Model (SCSM) constructed by the same developer of SCT. The original test was composed of seven items which was trimmed down to six items due to contextual concerns after expert validation. The seventh question was not included since it is not fitted to the context of Filipino learners.

Science Learning Self-efficacy (SLSE). The SLES is adapted from the work of Lin and Tsai (2013) to assess the self-efficacy in science learning. The instrument is composed of 32 items distributed in five dimensions namely conceptual understanding (5 items), higher-order cognitive skills (6 items), practical work (seven items), everyday application (8 items), and science communication (6 items). This is measured in a five-point Likert scale ranging from “1-strongly disagree” to “5-strongly agree.”

3.4. Data collection

The data collection involved online administration of the four instruments due to physical restrictions caused by the pandemic during the time of data gathering. The instruments were administered through the help of the science teachers of the SHS department in the research site. The four instruments were administered in three sessions. In the first session, the PCUT was administered to the students by the researcher. The PCUT was posted in the web-based program and allowed the students to answer the test in one hour. In the second session, the students were asked to answer the SCT for one hour. The SCT was simultaneously facilitated by the science teachers to all involved students in different sections. To protect the integrity of the tests, auto-proctoring software was installed. In terms of checking the SCT, three external science teachers were hired to objectively evaluate the answers of the students using the guidelines suggested by Hu and Addey (2002). In the last session, the SLSE was administered. The researcher explained how to answer the instrument to the facilitators and students. The data were then tabulated and arranged using spreadsheet in preparation for data analysis.

3.5. Data analysis

This study used descriptive and inferential statistics to address the research problems. The study used frequency, percentage, mean and standard deviation to describe the independent variables such as students' PCU Test, SLSE, and SC. In testing the assumptions for two-way MANOVA, pre-analysis screening procedures for examining multivariate assumptions were carried out using (1) Box's Test of Equality of Covariance Matrices; (2) Test of Normality (KS/SW); (3) Multicollinearity Test; (4) Correlation Analysis; and (5) Levene's Test of Equality of Error Variances. Lastly, two-way MANOVA was administered to determine the difference in students' PCU, SLSE, and SC when grouped according to sex and grade level.

4. Findings and Discussion

4.1. Descriptive Statistics

Table 2

Descriptive statistics according to sex and grade level

	Sex	Grade Level	Mean	SD	N
PCU	Female	Grade 11	27.0444	9.33214	45
		Grade 12	25.5000	5.83340	36
		Total	**26.3580**	**7.96133**	**81**
	Male	Grade 11	24.0870	7.50705	23
		Grade 12	24.4286	6.19331	21
		Total	**24.2500**	**6.83400**	**44**
	Total	Grade 11	26.0441	8.81389	68
		Grade 12	25.1053	5.93622	57
		Total	**25.6160**	**7.62295**	**125**
SLSE	Female	Grade 11	3.4820	.55980	45
		Grade 12	3.5164	.38638	36
		Total	**3.4973**	**.48782**	**81**
	Male	Grade 11	3.1991	.68325	23
		Grade 12	3.4962	.51132	21
		Total	**3.3409**	**.61885**	**44**
	Total	Grade 11	3.3863	.61422	68
		Grade 12	3.5089	.43218	57
		Total	**3.4422**	**.54033**	**125**
SC	Female	Grade 11	41.9556	23.95731	45
		Grade 12	54.1944	20.02972	36
		Total	**47.3951**	**22.99222**	**81**
	Male	Grade 11	39.6522	17.52818	23
		Grade 12	47.8095	17.36554	21
		Total	**43.5455**	**17.73245**	**44**
	Total	Grade 11	41.1765	21.88637	68
		Grade 12	51.8421	19.18592	57
		Total	**46.0400**	**21.29569**	**125**

Table 2 shows the mean and standard deviation of the participants when clustered according to sex and grade level. In terms of PCU, the female grade 11 students registered the highest mean score (M=27.04, SD=9.33). On the other hand, female grade 12 students reported the highest mean rating in SLSE (M=3.52, SD=0.38) and SC (M=54.19, SD=20.02). This indicates the female senior high school students generally perform better when compared to their male counterpart.

4.2. Test of assumptions

Prior to employing two-way MANOVA, several assumptions were needed to be satisfied. In this study, three dependent variables were included *(PCU, SLSE, and Scientific Creativity)* that are considered continuous variables. The independent variables used were sex and grade level which were consisted of two categorical and independent groups. Female and male for sex while grades 11 and 12 for grade level. Likewise, there was an independence of observations that there was no relationship between the observations in each group or between the groups. Different participants in each group were observed without participating in more than one group. The study further showed that the sample size was considered adequate because there were more cases than the number of observed dependent variables. In testing the assumption, pre-analysis screening procedures for examining multivariate assumptions (normality, outliers, multicollinearity, correlation, and Homogeneity of Covariance Matrices) were also carried out.

Table 3

Test for homogeneity of covariance

Box's Test of Equality of Covariance Matrices	
Box's M	34.160
F	1.802
df1	18
df2	27090.101353
Sig.	.020

Box's M test (also called Box's Test for Equivalence of Covariance Matrices) is a parametric test used to compare variation in multivariate samples. In particular, it examines whether two or more covariance matrices are homogeneous. With a sig. value of $p = 0.020$

greater than the threshold $p = 0.05$ as shown in table 3, it can be concluded that the assumption of homogeneity of covariance has been overcome across sex and grade levels. This indicates that the observed covariance matrices of the dependent variable are equal across groups.

Table 4

Test of normality of residuals of the dependent variables

Dependent Variables	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PCU	.088	125	.020	.985	125	.179
SLSE	.056	125	.200*	.985	125	.195
SC	.108	125	.001	.943	125	.020

Table 4 presents the results from two well-known tests of normality, namely the Kolmogorov-Smirnov Test and the Shapiro-Wilk Test. Since the sample is 125, which is larger enough to 50, the Shapiro-Wilk Test was used to determine the normality of the data. The independent variables PCU (p=0.179) and SLSE (p=0.195) were normally distributed since the Sig. value of the Shapiro-Wilk Test is greater than 0.05. However, the SC (p=0.020) significantly deviate from a normal distribution since the sig. value is lower than 0.05. Thus, SC data is not normal.

Table 5

Multicollinearity statistics of dependent variables

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	11.147	.297		37.482	.000		
PCU	-.009	.006	-.131	-1.457	.148	.936	1.069
SLSE	.072	.084	.078	.862	.390	.928	1.078
SC	.006	.002	.260	2.863	.005	.918	1.090

Table 5 shows the multicollinearity statistics of dependent variables. Multicollinearity is the unwanted scenario where one independent variable is a linear function of other independent variables (Ibrahim et al., 2018). The Variance Inflation Factor (VIF) has the maximum value of 1.090 as indicated in table 7, which is far below 10.0. VIF of 10 and above indicate that there is multicollinearity (Ibrahim et al., 2018). Since all the VIF values are far below 10.0 and the tolerance readings are reasonable, it means that the study do not have multicollinearity issues.

Table 6

Correlation Analysis of Dependent Variables

Dependent Variables	1	2	3
PCU			
SLSE	.185*		
SC	.212*	.230*	

*Correlation is significant at the 0.05 level (2-tailed).

Multicollinearity also relates to correlation matrix, and it occurs when predicted variables are highly (0.9 and above) correlated. Since the correlation coefficient r-values are less than the threshold as shown in table 6, the concern of no multicollinearity was further verified.

Table 7

Test of equality of variance of dependent variables

Levene's Test of Equality of Error Variances				
	Levene Statistic	**df1**	**df2**	**Sig.**
PCU	4.046	3	121	.004
SLSE	2.017	3	121	.115
SC	1.958	3	121	.124

Levene's Test of Equality of Variance is used to examine whether or not the variance between independent variable groups is equal also termed as homogeneity of variance. Non-significant values of Levene's test suggest equal variance between groups. Table 7 shows that only PCU (p=.004) emerged to be significant since its p-value is less than 0.05. This suggests that the null hypothesis that the error variance of the dependent variable is equal across groups is not supported. On the other hand, SLSE (p=.115) and SC (p=.124) obtained a non-significant result indicating that the variance between independent variable groups is equal.

4.3. Multivariate analysis

Two-way MANOVA was used to analyzed the data in this study. MANOVA is used to investigate whether there is any significant variation between independent groups on more than one continuous dependent variable. In the present study sex and grade level were considered independent variables where each was composed of two categories. On the other hand, three continuous variables served as dependent variables namely PCU, SLSE, and SC. The results of MANOVA were presented as follows:

Table 8

Multivariate test for sex and grade level

	Effect	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power
Intercept	**Pillai's Trace**	.977	1722.898	3.000	119.000	.000	.977	5168.693	1.000
	Wilks' Lambda	.023	1722.898	3.000	119.000	.000	.977	5168.693	1.000
	Hotelling's Trace	43.434	1722.898	3.000	119.000	.000	.977	5168.693	1.000
	Roy's Largest Root	43.434	1722.898	3.000	119.000	.000	.977	5168.693	1.000
Sex	**Pillai's Trace**	.032	1.311	3.000	119.000	.274	.032	3.932	.342
	Wilks' Lambda	.968	1.311	3.000	119.000	.274	.032	3.932	.342
	Hotelling's Trace	.033	1.311	3.000	119.000	.274	.032	3.932	.342
	Roy's Largest Root	.033	1.311	3.000	119.000	.274	.032	3.932	.342
Grade Level	**Pillai's Trace**	.074	3.149	3.000	119.000	.028	.074	9.446	.719
	Wilks' Lambda	.926	3.149	3.000	119.000	.028	.074	9.446	.719
	Hotelling's Trace	.079	3.149	3.000	119.000	.028	.074	9.446	.719
	Roy's Largest Root	.079	3.149	3.000	119.000	.028	.074	9.446	.719
Sex*Grade Level	**Pillai's Trace**	.022	.901[b]	3.000	119.000	.443	.022	2.703	.243
	Wilks' Lambda	.978	.901[b]	3.000	119.000	.443	.022	2.703	.243
	Hotelling's Trace	.023	.901[b]	3.000	119.000	.443	.022	2.703	.243
	Roy's Largest Root	.023	.901[b]	3.000	119.000	.443	.022	2.703	.243

Table 8 provides the multivariate test for sex and grade level. Pillai's trace is used as a test statistic in MANOVA and MANCOVA. This is a positive valued statistic ranging from 0 to 1. Increasing values means that effects are contributing more to the model; reject the null hypothesis for large values. As sample size decreases, unequal n's appear, and the assumption of homogeneity of variance-covariance matrices is violated, Pillai's criterion is more recommended to be used. This test is considered to be the most powerful and robust statistic for general use, especially for departures from assumptions. For example, if the MANOVA assumption of homogeneity of variance-covariance is violated, Pillai's is an appropriate option.

Based on Pillai's Trace as revealed in table 8, there was a statistically significant difference in independent variables based on grade level, F= 3.149, p < .0005; $Pillai's\ Trace\ V(s)$= 0.074; $partial\ \eta 2$ = .074.

Table 9

Univariate table for grade level

Source	Dependent Variable	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power
Contrast	**PCU**	10.254	1	10.254	.176	.675	.001	.176	.070
	SLSE	.779	1	.779	2.730	.101	.022	2.730	.374
	SC	2948.366	1	2948.366	6.849	.010	.054	6.849	.738
Error	**PCU**	7029.880	121	58.098					
	SLSE	34.513	121	.285					
	SC	52086.005	121	430.463					

Table 9 reveals the univariate table for grade level. Dependent variable with sig. values less than 0.05 indicate that the grade level are significant factors that affect itself. Based on univariate analysis, PCU (p=0.675) and SLSE (p=0.101) were unaffected by variation in grade level as revealed on the computed sig. values. On the other hand, SC sig. value (p=0.010) is lower that the threshold indicating that grade level determines the STEM students' scientific creativity.

Table 12

Estimated Marginal Mean

Dependent Variable	Grade	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
PCU	11	25.566	.977	23.632	27.500
	12	24.964	1.046	22.893	27.036
SLSE	11	3.341	.068	3.205	3.476
	12	3.506	.073	3.361	3.651
SC	11	40.804	2.659	35.540	46.068
	12	51.002	2.848	45.363	56.641

4.4. Discussion

The study revealed that STEM students do not demonstrate significant variation when it comes to their conceptual understanding in science, specifically Physics, when grouped according to gender and grade level. This suggests that gender and grade level are not determinants of student's ability to understand science lessons. This finding is supported by the study of Jia et al. (2020) that boys tend to outperformed girls in achievement test on both high- and low-score ranges. However, no gender difference of science achievement in both Grade 4 and Grade 8 in a province in China. Similarly, Niemenen (2013) revealed no gender difference in learning the force concept using pretest results of representational consistency and scientific reasoning as covariates. On the other hand, literature also revealed contrasting results on the present study. Bates et al. (2013) found that students at all three universities under study exemplified a statistically significant gender difference in favor of male students in terms of their conceptual understanding in Newtonian mechanics. Sagala et al. (2019) further revealed that there are differences in the results of understanding the concept between male and female students where male students are higher than female students. Similarly**,** Cahyanto et al. (2019) uncovered that female had a better conceptual knowledge than males in terms of their pre-conceived knowledge resulting to differences between male and female students.

On the other hand, SLSE beliefs was also examined and revealed that no significant difference exists among the STEM students when clustered according to their gender and grade level. This indicates that the students' beliefs about their capabilities to perform any science tasks well is not determined by their gender preference and academic level. In fact, a similar study conducted by Baji (2020) found that there was no significant difference in academic self-efficacy between male and female students. However, the mean value of female students indicated a higher level of academic self-efficacy (mean =78.36) over the male students (mean =78.16). Sezginturk (2020) uncovered no statistically significant mean difference between boys and girls with respect to science self-efficacy dimensions with both genders reporting not to be highly self-efficacious. However, Aurah (2017) employed MANOVA to examine science self-efficacy in terms of gender and detected a statistical difference, with female students reporting better self-assessment than male students. The same result was revealed by Al-Balushi et al. (2022) indicating that there is a gender gap in science achievement, which is associated to their science learning self-efficacy. Kassaw and Astatke (2017) revealed a similar scenario regarding gender difference in general self-efficacy.

The study further shows the SC scores based on gender revealed no significant differences. It suggests that no statistical disparity can be identified between male and female in terms of their SC scores. It follows that the absence of variance between males and females in SC offers equal chances for every person to develop their scientific creativity. The same result was revealed by Duruk (2020) that SC did not significantly differ when group according to sex. Male have a tendency to have higher levels of self-efficacy than female in math and science-analytic creativity, which in turns affects creative outcomes (Kaufman, 2006; Karwowski et al., 2015). Jia et al. (2020) found that male and female students did not demonstrate significantly different levels of academic self-efficacy. However, female students reported higher level of academic self-efficacy when compared to male. Fadllan et al. (2022) and Fadllan et al. (2018) found that SC of male and female students is not significantly different. Aruan et al., (2016) further uncovered that SC is not influenced by a learners' gender. This suggests that gender has no significant effect on students' scientific creativity. It can be noted, however, that the SC of male students is higher than females in introductory Physics.

5. Conclusion

The study examined the PCU, SLSE, and SC of senior high school STEM students, revealing significant differences based on sex and grade level. Female students performed better in conceptual understanding, self-efficacy, and creativity. However, no significant difference was found in PCU, SLSE, or SC when grouped by sex. This indicates that the higher the level, the more creative the students are. It can be attributed to the fact that students gained more knowledge and skills in higher years, which are salient inputs to express creativity in scientific contexts.

The study provides practical recommendations for teaching and learning in STEM fields. It recommends intentional support for male students due to low performance in conceptual understanding, self-efficacy and creativity. Fostering self-efficacy and creativity through growth mindset encouragement and open projects is also essential. Furthermore, diverse learning strategies, collaboration, and continuous assessment are needed to capture the varied needs of the students. Professional development, cross-class collaboration, and parental involvement for teachers are also recommended to encourage a culture of inquiry and improve students' STEM education.

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