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Effect of science process skills and entry grades on academic scores of student teachers

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ABSTRACT
The development and acquisition of science process skills (SPS) in science education are closely linked to the development of 21st-century skills and improvements in academic performance. To help facilitate the development of SPS in learners, teachers should acquire and exhibit SPS. This study assesses the SPS acquired by final-year students in a college of education who are pursuing a bachelor's degree in education, using regression correlation to find relationships between their acquired SPS, entry qualifications and academic performance. A parametric achievement test was used to assess the SPS acquired by the student teachers and extant data were used to construct their entry qualifications and academic performance. The data for the study were collected from 236 student teachers in four science colleges affiliated with the University of Cape Coast in Ghana. The results indicated that SPS contributed more to better academic performance than did students' entry qualifications. However, the nature of assessment of academic performance was such that basic SPS was a better influencer of academic performance than integrated SPS. It is recommended that, aside from entry qualifications, SPS acquired by candidates aspiring to pursue science programmes in tertiary institutions should be considered for admissions, and academic assessment instruments should be improved to encourage acquisition and development of integrated SPS.

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Introduction

The aim of science education is to build skills in students that equip them with the ability to apply those skills in their everyday life in a scientific manner (Opulencia, 2011). Curricular documents for science education in Ghana at various levels share this view (Ministry of Education [MoE], 2007a, 2007b, 2010a, 2010b, 2019). For example, MoE 2019 (p. 5) states, among other things, that: 'The science curriculum is designed to help learners to (a) develop a sense of curiosity, creativity, innovation and critical thinking for investigating and understanding their environment; (b) develop skills, habits and attitudes necessary for scientific inquiry; (c) communicate scientific ideas effectively; and (d) use scientific concepts in explaining their own lives and the world around them.

In science education, skills that allow one to function in a scientific manner (Padilla, 1990) and also help solve scientific problems like the ones espoused in the curricular documents incorporate science process skills (SPS; Akinbobola & Afolabi, 2010; Harlen, 1999; Nwosu & Okeke, 1995). Mushani (2021) asserted that SPS still supports the development of other skills individuals are supposed to possess for use in daily life. SPS are grouped into basic SPS (BSPS) and integrated SPS (ISPS; Ango, 1992; Padilla, 1990). BSPS include observing, communicating, measuring, inferring and predicting, while ISPS comprises data interpreting, controlling variables, hypothesising and experimenting. The BSPS are known to help with science learning and concepts formation, while the ISPS are notable for solving scientific problems (Akinbobola & Afolabi, 2010).

SPS have been linked to the development of 21st-century skills (Baran et al., 2021; Ergül et al., 2011; Opara, 2011; Osman & Vebrianto, 2013). Learners whose SPS are well developed possess better abilities to meet the demands of 21st-century life (Osman & Vebrianto, 2013). Ergül et al. (2011) also asserted that when learners acquire and develop SPS, they are able to better solve problems, think critically, make decisions, find answers and satisfy their concerns. An aim of science education is to inculcate the acquisition and development of SPS and to offer learners the ability to describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge and communicate their ideas to others (Opara, 2011).

Kayange and Msiska (2016) viewed 21st-century learning as the type of education that, although appreciating the acquisition of content knowledge, transcends mastering content into respecting and understanding cultural diversity and enabling learners to produce, synthesise and evaluate information that emerges from different subjects and sources. For science education to be relevant to the 21st-century era, science learning should put an emphasis on interactions between theory and practice, individuals and communities, formal and informal learning, learners and meta-cognitive brokers (Lee & Hung, 2012). It is obvious that SPS is an essential factor that influences the aspirations of the 21st-century era. Learners who acquire and develop SPS are likely to contribute more positively to the socioeconomic developments of this 21st-century era and future life.

Integrating SPS acquisition and development into the teaching and learning process to make learning relevant in the 21st century involves the participation of school systems and the abilities of teachers. Evidence from several studies suggests that schools do make a noticeable impact on learners' skill development and that teachers are an important part of learners' development (Darling-Hammond & Bransford, 2005; Dembélé & Lefoka, 2007; Rice, 2003; Tsui, 2009). It therefore becomes apparent that teachers must exhibit such dispositions as effective learners who are reflective in their practice, able to think critically and evaluate different points of view (Flores & Day, 2006). The need for teachers to acquire and develop SPS is necessary on two grounds. First, teachers are professionals with certain ethical, as well as technical, expectations placed upon them, and secondly, education must serve democratic purposes (Darling-Hammond & Bransford, 2005). Democratic perspectives held by professional teachers implies that they are multi-perspective thinkers, innovative, evaluative and have effective interactions with learners and curriculum content.

The need to develop SPS and 21st-century skills in not only students but also in teachers coincides with the recommendations made by the Presidential Committee on the Review of Education Reform in Ghana. The Presidential Committee recommended that the objective of teacher education should be the training and development of the right type of teachers, who are competent, committed and dedicated (Republic of Ghana, 2002). The need for relevant skills and knowledge for the present era brought about policies to upgrade teacher training institutions to Colleges of Education (CoE), with degree awarding status. The aim of the upgrade included training teachers who are capable of applying, extending and synthesising various forms of knowledge; developing attitudes, values and dispositions that create an environment that is conducive to quality teaching and learning in schools; facilitating learning and motivating individual learners to fully realise their potentials; and adequately preparing the learner to participate fully in the national development (Republic of Ghana, 2002). The recommended upgrading of teacher training institutions to CoE in Ghana happened with the first batch of CoE students, who are currently in the final year of their 4-year programme. Since the introduction of the Bachelor of Education programme in the CoE, no studies have been conducted to assess student teachers acquired SPS and its influence on their academic performance. It has therefore become imperative to assess their acquired SPS and how it impacts their academic performance in the CoE.

Literature Review

Research reviews of SPS in both the developed and developing worlds have indicated an inequality of SPS inclusion in science curricular documents (Akinbobola & Afolabi, 2010; Koomson, 2020; Mushani, 2021; Ongowo & Indoshi, 2013). Lack of appropriate evaluation of science curricular documents for SPS inclusion and development and acquisition of SPS have been blamed as the main factors affecting the progress of science education (Downing & Gifford, 1996; Duruk et al., 2017; Patonah et al., 2018; Siachibila & Banda, 2018). The basic science process skills are also known to be a basis for acquiring and developing the integrated science process skills (Padilla, 1990). Unfortunately, acquisition and development of SPS has been found to emphasize BSPS at the expense of ISPS (Akinbobola & Afolabi, 2010; Duruk et al., 2017; Koomson, 2020, 2021; Ongowo & Indoshi, 2013).

An analysis of the Turkish secondary school curriculum (Duruk et al., 2017) showed that the representation rate of SPS varied with grade level and unit, although the BSPS were generally more emphasised. An analysis of West African and Kenyan secondary school examinations (Akinbobola & Afolabi, 2010; Koomson, 2020; Ongowo & Indoshi, 2013) showed a similar trend of emphasis in curricula for chemistry, biology and physics, respectively. Koomson (2021) also found that while chemistry students in their final year of secondary education in Ghana had acquired mainly BSPS, including observing and communicating, and ISPS, including interpreting, SPS of classifying, hypothesising, controlling variables and experimenting were only minimally developed or acquired.

Evidence has indicated that a variety of teaching approaches during the science learning process impacts SPS development (Rauf et al., 2013). Some studies have also revealed that there is a positive relationship between SPS and academic success in science courses (Beaumont-Walters & Soyibo, 2001; Farsakoğlu et al., 2012). However, such studies in Africa and in Ghanaian CoE, in particular, are limited. Very little is known about the development and acquisition of SPS among student teachers who are expected to teach science at the primary and junior high schools in Ghana. Taale et al. (n.d.) explored science student teachers' views on the kind of practical activities and skills they engage in when teaching in Ghanaian CoE. Yaayin et al. (2021) also explored the use of the jigsaw model as an alternative to traditional practical approaches in organic functional group compounds. While the study linked their approach to improvement in performance, there was no reference to skills development. Taale et al. (n.d.) also indicated the student teachers' perceptions of the frequency of engagement in practical activities and skills, but the link to academic performance was not made. Beaumont-Walters and Soyibo (2001) assessed the performance of 164 students from Jamaican Reform of Secondary Education (ROSE) project high schools and 141 students from non-ROSE high schools. The six-way analysis of variance (ANOVA) conducted revealed, among other things, that the ROSE schools outperformed the non-ROSE schools. The link between the acquisition of SPS and academic performance was inferred rather than determined, however. The inference was based on the known fact that the ROSE schools were academically better than the non-ROSE schools. Similarly, Farsakoğlu et al. (2012) measured SPS acquired by students in Turkey and analysed the result against different grade levels with the expectation of linearity. The assumption was that increasing grade levels would accompany increasing academic ability, but a linear progression in acquisition of SPS was not realised in the study.

Harlen (1999) linked SPS to understanding scientific concepts with the assertion that SPS have a central role in learning with understanding. Countries that scored high in the Trends in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA) assessment frameworks, which assess mainly SPS, are touted as high achievers in science, and these assessments have compelled many to include SPS in their curricula. For example, a conclusion from the analysis of TIMSS 2019 was encouragement to involve pupils in field trips and to allow them design and conduct experiments (Sabah et al, 2023) in order to develop SPS. Investigations from Abungu et al. (2014), Hiğde and Aktamış (2022), Kasuga et al (2022), Koksal and Berberoglu (2014) and Uzun and Sen (2023) have aimed to justify the place of SPS in curricula. Usually, interventions with frameworks of SPS are incorporated into a controlled experimental approach involving pre- and post-tests. Reports in the literature have demonstrated various levels of effects. However, a limitation of such approaches is that quasi-experiments (QE) in social research usually lack randomisation and are replete with confounding factors that are typically difficult to identify and minimise (Andrade, 2021). The confounding effect is even more pronounced when univariate analysis is used in QE designs. The recommendation was made for the use of multi-variance regression analysis to limit confounding factors (Andrade, 2021).

For instance, Sackes (2013) undertook longitudinal studies involving 8731 kindergarten children (5–6 years old). The aim was to relate the factorial structure of the children's mathematics and SPS with an impact on their performance on mathematics and science achievement tests in the third grade (8–9 years old). The multilevel structural equation modelling tool used to analyse the data revealed that both mathematics and SPS are among the key determinants of children's success in the third grade. The results of the study indicated that mathematics and SPS together accounted for 27% of the variance in children's mathematics achievement in third grade and 22% of the variance in children's science achievement in third grade. The study used three instruments: a mathematics achievement test, science achievement test and survey questionnaire. The questionnaire collected information about teachers' backgrounds, classroom practices and ratings of children's skills. Although a standard scheme could be used to objectively assess the achievement test, they found that objectivity and standardization were likely compromised to a significant extent in the rating of the process skills of participants, particularly considering the number of assessors with diverse knowledge and skills who were involved in the study. This critique has footing in the observation that early childhood teachers' competencies at evaluating mathematics and SPS tend to vary considerably. Also, some teachers have fewer opportunities to observe children using SPS. These observations limit the accuracy of the procedure used to assess SPS in the study (Early et al., 2010; Sackes et al., 2011).

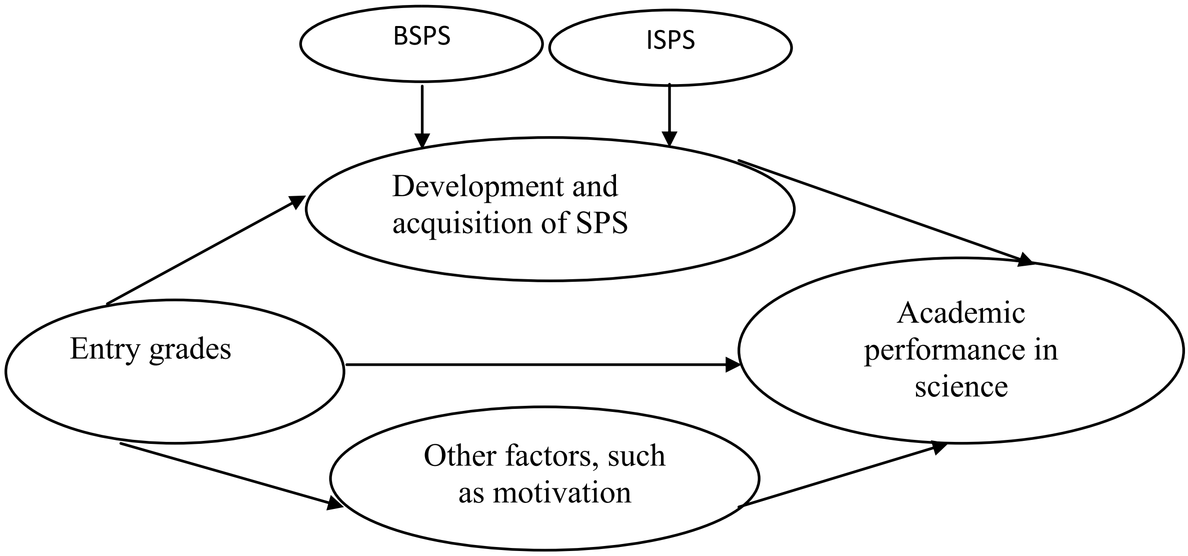
The present study aimed to improve objectivity in relating acquired SPS and academic performance of student teachers by using different data collection and analytical approaches. The study is unique in comparing the contribution of SPS to academic achievement with that of entering grades. Studies that relate entering grades to academic achievements include Spahr (1995), Hoskins et al. (1997), Zezekwa and Mudavanhu (2011) and Wambugu and Emeke (2013). In their assessment of the performance of students studying at the University of Plymouth, Hoskins et al. (1997) identified the key variables affecting student performance to be age, gender, discipline studied and entering grades. Entering grades (prior qualifications) is a key selection criterion for admission to most tertiary institutions. Spahr (1995) investigated the effect of entering grades on the graduating status of some 255 students admitted to a nursing programme, using multiple regression analysis to determine the contribution of the students' grade point average (GPA) and grades in three prerequisite support courses (biology, chemistry and algebra) on graduation status. The analysis showed that while contributions of the selected variables were significant, their effects on academic success were rather low. GPA was the greatest determinant, with about a 4.4% effect, followed by biology (0.33%), then chemistry (0.18%), with algebra being the lowest (0.02%). Many of the studies reviewed used students in primary and secondary schools and other tertiary students; however, only a limited number of studies have looked at preservice teachers' academic performance in relation to their SPS and entry grades. Wambugu and Emeke (2013) used regression analysis to study the effect of entry grades on achievements in biology, chemistry and physics and found that the effect of entry grades, while statistically significant, had a low contributory effect. Wambugu and Emeke (2013) called for alternative criteria for admitting students into tertiary programmes, particularly science-related programmes.

Conceptual Framework

The preceding review of the literature shows that SPS influences academic performance in science (Beaumont-Walters & Soyibo, 2001; Farsakoğlu et al., 2012). Lewin & Stuart (2003) asserted that effective teacher education relies on motivation and other characteristics of the student teacher. The issue of motivation and other learner characteristics is evidenced by the fact that the academic success of student teachers depends not only on content knowledge but also on the ability to learn how to learn and to regulate the learning process (Dembo, 2001). Studies such as Anane (2018, 2020), Wambugu and Emeke (2013) and Ogunleye and Agoro (2013) have related entry grades of student teachers in the CoE to their academic success.

Figure 1

Hypothetical Model of Influence of SPS Development and Acquisition, Entry Grades and Other Factors on Academic Performance in Science



The study, therefore, made the assumption that the development of SPS, entry grades and other factors, including motivation (Anane, 2020), influence academic performance in science, as hypothesized in Figure 1, and aimed to explore the relationship (if any) among SPS, entry grades and academic science course in CoE in Ghana. In line with the stated aim, the study focused on three research questions and two hypotheses.

Research Questions

Research Question 1: What is the emphasis of the SPS acquired by student teachers in the CoE science programmes?

Research Question 2: What contributions do SPS and entry grades make to subsequent academic performance?

Research Question 3: How does acquisition of SPS relate to contribution to academic performance?

Hypotheses

***HO1*:** There is no significant difference between the apparent effect of SPS and entry grades on subsequent academic scores.

***HO2* :** There is no significant difference between the apparent effect of BSPS and ISPS on subsequent academic performance.

Methods

Design

The study was a correlational study employing an achievement test and document analysis as means of collecting quantitative data to understand the relationships among process skills, entry grades and academic performance. The study assumed that SPS and entry grades of student teachers might contribute to their academic performance.

Measures

The achievement test, which was adapted from Koomson (2020, 2021), contained two parts The instrument is named the Students' Development of SPS Index Test (SDSPS). Part A collects biodata, such as index numbers, with the intent to access extant data in the form of entry grades and academic scores of the participants. Part B of the SDSPS is a parametric achievement test comprising 36 questions that assess nine higher order SPS. There are four questions for each SPS. The SPS under examination included observation (questions 1–4), measurement (questions 5–8), classification (questions 9–12), inference/prediction (questions 13–16), communication (questions 17–20), controlling variables (questions 21–24), data interpretation (questions 25–28), hypothesis (questions 29–32) and experimentation (questions 33–36). These skills were based on the Ghanaian senior high school curriculum (MOE, 2010a) and are relevant to student teachers because completion of senior high school is a prerequisite for admission to the CoE. The instrument was modelled on SPS instruments used with science attitude questionnaires to determine relationships of the SPS with science attitudes among Palestinian secondary school students (Zeidan & Jayosi, 2015). Although the style of construction of the test was modelled on that of Zeidan and Jayosi (2015), the content was based on the Ghanaian curriculum. The index numbers of the participants were used to retrieve their entry qualification and scores in a particular science course that was common and compulsory to all of the participants. The accessed result was used as a measure of their academic performance.

Reliability of Instrument

Koomson (2020, 2021) reported a reliability of 0.7 using two science groups (A and B) in similar environments. Both groups A and B, each comprising 21 participants, were tested with SDSPS, and the results were analysed using Cronbach's alpha reliability test. The reliability test was conducted after proofreading and validation by chemistry teachers. The reliability of the current study was checked by testing and retesting using 40 students selected from one CoE outside of the sampled population after 4 weeks, and the retesting was conducted using the same items. The Cronbach's alpha reliability test of the two results was 0.84.

Sample

The participants for the study were all science student teachers in the four science CoE affiliated with the University of Cape Coast who were willing and available at the time of data collection. All students in the population frame were requested to participate. A few students opted out, and others were absent on the day of data collection. In the end, 236 students, which comprised about 80% of the expected population, took part in the study. The participants were between 20 and 28 years old, with 48% being female and 52% male. Only 110 out of 236 participants willingly wrote their index numbers to access extant data for further analysis

Data Analysis

The result of the achievement test was analysed by assigning 1 to the correct answer and 0 to incorrect answers. Participants were scored for the overall SPS, BSPS and ISPS and all 10 subcategories of SPS, and the scores were converted into percentages. The academic scores were extracted from the extant data as percentages, with entry grade extracted as numbers, from a minimum of 6 to a maximum of 36, with the best entry grade being 6. These numbers and percentages allowed further analysis, including regression correlation and ANOVA.

Findings

Emphasis of Acquired Process Skills among College Student Teachers in Science Programmes

Research Question 1

What is the emphasis of the SPS acquired by student teachers in the CoE science programmes? Table 1 shows that participants who willingly gave their index numbers to access their academic and entry grades had mean scores better than the mean scores of the entire group of participants in all components of the SPS examined except the skill of observing.

Table 1

Descriptive Statistics of All Participants Compared to Those Providing Index Numbers for Follow-Up

Variable	Total Participants (*N*=236)			Participants Providing Index Number (*N*=110)		
	Mean	Std. Err.	Std. Dev.	Mean	Std. Error	Std. Dev.
SPS	45.3	1.1	16.6	50.7	1.7	17.7
BSPS	50.2	1.2	17.8	55.7	1.8	18.5
ISPS	39.3	1.4	21.2	44.4	2.1	21.6
Observing	60.4	1.7	25.4	59.1	2.5	25.7
Communicating	57.6	2.3	35.4	71.4	3.4	36.0
Data Interpreting	55.0	2.4	37.2	63.6	3.6	37.3
Measuring	52.0	1.7	26.8	55.2	1.9	20.3
Classifying	44.8	1.7	25.5	52.3	2.3	24.5
Inferring	39.2	2.0	30.9	45.0	3.0	31.7
Hypothesizing	35.3	2.4	36.3	37.1	2.2	22.9
Controlling Variables	35.1	1.8	27.3	41.8	2.9	30.3
Predicting	32.6	2.2	33.2	36.8	3.1	33.0
Experimenting	32.0	1.6	24.7	36.1	2.3	23.8
Entry Grade				23.5	0.4	4.3
Acad. Score				70.3	1.1	11.0

Note. SPS = Science process skills; BSPS = basic SPS; ISPS = integrated SPS

For example, the mean score for SPS was 45.3 for the entire group of participants ($N = 236$), but the group of participants who provided their index numbers ($n = 110$) had a mean SPS score of 50.7. Table 1 shows that student teachers in the CoE science programmes had acquired more BSPS (50.2%) than ISPS skills (39.3%). The top five acquired SPS in descending order of emphasis were observing (60.4%), communicating (57.6%), data interpreting (55%), measuring (52%) and classifying (44.8). Six of the acquired SPS fell below the passing mark of 50%: classifying (44.8%), inferring (39.2%), hypothesising (35.3%), controlling variables (35.1%), predicting (32.6%) and experimenting (32.0%). The only ISPS that scored higher than 50% was data interpreting.

Contributions of SPS and Entry Grades to Academic Performance

Research Question 2

What contributions do SPS and entry grades make to academic scores? Table 2 shows how the data in the study conform to assumptions made in using regression.

Table 2

Pearson's Correlation of the Dependent and Independent Variables

Variable	ISPS	BSPS	SPS	Academic Score	Entry Grade
ISPS					
BSPS	0.583* 0.000				
SPS	0.881* 0.000	0.897* 0.000			
Academic Score	0.313* 0.001	0.473* 0.000	0.445* 0.000		
Entry Grade	−0.073 0.447	−0.092 0.338	−0.093 0.332	−0.286* 0.002	

Note. *Correlation is significant at $p < .01$. SPS = Science process skills; BSPS = basic SPS; ISPS = integrated SPS

Table 2 shows that the data do not violate the assumption of multicollinearity. The independent variables, BSPS, ISPS and entry grades, correlate well with the dependent variable, academic score. The correlations among the independent variables, however, are not high ($< .6$) enough to violate the assumption of multicollinearity. Nevertheless, ISPS and BSPS correlated highly ($R > 0.8$ with SPS. Therefore, SPS was not included with either of them as a dependent variable in the same model. The consistency in the sustenance of the assumption of multicollinearity is also revealed by the tolerance and variance inflation factor (VIF) values of more than .1 and less than 10, respectively, for all variables, as shown in Table 4. Table 3 shows the regression model using SPS and entry grades as predictors of academic scores.

Table 3

Summary Model of Influence of Process Skills and Entry Grades on Academic Scores

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	.508	.258	.244	9.591

The R value in Table 3 indicates .508 with R^2 of .258. This shows that the two variables, SPS and entry grades, contribute 25.8% to academic scores.

HO1

There is no significant difference between process skills and entry grades on academic scores.Table 4 contains the regression coefficients of various predictors of academic scores.

Table 4

Regression Coefficients of the Variants

Variable	Standardized Coefficients	Sig.	Correlation	Collinearity Statistics	
	Beta		Part	Tolerance	VIF
SPS	0.445	0.000	0.445	1.000	1.000
BSPS	0.440	0.000	0.358	0.661	1.514
ISPS	0.056	0.592	0.046	0.661	1.514
Entry Grades	−0.246	0.004	−0.245	0.991	1.009

Note. VIF = Variance inflation factor; SPS = science process skills; BSPS = basic SPS; ISPS = integrated SPS.

Table 4 shows the part correlation coefficients of process skills and entry grades as .445 and .245, respectively. This shows that SPS and entry grades had unique contributions (part square) of 19.9% and 6%, respectively. Table 5 shows that the contributions from the two predictors (19.9% and 6%) are significant at $F(2, 107) = 18.6$, at $p < .0001$.

HO1 is, therefore, rejected. Acquired SPS is a significantly better predictor of academic performance than entry grades.

Table 5

ANOVA of Contributions of Process Skills and Entry Grades to Academic Scores

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3420.993	2	1710.496	18.594	0.000
	Residual	9843.380	107	91.994		
	Total	13264.373	109			

Contribution of Basic Skills and Integrated Skills to Academic Performance

HO2

There is no significant difference between contributions of basic and integrated skills on academic performance.

Table 6 shows the summary of the regression model using basic skills, integrated skills and entry grade as independent variables against academic scores as the dependent variable.

Table 6

Summary Model of Contributions of Process Skills and Entry Grades to Academic Scores

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	.533	.285	.264	9.462

The model shows that basic skills, integrated skills and entry grades contributed 28.5% to academic performance. Table 7 shows that the contributions made by the three independent variables were statistically different and significant at $F(3, 106) = 14.05$, at $p < .001$.

Table 7

ANOVA of Contribution of Process Skills and Entry Qualification to Academic Performance

	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3774.312	3	1258.104	14.052	.000
	Residual	9490.061	106	89.529		
	Total	13264.373	109			

The beta value of .422 (Table 4) indicates that BSPS is the best predictor and significantly increases the dependent variable by .422, with an increase of a unit of standard deviation. The part correlation coefficient of .358 shows that BSPS uniquely contributes about 12.8% to performance. Entry grades is the second predictor of performance and decreases the dependent variable by .246 at any increase of a unit of standard deviation. The ISPS makes the least contribution at beta value of .049. Thus, HO2 is rejected. The contribution of BSPS to academic scores is significantly different and better than that of ISPS.

Contributions and Acquisitions of Subcategories of SPS

Research Question 3

How does acquisition of SPS relate to contribution to academic performance? Table 8 contains the mean scores for the subcategory of process skills and the contributions (R^2) each make to academic performance.

Table 8

Relationship between Development of Process Skills and Contribution to Academic Performance

Process Skills	M	SE	R^2	F	Sig.
Communicating	71.30	2.5	.200	26.93	<.001
Data Interpreting	63.60	1.9	.122	14.94	<.001
Predicting	36.80	2.3	.114	13.84	<.001
Measuring	55.20	3.0	.076	8.85	<.001
Classifying	52.30	3.1	.061	7.01	.01
Inferring	45.00	3.4	.060	6.88	.01
Controlling Variables	41.80	2.9	.056	6.44	.01
Observing	59.10	3.6	.053	6.06	.02
Hypothesising	37.10	2.2	.047	5.29	.02
Experimenting	36.10	2.3	.014	1.59	.21
Correlation			.7		

Table 8 shows the skills in descending order in terms of contributions to academic performance. For instance, the skill of communicating (M = 71.30; SE = 2.5) contributes more (20%) at F = 26.93, $p < .0001$ than the contribution (12.2%) of the skill of data interpreting (M = 63.60; SE = 1.9) at F = 14.94, $p < .0001$. The R^2 values show descending order of contribution to academic performance, as are the mean values, from communicating to experimenting skills. The only exceptions are predicting and observing skills. The correlation between the M and the contributions (R^2) was positive and strong at $R = .7$. This implies that the skills acquired by students relate to skills required to perform on academic assessments.

Discussion

In this study, 46.7% (110 out of 236) of the participants gave their index numbers to allow for further collection of data to answer all the research questions and hypotheses. The results showed that this group of participants (46.7% of the sampled population) had higher mean scores for process skills. Analysis of the data provided by Anane (2020) indicated that the mean entry grades for students in the CoE is about 28. The mean entry grade of the 46.7% of participants was 23.5 (Table 1). The higher grades of the group perhaps explain their boldness with making their index numbers available and their subsequent higher scores in the SPS achievement test.

Contrasting this study to Koomson (2021), it can be seen that, in general, students' acquisition of SPS drops from senior high school chemistry education to CoE science programmes. Senior high school chemistry students' acquired skills were 51.1%, 44.7% and 48% for BSPS, ISPS and SPS, respectively (Koomson, 2021) as against 50.2%, 39.2% and 45.3% for the respective skills acquired in this study. This drop can be partly explained by the nature of the admission of students into tertiary institutions in Ghana. Generally, students who enrol in traditional universities have higher grades than their counterparts who enter CoE (Anane, 2018). However, the 46.7% of CoE respondents' acquired skills were found to be higher than even the senior high school chemistry students. They scored 55.7%, 44.4% and 50.7% for BSPS, ISPS and SPS, respectively.

Nonetheless, the average SPS for prospective science teachers (teacher trainees) for primary and junior high schools seems low considering the fact that they are required to help develop the SPS in their students. The acquired SPS in the CoE were consistent with those found among senior high schools concluding that skills such as observing, communicating, measuring and data interpreting were fairly well developed, but skills such as classifying, inferring, predicting, controlling variables, hypothesising and experimenting were underdeveloped. SPS of inferring, predicting and controlling variables interact between theory and practice to evaluate and synthesize new knowledge. Lack of these skills implies that student teachers are likely to lack the 21st-century skills espoused by Kayange and Msiska (2016) and Lee and Hung (2012).

What was significantly different from Koomson (2021) was that the classifying skill was found to be the least developed at the senior high school level, but it was found to be the fifth most prominent skill acquired at the CoE level, with the mean increased from 34% to 44%. This may be due to increases in practical activities involving classification at the CoE. Taale et al. (n.d.) indicated that student teachers identified classification and identification as the third most prominent practical activity among eight other skills in the CoE. This observation shows that SPS development and acquisition is dependent on a variety of teaching approaches during the science learning process (Rauf et al., 2013). The observed low score in acquired SPS is consistent in the literature, particularly in curricula where a teacher-centred approach to teaching is dominant. For example, Beichumila et al. (2022) found that the mean acquired SPS in a Tanzania school was 42.28%, which increased to 62.79% after a treatment of adding computer simulations and animations.

The study is, unique in demonstrating that acquired SPS contribute significantly better to academic performance than entry grades. Sackes (2013) found that 22% of children's achievement in science is explained by acquired SPS. The present study found that 19.9% of the student teachers' achievement in science is explained by their acquired SPS. The difference may be due to the effects of confounding factors in Sackes' (2013) methodological approach, as raised in the literature review. Spahr (1995) used multiple regression to analyse the effects of entry grades among scores in biology, chemistry and physics on students' grade point averages. The reported contribution of 4.4% for entry grades is similar to the 6.6% realized in this study. Wambugu and Emeke (2013) asserted that an alternative to entry grades should be sought as admission criterion because entry grades contribute less than 50% to academic achievement, as they reported that entry grades contributed to 43.7%, 22.5% and 3%, respectively, to academic achievements in biology, chemistry and physics. Unlike Spahr (1995) and the present study, Wambugu and Emeke (2013) used univariate regression analysis. According to Andrade (2021), the confounding effect is more pronounced when univariate analysis is used. Although we do not agree that entry grade should be discontinued as admission criterion because its contribution is below 50%, we agree that a better alternative should be sought. Acquired SPS may therefore satisfy the alternative that Wambugu and Emeke (2013) seek as admission criteria to tertiary institutions.

The present study also found that BSPS contributed significantly more to academic performance than ISPS. If BSPS, which demands lower cognitive ability than ISPS, is higher contributing, then it can be inferred that the academic assessment tool used requires mainly lower cognitive skills. If this is the case, then the emphasis of the academic assessment at the CoE is not so different from that of secondary schools, which is organised by the Kenyan and West African examination bodies (Akinbobola & Afolabi, 2010; Koomson, 2020; Ongowo & Indoshi, 2013). The examinations conducted by theses bodies in the area of chemistry, biology and physics are found to emphasise BSPS, with a significant level of recalling factual knowledge (Akinbobola & Afolabi, 2010; Koomson, 2020; Ongowo & Indoshi, 2013). The positive relationship found between the acquired SPS and contributions made to academic performance also seems to suggest that learners adjust their development and acquisition of SPS to the demands of academic assessments. In other words, acquisition and development of SPS depends not only on the variety of teaching approaches used during the science learning process but also on the nature of assessment tools used to give summative marks for the academic process. The analysis in this study therefore confirms Harlen's (1999) observation that the nature of assessment practice influences the development and acquisition of SPS.

Conclusion and Implications

The emphasis placed on acquiring and developing SPS in science education is as important as the emphasis on developing 21st-century skills in education in general. These skills, such as problem solving, critical thinking and decision-making, among others, are related to SPS, including observing, inferring, predicting, classifying, evaluating, experimenting and others classified as SPS in science education. The observation that these important skills are inadequately acquired and developed among teacher trainees, who are required to be future facilitators of these skills among basic school learners, needs immediate attention. The present study showed that using achievement in SPS to select candidates for science-related programmes, particularly at the tertiary level, is perhaps more appropriate than relying on their grades at the secondary level of education. The basis for this assertion is the evidence that acquired SPS contributes more to the success of candidates in science programmes than do entry grades. The authors recommend that in addition to entry qualifications, admissions into tertiary levels, particularly for science-based programmes, should be based on competencies in SPS. This move will compel development of these essential skills to not only understand science better but also to encourage innovation and creativity. Also, examinations of students at both the secondary and tertiary levels should be focused on testing these skills rather than emphasising factual recall of knowledge.

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