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Twenty first century skills and science achievement of grade 10 students: a causal – comparative study

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Abstract

This study determined if the 21st century skills constructs namely, digital age literacy, inventive thinking, effective communication, and high productivity were significant drivers of students' science achievement. It utilized an exploratory, descriptive, and causal-comparative designs involving four sections of Grade 10 students enrolled in Science Grade 10, AY 2016 – 2017. Two instruments were used in the study, the 21st century Skills of Science Students (21CSSS) and the Science Achievement Test (SAT). Result revealed that majority of the Grade 10 students both male and female have an average level of 21st century skills constructs and achievement in science. Also, result showed that Digital Age Literacy (DAL) and Inventive Thinking (IT) skills significantly affect the science achievement of the students, this is significant at 0.05 level because it does not contain 1 on its confidence limit, it can be generalized onto the entire population of Grade 10 students. However, the sex (male or female) is found not to be significant to science achievement, but the effect of it was kept because of the goal of the study is to control for initial differences in sex (male or female). Lastly, the science achievement of the high achieving students (HAS) and low achieving students (LAS) directly affected by their DAL skill with an odd ratio estimate of 0.877 and IT skill with an odd ratio estimate of 0.734. Thus, the science achievement of HAS and LAS is explained by their DAL and IT skills.

Keywords: 21st century skills, high achieving students, low achieving students, science achievement, sex (male or female).

Introduction

The 21st century era deems Science Education as one of the most important aspects for a country to be successful in technological advancement and to be globally competitive in the job market and workplace. Science Education offers a variety of opportunities to the students in enriching and developing their innate abilities and skills.

These opportunities are important for the students to cope with their academic requirements, to adapt into different relevant situations, and to learn the practicalities of life. As the students prepare to be globally competitive, they should use properly their enhanced and developed 21st century skills as important factors in the accomplishment of their tasks. The students' accomplishments should be assessed not only by answering questions in a pen and paper test but also the capability to use their prior and acquired knowledge and their ability to apply the 21st century skills in real life situations[1]. Thus, recognizing the essence of the 21st century assessment can be applied in real life situations or it can lead to meaningful and authentic performance tasks among the students. Indeed, there is a drastic decrease in the students' achievement in science based on National Achievement Test (NAT)[2], Trends in International Mathematics and Science Study (TIMSS)[3], and Center for Educational Measurement(CEM)[4] results.

These are reasons why students lose their interest in Science by the United Nations Educational, Scientific and Cultural Organization (UNESCO). First, Science teaching is predominantly transmissive to students, this means that learning the principles in Science is only a question of resembling a wipe and wading-up the information as it originates from the educator or from the reading material. Second, Science knowledge is precise and systematize whereas it is inevitable because all of the principles, theories, and laws are based on experiments, facts, and evidences. Third, the content of Science is ideal that makes it irrelevant to certain situation such a large amount of what is instructed is uninteresting in light of the fact that it is not identified with the regular day to day existences. Lastly, learning Science is relatively difficult, for both low achiever and high achiever students[5].

The 21st century education requires the students the following essential skills constructs: digital age literacy, inventive thinking skills, effective communication, and high productivity[6]. More often, the 21st century essential skills consider the individual differences among the students, these individual differences mean that the students would also have different coping mechanisms to achieve high performance in Science Grade 10. The 21st century skills are significant factors to consider and develop for the learners in the K to 12 basic education curriculum[7].

To address this certain implications, the Department of Education (Dep Ed) implemented the K to 12 Basic Education Curriculum that is geared towards the progressive development of a holistically developed Filipino student with essential 21st century skills who is ready for employment, entrepreneurship, middle level skills development, and higher education upon graduation from Grade 12[8].

Therefore, a demand in investigating the students' 21st century skills constructs and their Science achievement or performance should be done to address certain phenomena in education. The result of this study will greatly help the teachers, administrators, and other school personnel to better understand the students in terms of their essential skills and achievement for the 21st century learning among the diverse kinds of learners. In addition, the teachers will be guided in their choice/s of teaching strategies to improve students' achievement or performance that considers and addresses the needs of the different kinds of students in the 21st century era. It is along this concern that this study was conducted. It happens to contribute to a body of knowledge on what 21st century skills constructs are attributed to the achievement of Grade 10 Students in Science.

Methodology

The study was designed to be a quantitative study, because of the existence of qualitative variable and the quantitative nature of the model, because a research instrument was used on the sampled population; thus, data were gathered in a uniformly objective method and not subjectively derived. The purpose of this study was to determine which among the 21st century skills constructs affect the science achievement of the students. Also, this study was designed to be exploratory in nature because there was no prior hypothesis to be confirmed or rejected. While confirmatory methods were used to validate the research instrument served as an auxiliary method, thus, the research questions remain to be exploratory. The causal variable for this study is the 21st century skills constructs which was not manipulated and the effect of these constructs on the science achievement among the high achieving and low achieving students was identified. Lastly, this study is a comparative in nature because the research questions aim to explore factors controlling for differences across students' sex (male or female). Hence, this study involved 289 grade 10 students of the Junior High School enrolled in Science Grade 10 and there were 70 male student– respondents and 92 female student – respondents.

Instruments and Validation: The instrument used in the study to determine the level of students' 21st century skill was entitled The Perception of the 21st Century Skills of Students Questionnaire (P21Q)[9]. The P21Q was modified and recast by the researcher and have been validated by different specialists in the field of science and education to fully assess the 21st century skills of the students. To fully address the research questions, the title of the questionnaire was changed to 21st Century Skills of Science Students (21CSSS).

In this phase, the development of Science Achievement Test (SAT) research instrument was made by the researcher and it underwent three processes namely, face and content validation by the experts, item analysis, and reliability test. And the final form of Science Achievement Test (SAT) was used to determine the level of achievement of the respondents.

Data Gathering and Administration of Instruments: The actual gathering of the data and the administration of the research instruments namely, 21st Century Skills of Science Students (21CSSS) and Science Achievement Test (SAT). The 21CSSS was administered to classify the students' 21st century skills constructs as to excellent, above average, average, below average, and poor using standard of nine (stanine) scores. While, the SAT was administered to determine students' achievement in science by raw score. The determination of the two groups of students as to high and low achieving students and their level of Science Achievement Test (SAT) were based on their stanine scores. This phase revealed the Science Achievement Test's raw scores in classifying the students who are high and low achievers. Also, the level of the students 21st century skills was classified based on the stanine scores.

Internal Consistency and Dimension Reduction: The reliability and the dimension reduction techniques were the preliminary analyses for this study. The Cronbach's Alpha reliability test was employed to the instruments to ensure the unified understanding of the respondents. Dimension reduction techniques were used in this study to explain the relationships of the many variables of the research instrument in terms of a simpler, underlying structure of the variables. First, the Principal Components Analysis (PCA) estimates the appropriate weights for each survey question, considering its relationships with others, and provides an organic way to extract a score by computing principal components. Second, the Confirmatory Factor Analysis (CFA) was used to validate whether certain survey questions, make up the four constructs of the 21stcentury skills of the students[10].

Regression Analysis: A regression analysis was used to determine which variables affect the science achievement of the students. In this study, achievement was measured as a test score, so that it is important that the predicted scores should lie between zero and a perfect score. One model which is appropriate for ordinal data is the Cumulative Logistic Regression Model, which models the (cumulative) probability of getting a lower or higher stanine (consequently, having a lower or higher score). The dependent variable for this statistical model is the Science achievement test stanine scores of the students. The event of interest for this model is the probability of having a lower stanine (i.e. getting a lower score), so that the odds measure the likelihood of scoring higher. For this study, the effect of sex (male or female) was kept, regardless of its significance, since it is a known yet controllable factor. When the model consists of only discrete variables, it is called an Analysis of Variance (ANOVA)-type model, while in the case

of the presence of both discrete and continuous variables, it is called an Analysis of Covariance (ANCOVA)-type model[11]. For this type of model, it is assumed that the effect of the independent variable is similar across all ordinal levels of the dependent variable – the proportional odds assumption. Thus, the first step in making inferences about the Cumulative Logistic Regression model is to determine if this assumption is satisfied through the Score Test for the Proportional Odds Assumption. After which, the joint significance of the explanatory variables in explaining the response variable is tested using the Global test. Finally, the marginal significance of the explanatory variables is tested by assessment of the estimated confidence interval[12].

Results and discussion

Confirmation of the Factor Model: In quantifying the overall 21st century skills, the factor model must be checked first. Thus, in confirming the factor model, the null and alternative hypotheses are as follows: i. H0: There is no significant difference between the true factor model and the hypothesized factor model. ii. H1: There is a significant difference between the true factor model and the hypothesized factor model.

This is equivalent to testing whether a single construct is a function of its respective survey questions and none other. If this is confirmed, it means that the total score for the 21st century skills is simply a linear combination of the scores for the four constructs; otherwise, it is unequal, the Principal Component Analysis (PCA) will be needed to estimate a total score. The null hypothesis was tested using a Chi-Squared test, and is rejected when the p-value of this test is less than the 5% level of significance. However, to confirm the hypothesized model, it is desired that the null hypothesis is not rejected; moreover, the goodness-of-fit indices must indicate that the fit of the model is reasonably strong. Table-1 presents the goodness-of-fit measures and summary.

The bold-faced statistics and underlined estimates are those which are important in determining goodness-of-fit. While the incremental indices should report a value of 90% to conclude adequacy of fit, the estimated indices, are all below 60%, which indicates the other way around. For the parsimony indices, the estimated value should be, or the confidence interval should contain, 5% to conclude the same; but the point and interval estimates are at 6.46% (6.1%-6.82%), which also indicate otherwise. Lastly, the p-value of the Chi-Squared test is reported to be much less than 1%, so that the null hypothesis is rejected, and thus, it can be concluded that there is a significant difference between the hypothesized factor model and the true factor model. However, this does not mean that the factor model is incorrect or not appropriate in the study, thus, it indicate that is incomplete or improperly specified. Thus, remember that the confirming the hypothesized factor model is not the main purpose of the study, rather, it is simply checking the variable relationships before proceeding with the model.

Table-1: Fit Summary.

Absolute Index	Fit Function	33.5306
	Chi-Square	5398.4343
	Chi-Square DF	3229
	Pr > Chi-Square	<.0001
Parsimony Index	RMSEA Estimate	0.0646
	RMSEA Lower 95% Confidence Limit	0.061
	RMSEA Upper 95% Confidence Limit	0.0682
	Probability of Close Fit	<.0001
Incremental Index	Bentler Comparative Fit Index	0.5564
	Bentler - Bonett Normed Fit Index	0.3425
	Bentler - Bonett Non - normed Index	0.5437
	Bollen Normed Index Rho1	0.3238
	Bollen Non - normed Index Delta 2	0.5645
	James *et al.* Parsimonious Normed Fit Index	0.333

Normality Assumption: A necessary assumption to be checked before dividing the distribution into stanines is the Normality assumption – whether the data follow a Normal distribution. The Statistical Analysis System (SAS) software has four tests for Normality – the Shapiro-Wilk test, Kolmogorov-Smirnov test, Cramer-von Mises test, and Anderson-Darling test – all of which tests the same hypotheses: i. H0: There is no significant difference between the Normal distribution and the data. ii. H1: There is a significant difference between the Normal distribution and the data.

The null hypothesis is rejected for one test when the p-value is less than the 5% level of significance; however, it is desired for this study that the null hypothesis is not rejected. Because there are four tests being considered, the null hypothesis is concluded to be not rejected when 3 out of 4 tests do not reject H0 at 5% level of significance. The following table reports the results of the Normality tests.

In Table-2, a bold-faced p-value means that the test rejects null hypothesis at the 5% level of significance. Then three out of four of the tests for the Normality of the Science Achievement test and effective communication scores reject null hypothesis, and thus, can be concluded that those variables are not normally distributed. Consequently, it means that the stanine scores

cannot be used for these variables because the Normality assumption has been violated.

For these variables, an alternative way to discretize the scores is by dividing their distributions using sample quantiles. An α-quantile is a value of the distribution where α100% of the distribution falls below such value, while (1-α) 100% of the distribution falls above such value. For this study, however, the values of the sample quantiles are not of much interest because they will only be used to divide the distribution the same way as stanine scores do. Table-3 and Figure-1 results present the distributions per Normal/Empirical stanine.

Table-2: Test for Normality.

Indicators	Shapiro-Wilk	Kolmogorov-Smirnov	Cramer-von Mises	Anderson-Darling
Science Achievement Test	0.0867	<0.0100	0.0370	0.0411
Digital Age Literacy	0.3210	>0.1500	>0.2500	>0.2500
Inventive Thinking	0.0203	0.0846	0.1028	0.0654
Effective Communication	0.0003	0.0270	<0.0050	<0.0050
High Productivity	0.0310	>0.1500	>0.2500	0.1487
Overall 21st Century Skills	0.0774	0.1047	0.1337	0.1271

Table-3: Friction Distribution of Variables.

Indicators	Stanine								
	1	2	3	4	5	6	7	8	9
Science Achievement Test (Empirical)	17	17	17	18	21	24	15	16	17
Digital Age Literacy (Normal)	7	12	16	28	38	22	17	19	3
Inventive Thinking (Normal)	10	10	14	28	28	33	22	13	4
Effective Communication (Empirical)	18	18	18	18	18	18	18	18	18
High Productivity (Normal)	3	19	16	33	24	26	19	14	8
Overall 21stCentury Skills (Normal)	11	8	18	20	43	27	19	11	5

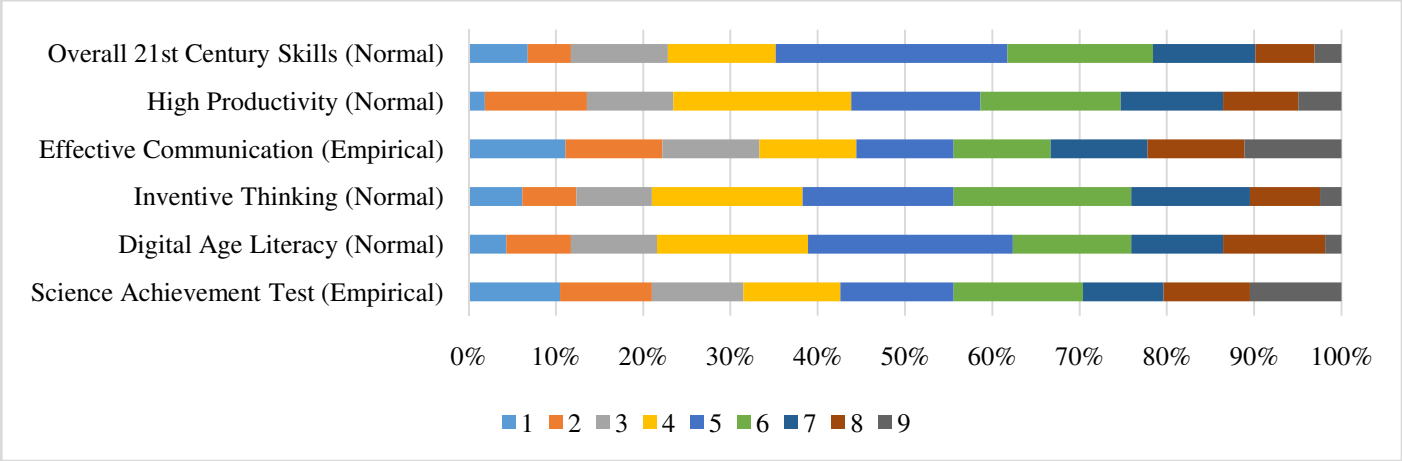

Figure-1: Distribution of Stanine of Science Achievement Test and 21stCentury Skills Constructs.

Relationship of 21st Century Skills, Sex (male or Female), and Science Achievement: Table-4 shows the estimates and the confidence intervals for the odds ratios for each of the 21st century skill construct and reflects whether the total score of the 21st century Skills Constructs was significant in explaining the SAT Score of the students. The estimated odds ratio is 0.773, which means that the probability of getting a lower stanine score decreases by 0.773 times for every unit increase in the standardized scores for 21st century skills constructs. Moreover, the confidence interval does not contain the value of 1, so that it is significant to the entire population of grade 10 students. It can be said that the SAT stanine scores were significantly affected by the 21st century Skills Constructs, thus, the relationship is direct. However, it implies that students' high standardized score for the 21st century skills constructs mean a higher SAT stanine score. Also, the implication of the current result is that the students' high or low levels of Digital Age Literacy, Inventive Thinking, Effective Communication, High Productivity, and Overall 21st Century Skills constructs would probably affect the level of Science Achievement as to High Achieving Students (HAS) or Low Achieving Students (LAS).

Table-4: Odds Ratio Estimates and Confidence Intervals (Model 1).

Effect	Estimate	95% Confidence Limits	
Sex (F vs M)	0.808	0.465	1.401
21st Century Skills Constructs	0.773	0.715	0.833

Tables-5-6 shows the global test, the estimates and the confidence intervals for the odds ratios for significant 21st century skills constructs as to DAL and IT.

Table-5: Global Test.

Test	Test Statistic	*p*-value
Likelihood Ratio	50.4691	<.0001
Score	41.3365	<.0001
Wald	47.9749	<.0001

Digital Age Literacy, Inventive thinking, and Science Achievement: Table-6 shows the Global tests report a negligible *p*-value, which then permits that the selected variables are jointly significant at the 5% level. Moreover, table 6 shows that Digital Age Literacy and Inventive Thinking are marginally significant because their confidence intervals do not contain a value of 1. Since this model has a simpler form, yet it can capture much of the variability of the response – so that it is parsimonious – it can now be concluded that this is the final model which could be used to explain the relationships of the 21st century skills constructs with the science achievement of the students.

Table-6: Odds Ratio Estimates and Confidence Intervals (Model 2a).

Effect	Estimate	95% Confidence Limits	
SEX (F vs M)	0.806	0.464	1.396
DAL	0.734	0.624	0.86
IT	0.877	0.771	0.995

Since, the performance of the High Achieving Students (HAS) and Low Achieving Students (LAS) is one of the concerns of this study. The odd ratio estimate and confidence intervals revealed that the significant 21st century skills are the digital age literacy (DAL) with the estimated odds ratio of 0.734 and the inventive thinking (IT) with the estimated odds ratio of 0.877 respectively. Moreover, the DAL and IT skills are the independent variables that significantly affects the variability of science achievement of the HAS and LAS. Therefore, when the level of DAL and IT skills of the students is poor there is a high probability that the students will be categorized as LAS. But, when the level of the DAL and IT skills of the students is excellent there is a high probability that the students will be categorized as HAS. In addition, both DAL and IT skills do not contain 1 in the 95% confidence limits then the direct relationship of DAL and IT to HAS and LAS is true to the entire population of the Grade 10 students.

Based on the results, at 5% level of significance, DAL and IT skills are the significant variables in explaining the variability of the SAT stanine scores because their confidence intervals do not contain 1. SEX, however, is not a significant variable because of the opposite reason; but because the goal of this study is to control for the effects of sex (male or Female), it is retained in the statistical model.

Sex (Male or Female): The estimated odds ratio is 0.806, which means that the likelihood of getting a lower SAT stanine score than a higher stanine score for females is only 0.806 times that of males. Simply put, males tend to have lower stanine scores, while females tend to have higher stanine scores. However, because the confidence interval contains 1, this is insignificant at the 5% level, so that it is only true for the sample and cannot be generalized to the population.

Digital Age Literacy: The estimated odds ratio is 0.734, which means that for every unit increase of the standardized DAL score, the possibility of getting a lower stanine score than a higher stanine score changes by a factor of 0.734. Simply put, the probability of having a lower stanine score decreases as the standardized DAL score increases. Now, since the confidence interval does not contain 1, this is significant at the 5% level. Thus, this can be generalized onto the population, and can be concluded that digital age literacy is a contributory factor for the science achievement of the students.

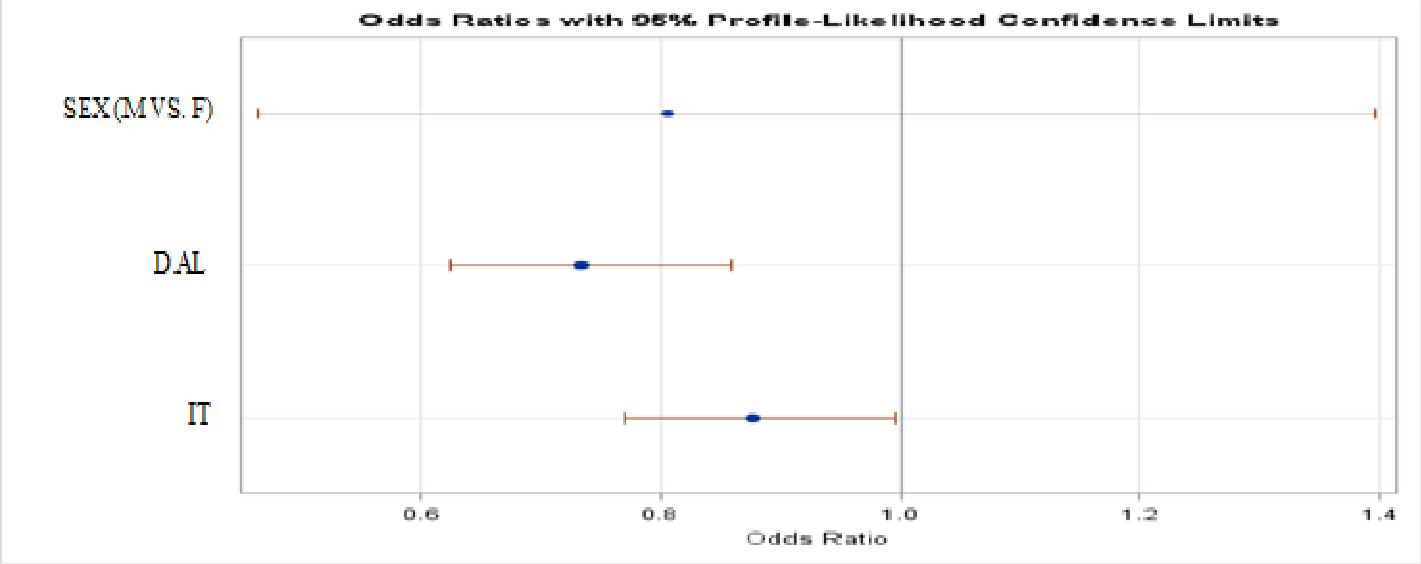

Figure-2: Odds Ratios with 95% Profile – Likelihood Confidence Limits.

The related finding was discussed by Taskin and Kandemir[13] and Pheeraphan[14] that the core medium for the 21st century learning is technology which is captured by the Digital Age Literacy skill construct, the integration of technology to teaching and learning process can affect the students' achievement and performance. These findings support the study of Bayrak and Bayram[15], which revealed that the use of Digital Age Literacy and Technology as the students' 21st century skills can significantly affect the students' science achievement.

Inventive Thinking: The estimated odds ratio is 0.877, which means that for every unit increase of the standardized IT score, the possibility of getting a lower stanine score than a higher stanine score changes by a factor of 0.877. Simply put, the probability of having a lower stanine score decreases as the standardized IT score increases. Now, since the confidence interval does not contain 1, this is significant at the 5% level. Thus, this can be generalized onto the population, and can be concluded that inventive thinking affects the science achievement of the students. This result was supported by the study of Hassanc, Osmana and Hamidb[16], the Inventive Thinking Skill Construct of the students is the most relevant skill for the 21st century education. According to Wan Husin, Arsad, Othman, Halim, Rasul, Osman and Iksan[17] one of the strategies that can enhance all the 21stcentury skills constructs is the problem-based learning which can help the students to solve real world problems based on authentic and real life experiences through project work and education today requires students to have developed and enhanced 21st century skills constructs to cope in a dynamic society.

Conclusion

The following conclusions were derived. Majority of the Grade 10 students have an average level of 21st century skills constructs and science achievement. The students' 21st century skills constructs and science achievement have a direct relationship, meaning when the 21st century skills constructs is high the science achievement will also be high and vice versa. Male students tend to have low Science achievement, stanine scores while female students tend to have high science achievement, stanine scores but it is only true to the sample of the study. The cause of the science achievement of the students are the digital age literacy and inventive thinking skills constructs, so, the higher the digital age literacy and inventive thinking of the students there is a likelihood that their science achievement will also be high, thus, the relationship is direct. The performance of high achieving students and low achieving students is more attributed to their digital age literacy and inventive thinking skills constructs.

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