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Effectiveness of Spiral Approach in Physics Education

Jhoanne Catindig¹, Br. Joseph Scheiter²

^{1,2} Brother Andrew Gonzales, College of Education,
De La Salle University, Manila, Philippines

The study highlighted the difference of the G11 and H4 students' performance in Newtonian physics using pre and post tests scores. The G11 students came from the new K-12 curriculum, which followed the spiral approach of science teaching, while the H4 students came from the old RBEC, which followed the linear approach. Both groups took Newtonian physics simultaneously but had different physics exposure from G8 to G10 and H1 to H3. Pre and posttests were given to the students before and after proper discussion of Newtonian physics. Pre-test results revealed that the H4 students outperformed the G11 students in majority of the items in Kinematics, Forces, 1st Law and 3rd Law of Motion. On the other hand, posttest revealed that the G11 students were able to catch up with the H4 students for there was no significant difference in the average mean scores. Normalized gain revealed that the G11 students under the spiral approach learned more in Newtonian physics than the H4 students at $p < 0.05$. This might be caused by the competency, qualifications and seniority of the physics teachers and the number of years the students was taking physics (G8-10). The study revealed that the spiral approach of teaching physics was better than the old linear approach.

Keywords: Spiral Approach, Linear Approach, RBEC, K-12, G11, and H4.

1. INTRODUCTION

Philippines' education is now changing from the Revised Basic Education Curriculum (RBEC) to K-12 Enhanced Basic Education. This new curriculum was implemented last SY 2012-2013 under the DepEd Order No. 31 s. 2012 and have started to launch its Senior High School on SY 2016-2017.

Philippines is the only country in Asia and one of the three countries in the world that has only 10 years of pre-university education. With the new K-12 curriculum, the country now follows the global standard of 12 years of basic education. The Department of Education mentioned that it was found out that it is the best number of years for learning of basic education and recognized as the standard for students and professionals globally¹.

The Revised Basic Education Curriculum (RBEC) follows the linear approach of teaching while K-12 Enhanced Basic Education follows the spiral approach. Subjects in RBEC are being taught per year level. In

Science education, the students take integrated science in 1st year, biology in 2nd year, chemistry in 3rd year and physics in 4th year. In the new K-12 curriculum, students take earth science, biology, chemistry and physics per quarter, every year starting grade 7 to grade 10.

In an all-boys school, the new K-12 curriculum was adopted since SY 2012-2013. On school year 2016-2017, the institution had its first batch of grade 11 students under the spiral approach, and the last batch of H4 students from the linear approach.

In this study, the researcher took the opportunity to measure the effectiveness of the spiral approach in physics education in an all-boys school in preparing the students in learning physics using the Force Concept Inventory (FCI) pre and posttest scores.

Reasons of Changing the Curriculum

The Philippine government under the administration of Pres. Benigno Aquino was committed to achieving its Education for All (EFA) goals not only for

the development of each Filipino person, but also for the improvement of social and economic status of the country. Part of the Education For All (EFA) Action 2015, Critical Task No.5 is the expansion of basic education from 10 to 12 years. This change planned to give more time to the students to study and to focus in their chosen specializations; for all families to be able to afford basic education with proper certification; and for all graduates to be locally and internationally competitive².

Abueva, A. (2015)³ said that the implementation of the K-12 Enhanced Basic Education is the key for the country's development. Cruz, I. (2010)⁴ also mentioned that graduates of this new program would produce a more skilled and competent labor force since students can specialize in their chosen field of interest. Filipino graduates will also be recognized abroad since Philippines will follow the international standard of 12 years of basic education.

Force concept inventory (FCI) as a tool

The Force Concept Inventory has been widely used as a tool to measure and identify the present and later status of the students in learning basic mechanics in physics. It is widely used as an instrument to measure learning progression of the students in high school and college⁵. Results were also used to measure conceptual coherence^{6,7} conceptual understanding⁸, predict future grades and performance of the students^{9,10,7}, common misconceptions on forces¹¹⁻¹⁶ and the effect of language^{17,18} and context on students' analysis¹⁹⁻²¹. FCI has been used for about 30 years in different countries. As of 2000, 200 high school physics teachers have used FCI²² with over 20,000 students to evaluate the effectiveness of physics instruction²³.

According to Lasry, L. (2011)²⁴, the Cronbach reliability of the force concept inventory questions is 0.80. This value is within the accepted Cronbach reliability range of 0.8 to 0.9^{25,26}. This implies that the questions in the FCI are within the range of very good for classroom use and near the range of an excellent reliability.

In this study, the FCI was used to quantify the effectiveness of spiral approach by measuring the students' performance in Newtonian physics using the pre and posttest scores. FCI was also used to determine the competency of science teachers in teaching Newtonian physics to Grades 8-11 and Year/H1-4.

Force concept inventory (FCI) in different Curricula

In physics education, much research has been done to measure the effectiveness of curriculum and teaching method differences on student learning²⁷. Comparative studies are commonly done using common assessment instruments on both reformed and traditional classes before and after instruction to evaluate the effectiveness of these efforts^{28,29}.

Bao et al. (2009)³⁰ used quantitative assessment instruments like the Force Concept Inventory (FCI), the

Brief Electricity and Magnetism Assessment (BEMA) and Lawson's Classroom Test of Scientific Reasoning (LCTSR), to compare US and Chinese college 1st year students conceptual understanding in physics and general scientific reasoning. These countries have diverse K-12 curricula in math and science, which appears in the amount of instructional time and the amount of emphasis on conceptual, physics understanding and problem solving skills^{31,32}. The researchers have found that since Chinese students spent more time in physics instruction, their FCI and BEMA results are much higher than that of the US students. However, in terms of LCTSR, the results of both countries are nearly identical which suggests that the differences of US and China curricula do not cause much variation in students' scientific reasoning ability.

In the recent study of Caballero et.al (2012)²⁸, the Force Concept Inventory was used to measure students' understanding of introductory Newtonian physics between two courses in the US: the Matter and Interactions (M&I) mechanics course and a Pedagogically-Reformed Traditional Content (PRTC) mechanics course. The differences of the two mechanics courses lie on the hierarchy of the physics topics being discussed and the teaching strategies. The PRTC course started with kinematics followed by dynamics, while the M&I course started with dynamics followed by kinematics. Pre-tests and posttests were given prior and after teaching introductory physics in their classes. The researchers compared students' performance on the overall FCI results and on individual items between the two courses. Results showed that students in the PRTC course outperformed their colleagues in the M&I course in nearly all the FCI items.

This study aims to quantitatively measure the effectiveness of spiral approach in physics education by answering the following research questions:

- (1) Is there a significant difference in students' achievement in Newtonian physics between spiral (K-12) and linear approach (RBEC)?
- (2) What are the factors affecting students' learning of Newtonian physics?

2. METHODOLOGY

The Sample

The participants were 146 H4 students and 82 G11 students from an all-boys school in San Juan City, Philippines. The H4 students learned physics under the linear approach while the G11 students learned physics under the spiral approach. Both groups were enrolled in the school for school year 2015-2016 and were both taking physics for one quarter. Lesson plans, assessments and lesson phasing were the same for both group.

The data was in the form of FCI scores thru pre and posttests. Additional information of students like previous science teachers, IQ level, age, and previous math and science grades were also gathered.

Research Instrument

The Force Concept Inventory (FCI), a standardized 30-item multiple-choice type of test^{33,34}, was used as the main instrument to measure students' performance in Newtonian physics.

Procedure

The procedure was focused on two major parts: (1) preparation, sampling and administration of instruments, and (2) data analysis.

Part 1: Preparation, Sampling and Administration of Instruments

FCI pre and posttests were administered to measure the performance of G11 and H4 students in Newtonian physics. The physics teachers gave the pretest in one of the science sessions on June 2015 to both G11 and H4 students. On July to December 2015, students had the discussion of Newtonian physics with their respective physics teachers. Then on January 2016, the physics teachers administered the post in one of the physics sessions.

In the latter part of the study, the majority of the science teachers were asked to answer the FCI for 40 minutes. They were also asked to indicate their college degree, present teaching load and years of teaching in the institution. All of these data was used to analyze the results of the pre and posttest scores of the G11 and H4 students.

Part 2: Data Analysis: t-Test Method and Cohen's d

To determine if there is a significant difference between the pre and post test scores, T-Test at $p < 0.05$ was used in SPSS.

Cohen's effect size was also used to quantify how big the difference is between the G11 and H4 at $p < 0.05$. To compute for Cohen's effect size, the researcher used the equation $d = \frac{M_1 - M_2}{\sqrt{\frac{SD_1^2 + SD_2^2}{2}}}$, wherein M_1 is the mean FCI

scores of the H4 students, M_2 is the mean FCI scores of the G11 students, SD_1 is the standard deviation of the FCI scores of the H4 students and SD_2 is the standard deviation of the FCI scores of the G11 students. The table below gives a table of the Cohen's standard and effect size³⁵.

Table 1: Cohen's d Standard

Cohen's Standard	Effect Size
High	0.8
Moderate	0.5
Low	0.2

Table 1 shows that an effect size of 0.2 means that the difference between the two groups is at low practical significance, 0.5 means moderate practical significance and 0.8 means high practical significant difference³⁵.

3. RESULTS AND DISCUSSION

t-Test on FCI Scores

SPSS was used to process the data gathered from the pre and posttest scores of the G11 and H4 students.

3.2 Figures and Tables

Table 2: Pretest results of G11 and H4 students in FCI

Year Level	N	Mean	Std. Deviation	p-value
H4	146	7.95	2.978	
G11	82	6.95	3.150	0.019

Table 2 shows that there is a significant difference between the students' scores in pre instruction test for the calculated p value is 0.019.

Table 3: Summary of the items with significant difference in the pre test of Grade 11 and H4 at $p < 0.05$

Item	p value	Topic	Grade Level
1	0.000	Kinematics	H4
2	0.003	Kinematics	H4
4	0.044	3 rd Law of Newton	H4
6	0.44	1 st Law of Newton	H4
28	0.001	3 rd Law of Newton	H4
29	0.017	Forces	H4

In terms of individual items, the H4 students significantly outperformed the G11 students in most of the items in Kinematics, 1st and 3rd Law of Motion, and Forces. For the rest of the items, both groups performed equally at $p < 0.05$. Some possible reasons for this difference are the following:

- (1) The H4 students have taken the topic coverage of FCI, which was Force, Motion, and Laws of Motion when they were in H1. However, the G11 students only took Motion when they were in G8-10.
- (2) Greater number of H4 students have encountered higher number of physics major as their science teachers as compared to the G11 students.

Table 4: FCI scores of the science teachers in terms of college degree

College Degree	FCI Average Score/ 30 items	
Physics	29.6	99%
Chemistry	6.0	20%
Biology	10.3	34%
Others	12.0	40%

Table 4 shows that the physics major science teachers had the highest mastery of the topics in FCI.

Table 5: Posttest average mean scores of G11 and H4

Table 5 shows that there is no significant

Year Level	N	Mean	Std. Deviation	p-value
H4	146	11.33	4.10	0.089
G11P	82	12.30	4.22	

difference in the mean score of the Grade 11 (Mean=12.3, SD=4.2) and H4 students (Mean=11.3, SD=4.1) at p<0.05.

However, in terms of the individual items, Table 6 revealed that G11 students significantly outperformed the H4 students in almost all of the topics – Kinematics, 2nd Law and 3rd Law – except in Forces where the number of H4 students who got the correct answer was significantly higher.

Table 6: T-Test result of the individual items in the posttest in of Grade 11 and H4 students at p < 0.05

Further, Cohen's effect size value for items 4, 17,

Item	p value	Topic	Grade Level
4	0.000	3 rd Law of Newton	G11
17	0.003	Forces	H4
19	0.044	Kinematics	G11
27	0.044	2 nd Law of Newton	G11
28	0.000	3 rd Law of Newton	G11

19, 27 and 28 (d = 0.5, 0.3, 0.3, 0.4, 0.4) suggested moderate to high practical significance.

The normalized gain for each student, $g = \frac{f_{post} - f_{pre}}{1 - f_{pre}}$ was calculated for both groups and compared using t-test as shown by the table below.

Table 7: Normalized gain average mean scores of Grade 11 and H4 students

Year Level	N	Mean	Std. Deviation	p-value
H4	146	.138	.229	
G11P	82	.230	.168	0.001

The normalized gain of G11 students is significantly higher (Mean = 0.230, SD= 0.168) than the H4 students (Mean = 0.138, SD = 0.229) at p < 0.05³⁷. The table reveals that the G11 students under the spiral approach learned more than their H4 peers under the linear approach in Newtonian physics.

In terms of physics teachers who taught the students Newtonian physics, the G11 students had more competent teachers than the H4 students as shown by the table below.

Table 8: G11 and H4 physics teachers of SY 2015-2016

G11 Physics Teacher	H4 Physics Teacher
Senior with MA units + IBDP certificate	New with MA units
Senior with MA units + IBDP experience	New
Junior + IBDP experience	Junior with IBDP experience

A senior teacher is someone who has taught for 10 years and above, junior teacher for 4-9 years and new teacher for 0 to 3 years. All G11 physics teachers had an experience in teaching in International Baccalaureate Diploma Program (IBDP) – a program that provides an internationally accepted qualification for entry into higher education and is recognized by many universities worldwide. In addition to that, two out of the G11 physics teachers had master units (MA) in teaching physics.

4. CONCLUSIONS

The pre and posttest, and normalized gain results revealed that the G11 students significantly performed better in Newtonian physics than the H4 students. The normalized gain revealed that the G11 students under the spiral approach gained more knowledge in Newtonian physics than the H4 students from the linear approach. Results also showed that students' performance in Newtonian physics might have been affected by the following factors:

- (1) Science topics taken in the previous years, G8 to G10, H1 to H3: The number of years of exposure and preparation in physics might have affected the students' performance in Newtonian physics. More exposure in the subject means that the students were able to understand the lessons better.
- (2) Competency, qualification and seniority of the teachers: Data revealed (Table 8) that a more experienced, more trained and more studious teachers have positively affected (Table 7) the students' performance in Newtonian physics.
- (3) College degree (mastery) of the teachers: G11 and H4 students who had physics major science teachers performed better than the rest of the students who took the FCI test. It revealed that the mastery of the science teachers (Table 4) have a significant effect on students' performance in Newtonian physics.

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