Pedagogical Content Knowledge and Students' Cognitive Ability in Physics

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Abstract
This study aimed at determining the impact of the Pedagogical Content Knowledge (PCK) instructions in the Cognitive Ability in Physics of low achieving students as Treatment Group. This used one-way analysis of variance to test the significant differences in Physics' Pretest and Scores in Physics between the Treatment and Control Groups. Pearson correlation was used for bivariate relationships, while, Multiple Linear Regression Analysis was applied to establish the significant GPA Model in Science of the Grade 7 students as influenced by the five components of the PCK Instructional Model.
Findings revealed that the Treatment Group had the High mean rating in the Pedagogical Content Knowledge instructions. Mean scores in the Pretest and Posttest showed positive gains by an advanced of one level with the Treatment and Control Groups; with the latter taking the lead in score-points even if they were on the same Average levels. Highly Significant differences in the Science's Pretest and Posttest were evident in all of the Four Areas when grouped according to the two groups. This suggested that really the Control Group settled to higher performance even without the explicit intervention of the PCK Instructions, however, gave positive impact to the students' learning assessment in the Treatment Group. As a result high achieving students had better Cognitive Ability than the Low Achieving ones prior to giving formal lectures in the four areas of Physics.

Keywords: Pedagogical, Cognitive, Physics

Introduction

To influence students' learning science teachers must possess the knowledge on Pedagogical Content Knowledge or PCK (Frank and Spencer 2012). However, there is a prevalent dilemma of students' dismal performance in physics (Starr 2005). In fact, Science and Engineering readiness Index (SERI) shows that Math Education and Readiness Qualification in twenty one states in the U.S. earned a score far below average (White and Cottel 2011). In addition, despite of the intervention applied for improved instruction from the Learning Physics as One Nation (LPON) project, students from thirty two schools in the country perform low to very poor levels (Bernirdo et. al. 2013).

This disappointing performance was the fact that only fifteen percent of high school physics teachers were qualified to teach the subject (Ogena 2010) this obviously shows deficiency with PCK in teaching the subjects and become the dearth in the part of the researcher to go into this kind of study. Implications were emphasized that programmed instructions like the Pedagogical Content Knowledge was more effective in teaching Physics with low level achievers. The highly significant differences in both the Pretest and Posttest as regards the Cognitive Ability of the students gave proper insights that the Teacher was knowledgeable about the PCK instructions; that these were indispensable in effective teaching.

Theoretical Framework/ Conceptual Framework

This study connected to Shulman's (1986) model of teacher knowledge called pedagogical content knowledge (PCK) as presented in the work of Abell (2007). Pedagogical Content Knowledge (PCK) has been defined as "the transformation of subject-matter knowledge into forms accessible to the students being taught" (Geddis, 1993).

Several Lines of research used frameworks other than Shulman's to understand science teacher knowledge. These studies have demonstrated how teacher knowledge develops over time with respect to various inputs and perturbations, but did not classify teacher knowledge as Shulman did. The pedagogical content knowledge (PCK) includes the following components, to wit: 1. orientations: "general way of viewing or conceptualizing science teaching"-(e.g., fact acquisition, conceptual development, and content understanding); approaches to teaching (e.g., transmission, inquiry, and discovery). 2. knowledge of learners: requirements for learning certain concepts; areas students find difficult, approaches to learning science, and common alternative conceptions; many teachers are unaware of students' likely misconceptions [teachers have many of the same misconceptions student have]; veteran teachers are able to predict and plan around these difficulties; experienced teachers are able to provide evidence to support their interpretations of students. Overall it appears that teachers lack knowledge of student conceptions, but that this knowledge improves with teaching experience. 3. Curriculum knowledge: (a) knowledge of mandated goals and objectives (e.g., state and national standards); and (b) knowledge of specific curriculum programs and materials. Although science teachers recognize a variety of goals for science teaching, they tend to emphasize content goals over attitudinal or process goals. We know little about the knowledge teacher bring to bear on the analysis, selection, or design of science curriculum materials. 4. Knowledge of science instructional strategies: (a) subject specific strategies (e.g., learning cycle, use of analogies or demos or labs); and (b) topicspecific teaching methods and strategies, including representations, demonstrations, and activities. More science education research should be devoted to examining what teachers understand about classroom inquiry strategies and science teaching models, and how they translate their knowledge into instruction. 5. Science assessment: this includes (a) what to assess, and (b) how to assess (methods); according to Briscoe (1993), a teacher's ability to change his/her assessment practices is "influenced by what the teacher already knows or understands about teaching, learning, and the nature of schooling". These studies of teacher knowledge of assessment in science provide rich research models that demonstrate a link between PCK for assessment and science teaching orientation. More studies are needed to better understand what teachers know about assessment, and how they design, enact, and score assessments in their science classes. To Conceptualize the Shulman's model, figure 1 is presented below:

$$\mathbf{Y = \beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5+\varepsilon}$$

Figure 1: The Proposed Model

Where: Y: Predicted Average Grade in Physics in which the value used as Dependent Variable is the Mean scores in Physics for each student in the Posttest**. And $\mathbf{X_1}$:** Orientations, $\mathbf{X_2}$ is Knowledge of the Learners, $\mathbf{X_3}$ is Curriculum Knowledge, $\mathbf{X_4}$ is Knowledge of Physics Instructional Strategies, and $\mathbf{X_5}$ is Physics Assessment. $\boldsymbol{\beta_0}$ is the constant term**;** $\boldsymbol{\beta_1}$**,** $\boldsymbol{\beta_2}$**,** $\boldsymbol{\beta_3}$**,** $\boldsymbol{\beta_4}$**, and** $\boldsymbol{\beta_5}$ are the beta coefficients respectively for the five independent variables, and $\boldsymbol{\varepsilon}$ is the error term and is uniformly distributed when the model is formulated for prediction function which is equal to zero.

Methodology

This study was quasi-experimental with model building. This measured the level of PCK instructions as rated by the Grade 7 students in components like: Orientations, Knowledge of the Learners, Curriculum Knowledge, Knowledge of Physics Instructional Strategies, and Physics Assessment. Survey questionnaire for these five components in Pedagogical Content Knowledge was provided in which ten-item statements were rated by these High and Low Achiever students to measure the extent their teacher had applied this approach in their Physics subject. This study was conducted in Immaculate Conception Academy, Inc. in Dancalan, Ilog, Negros Occidental. Complete enumerations of the total 196 Grade 7 students were the respondents of the study. The Treatment Group was composed of the Low Achievers who's General Percent Average (GPA) in Grade Six ranges from 75% to 84% and for the High Achievers, from 84% and up. There were two types of instruments used. First was the survey instrument for the Pedagogical Content Knowledge which was modified from internet sources (Alev et al., 2012).

The second was the test questionnaire taken from the topics about Energy in Physics by Rabago et al. (2010), as presented in the research design. The researcher personally conducted this quasi-experimental study with the Grade Seven students including the administration of the Survey Questionnaires in Pedagogical Content Knowledge with Physics' Pretests and Posttests. He used to teach Physics as part of the General Science curriculum. The researcher used to teach in this school with these students to warrant him to finish this data gathering on time.

Data Analysis

Profiles of the Grade 7 students in terms of Gender, Types of Achievers, and Average Grade in General Science subjects were dealt by frequency and mean distributions. The students' levels in the Pretest and Posttest of Physics when grouped according to Treatment and Control Groups were computed by getting the mean scores with their respective levels. The significant mean differences in Physics' Pretest and Posttest between the Treatment and Control Groups were determined with the use of One Way Analysis of Variance (ANOVA). The significant bivariate relationships among the five components of Pedagogical Content Knowledge (PCK) were analyzed through Pearson Correlations. This provided the ideas of the trends of directions between the two components, pair-wise. The significant Physics Model of the Grade 7 students using PCK instructions was formulated using Multiple Linear Regression Analysis.

Summary of Findings

The results of the pedagogical content knowledge instructions as applied to Physics together with the cognitive ability of the Grade 7 students are analyzed and interpreted. The results are tabulated and incorporated with discussions.

Table 1 presents the Profile of the Grade 7 students in Terms of Gender, Types of Achievers, and Average Grade in Science.

	Types of Achievers				Total	
Gender	**Low Achievers**	**GPA**	**High Achievers**	**GPA**	**f**	**%**
Male	71	79%	19	88%	90	45.92
Female	93	79%	13	86%	106	54.08

The results of 16% High Achieving students support the study of Dey (2012) in which this group of students really excels because of the study habits they have made late every night which makes the difference and the valid reason of their few in numbers compared to those of the 84% low achieving students. This means that what constitutes most likely of the fewer percentage of the High Achievers is their perseverance to withstand with long hours of studying that is rarely done by the Low Achievers (Ali, 2007).

Table 2 presents the levels of Pedagogical Content Knowledge in terms of its five components when grouped according to types of achievers.

Pedagogical Content Knowledge Components	Treatment Group: LA		Control Group: HA	
	Mean	**Level**	**Mean**	**Level**
1. Orientations	3.70	H	3.30	A
2. Knowledge of the Learners	3.83	H	3.06	A
3. Curriculum Knowledge	3.73	H	3.27	A
4. Knowledge of Physics	3.69	H	3.14	A
5. Physics Assessment	3.44	H	3.42	H
Total	3.68	H	3.24	A

A: Average (2.61-4.60) H: High (3.41-4.20)

The Grade 7 students under the Treatment Group rated the Pedagogical Content Knowledge (PCK) components a total mean of 3.68 interpreted as High (H) level. While the students under the Control Group rated 3.24 for Average level. The High ratings given by the students under the Treatment Group with the five pedagogical Content Knowledge (PCK) intervention components signify that they have been mediated with this type of instruction. And the students' overall rating of Average from the Control Group simply shows of the conservative applications of the PCK instructions in a subtle way of dealing with them in the classroom.

Table 3 Presents the Students' Cognitive Ability in the Pretest and Post Test in Physics

Test Areas In Physics	Treatment Group				Control Group			
	Pretest		Posttest		Pretest		Posttest	
	Mn	Lev	Mn	Lev	Mn	Lev	Mn	Lev
1. Constant Uniformly Accelerated Motion	4.43	L	4.68	A	5.25	A	6.22	A
2. Sound and Light Waves	2.76	L	4.80	A	5.19	A	5.56	A
3. Heat	4.58	L	5.37	A	5.38	A	6.44	H
4. Electricity	4.12	L	5.06	A	4.94	A	5.75	A
Total	3.97	L	4.98	A	5.37	A	5.99	A

Notation: Mn: Mean Lev: Level
L: Low (2.81-4.60) A: Average (4.61-6.40) H: High (6.41-8.20)

The overall Cognitive Ability of the students in the Treatment Group as measured through the Pretest reveals Low mean rating (3.97) and has improved to Average in the four test areas of the students in the Posttest of (4.98). Specifically, these increases are shown in the following areas The results further indicate that the students under the Control Group perform better during the Pretest which means that those with better GPAs generally have better performance in the examinations (Jabeen and Kha, 2013). In other words, performance has improved for these students from pretest to posttest after they have experienced a coached dynamic assessment intervention.

Table 4.1 Shows the Significant Difference in the Pretest According to Treatment and Control Groups

		Sum of Squares	df	Mean Square	F	Sig.
UA	Between Groups	19.512	1	19.512	7.318	.007
	Within Group	517.238	194	2.666		
SO	Between Group	126.700	1	126.700	75.957	.000
	Within Group	323.601	194	1.668		
HE	Between Group	12.938	1	12.938	5.474	.020
	Within Group	458.506	194	2.363		
EL	Between Group	22.624	1	22.624	8.331	.004
	Within Group	526.820	194	2.716		

Values in the above-table indicate highly significant differences in pretest scores in the cognitive ability of the students in both the Treatment and Control Groups giving the edge of High Achieving students in the Control Group. This has made the null hypothesis rejected to infer that in the Pretest the High Achievers perform better than the Low Achievers.

Table 4.2 Significant Difference in the Posttest According to Treatment and Control Groups

		Sum of Squares	df	Mean Square	F	Sig.
UAp	Between Groups	62.158	1	62.158	28.560	.000
	Within Groups	422.225	194	2.176		
	Total	484.383	195			
SOp	Between Groups	17.676	1	17.676	8.153	.005
	Within Groups	420.625	194	2.168		
	Total	438.301	195			
HEp	Between Groups	30.750	1	30.750	12.127	.001
	Within Groups	491.924	194	2.536		
	Total	522.673	195			
ELp	Between Groups	12.712	1	12.712	10.132	.002
	Within Groups	243.390	194	1.255		
	Total	256.102	195			

Posttest results show highly significant differences according to Treatment and Control Groups to reject the null hypothesis. Although both groups settled to Average levels in their Cognitive Ability but the difference in points suggests that the Control Group obtain higher than that of the treatment Group; proving the Control Group to perform better by point-estimates. These findings further confirm that in the part of the Treatment Group the influence of Pedagogical Content Knowledge approach has made them performed better in the Posttest with one level increase; that is from Low level from the pretest to Average level rating in the posttest.

Table 5 Significant Correlations in the Components of Pedagogical Content Knowledge

		Orientations	Knowledge of Learners	Curriculum Knowledge	Knowledge in Physics	Physics Assessment
Orientation	Pearson Corr.					
	Sig. (2-tailed)					
Knowledge of Learners	Pearson Corr.	.143(*)				
	Sig. (2-tailed)	.046				
Curriculum Knowledge	Pearson Corr.	.291(**)	.326(**)			
	Sig. (2-tailed)	.000	.000			
Knowledge in Physics	Pearson Corr.	.249(**)	.294(**)	.297(**)		
	Sig. (2-tailed)	.000	.000	.000		
Physics Assessment	Pearson Corr.	-.295(**)	-.151(*)	-.199(**)	-.186(**)	
	Sig. (2-tailed)	.000	.035	.005	.009	.
	N	196	196	196	196	196

There are five highly significant and positive low strengths of relationships in Curriculum Knowledge and Orientation (.29) as well as Knowledge of Learners (.33). Also there are three to Knowledge in Physics with Orientation (.25), Knowledge of Learners (.29); and Curriculum Knowledge (.30). These coefficients suggest that when this pair of components goes together, they are likely going toward positive directions. The higher the rating found in Curriculum Knowledge corresponds to the high rating similarly in Orientation. The same connotations and interpretations can be applied to Knowledge in Physics paired with Orientations, Knowledge of Learners and Curriculum Knowledge. There are three negative but significantly low coefficient of correlations and one moderately low significant bivariate relationships respectively to Physics Assessment with Knowledge of Learners (-.15), Curriculum Knowledge (-.20), Knowledge in Physics (-.19), and Orientation (-.30). This means that as the ratings increase in Knowledge of Learners (3.83), Curriculum Knowledge (3.73), Knowledge in Physics (3.69) and Orientations (3.70) there correspond the decreasing trends in Physics Assessment rating (3.14) within the alpha level of less than .05. These significant correlations make the null hypothesis rejected to generalize that these PCK components are correlated (Please refer to Table 2).

Table 6 Significant Physics Model Using Pedagogical Content Knowledge

Model 2	F	Sig.	R	R^2	R^2adj
	49.53	.00	.75	.57	.55

Explanatory Variables	Unstandardized Coefficients β	Unstandardized Coefficients Std Error	Stdized. Coef. Beta	T	Sig
(Constant)	4.456	.324		13.77	.000
Orientations **(X_1)**	-.197	.050	-.205	-3.933	.000
Knowledge of the Learners **(X_2)**	-.392	.043	-.478	-9.200	.000
Curriculum Knowledge **(X_3)**	.121	.049	-.131	-2.457	.015
Knowledge of Physics **(X_4)**	-.220	.046	-.248	-4.755	.000
Physics Assessment **(X_5)**	.034	.045	.039	.767	.444

Results in the Multiple Regression Analysis reflect the F-test to be highly significant with adjusted R square of .57 or 57%; with four explanatory variables register highly significant in their t-tests. This means that there is 57% of the total variance that these variables can explain to the students' GPA in Science. And it means the other 43% is explainable by other variables not in PCK. The adjusted R square value (.57) is preferred because there are three model extractions out of the data sets to really look into which of the transformations could have offered the best model for prediction and strategy formulation of the Grade students' Grade Percent Average (GPA) in Science of Immaculate Conception Academy. The Model selection is made, and out of three trials, it is Model 1 that gives highly significant variables. The other two, are processed through using the scores in the Posttest in Physics Cognitive Ability segregating the Treatment and the Control Groups of which the extraction reveals no significant variables that can influence their Cognitive Ability in Physics (Appendix E).

Conclusion

For the inferentially analyzed results, the following major conclusions were given: Significant differences in the Pretest scores proved that High Achieving students had better Cognitive Ability than the Low Achieving ones prior to giving formal lectures in the four areas in Physics. Hence better GPA was a significant student factor to obtain better scores in Cognitive Ability. With significant differences in the Posttest, despite the Average levels the Treatment and the Control Groups had achieved, this inferred to conclude that the Control Group manifested significantly higher scores in point-estimates at that range of Average level-interval against the Treatment Group. The increased performance level in the test scores form Low to Average by the Low Achieving students in the Treatment Group indicated the effectiveness of the application of the Pedagogical Content Knowledge as a form of mediated instructions in Physics. Therefore PCK instructions must be sustained. Highly significant positive correlations among the components of PCK also implied positive influence toward better academic scores, hence, taking initiatives in improving PCK instructions must be pressed to be implemented effectively; particularly to students with learning difficulties. The three negative coefficients of the extracted significant variables in the model gave decreasing effects to the science GPA therefore offered a disadvantage to the part of the High Achieving students. With considerable amount of variance at 57%, the formulated model became worthwhile; therefore, this model would efficiently serve as bases for the formulation of effective PCK strategies.

Recommendations

Based on the findings, the following major recommendations were given: The Pedagogical Content Knowledge instructions must be applied and sustained across subject areas which are highly analytical especially with the low achieving students, specifically on activities based on Curriculum Knowledge. Authentic assessment through itemized questionnaires must be strategized according to the Cognitive levels of the students. More specifically with the incorporations of pictorial representations to provide fair evaluation, and become feasible in both the teacher and students to become a significant predictor for GPA in General Science. Science and Math Teachers must go hand in hand in tackling classroom issues in workshops and seminars particularly in enriching and improving the learning and understanding of these low achieving students. Teaching with these students must employ different methods in both content and pedagogical courses. This would be initiated particularly in terms of PCK components that give decreasing effects, particularly to students' Grade Percent Average (GPA) in General Science. Special mention to components like: Orientations, Knowledge of the Learners, Knowledge of Physics in faculty professional growth education programs (Kaya, 2009) since these courses are important for improved learning of these students as emphasized by Nakiboğlu and Karakok (2005), and, Tekin (2006). In so doing, these components would provide better chances to students for a realistic enhancement in their Physics performance. For the different higher institutions of learning, teaching through PCK course should be given more time and attention by the teaching staff in different Colleges especially to College of Teacher Education. Teaching through PCK should always be videotaped, so that students will have the opportunity of observing their own teaching in order to improve upon it during re-teach. Education department should give more instruction or education on how to conduct a lesson through PCK. This PCK peer teaching should be constantly and effectively organized. The different Colleges should effectively handle the methodology aspects of each subject. The effective production, improvisation and utilization of self-made relevant instructional and assessment materials should be encouraged and implemented. More research activities should be carried out through PCK in other subject areas by considering these three recommended research problems. 1. Designing and implementing Pedagogical Content Knowledge for problem-based learning in high school science. 2. Applications of Computer Interface to Pedagogical Content Knowledge (PCK) in high school Physics. 3. E-Tech PCK Instructions for College Physics.

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