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Isaac Buabeng
University of Cape Coast

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Physics classroom interactions: Teaching strategies and practices

Isaac Buabeng[1]

University of Cape Coast, Ghana

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Abstract: This study investigated the interactions that occurred as part of the learning from a national survey of high school physics teachers in New Zealand (NZ) in relation to decile ranking. Specifically, the study investigated how often particular teaching strategies and practices such as: teaching approaches, teacher feedback and guidance, and ICT usage, occurred during physics teaching. Data were analyzed using descriptive statistical and inferential statistics – MANOVA. Among other things, the study revealed that learners were not exposed to the teaching methods that potentially give them the chance to observe, engage and/or discover expert strategies in context. There was a lack of use of problem-based or inquiry learning models for learning. However, there was no significant difference between teaching in the various decile rankings. The implications of the findings are discussed.

Keywords: *Classroom interactions; Teaching strategies; Teaching practice; Physics teaching.*

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Introduction

Researchers over the years have maintained that teachers form a strong causal factor in defining the quality of education in schools (Archibald, 2006; Darling-Hammond & Baratz-Snowden, 2005; Golla, de Guzman, Ogena, & Brawner, 1998; Hake, 1998). There is a drive for teachers to ensure that students have

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[1] **Corresponding author:** Isaac Buabeng

Email: ibuabeng@ucc.edu.gh

acquired creative and critical thinking abilities ready to face the realities of life. Central to acquiring creative and critical thinking is the ability of teachers to design teaching sequences that provide experiences and develop capability among the students to respond to situations that beset them so that their learning becomes meaningful (Darling-Hammond & Baratz-Snowden). In other words, there is a need to develop adaptability, transfer of thinking skills and to undertake active inquiry on real science-related problems (Conner, 2016).

With regards to effective methods of instruction (also called effective pedagogy) in the teaching of physics, a number of methods have been suggested in the literature. Prominent among them are inquiry-based teaching, activity-based teaching, guided discovery, demonstration and expository teaching. Though all these methods, and many others, are recommended, inquiry-based learning and guided discovery have been praised for requiring the students to do more than just report on a topic (Bencze, Alsop, & Bowen, 2009; Cahyadi, 2007; Centre for Inspired Teaching, 2008; McDermott, 2001; McDermott & Shaffer, 2000; Sokoloff & Thornton, 1997).

Furthermore, the 2011 TIMSS report stressed that students can meaningfully build upon their knowledge and understanding of science through the process of scientific inquiry and therefore commended countries that have been engaging students in this process (International Association for the Evaluation of Educational Achievement [IEA], 2012). This is a wake-up call for other countries to place considerable emphasis on teaching and learning of science through inquiry-based processes. Science with physics in particular, is best practiced through active engagement and inquiry into the physical phenomena in the world.

Effective learning of physics (learning with understanding) is described as a type of learning in which learners take responsibility for their own learning through active construction and reconstruction of their own meanings for concepts, events, experiences and phenomena (Brass, Gunstone, & Fensham, 2003).

Thus, learning with understanding recognises the extent to which students engage with and maintain constructivist ways of learning, i.e. through active participation, learners take control of their own learning. Research findings suggest that much of students' learning in physics does not involve them in developing conceptual understanding (Brass et al.; Freitas, Jiménez, & Mellado, 2004; Gunstone, Mulhall, & McKittrick, 2009). For example, Brass et al. found that, in Victoria, Australia, some high school and university teachers were more focussed on what their students could not do. Hence the idea of effective learning being students taking control of their own learning was rejected. Also, Freitas et al. concluded in their study, conducted in Portugal that some teachers still see their role as transmitting the knowledge they have to their students. Hence most often, teachers presented solutions to students rather than asking questions. Memorization of what the teacher has previously transmitted was prevalent and that "students write down in their daily notebooks everything that the teacher says" (p. 120).

Research has found that if students do not exercise control or responsibility over their own learning, their understanding of concepts and their attitude to learning are negatively affected (Brass et al., 2003). Effective learning thus occurs when learners have knowledge of their own learning, are aware of their own learning and seek to control their own learning and relate the knowledge acquired to the physical world. Learning by inquiry engages students actively in the construction of their own knowledge. The importance of teacher abilities to create an enabling atmosphere that allows meaningful classroom interaction with students cannot be underestimated. More so, the types of classroom interactions created by the teacher and the types of questions he/she uses to structure the teaching, play an important role in the kinds of thinking skills learners employ, the range of information processed by the learners and the thinking skills they may learn (Darling-Hammond & Baratz-Snowden, 2005; Smart & Marshall, 2012).

Policy makers in NZ have over the years, defined quality teachers as being those who form effective learning relationships with students and teach in culturally appropriate and responsive ways and are able to overcome all other influences on student achievement (Ell & Grudnoff, 2013). The authors, based on their findings, commented that to improve student achievement and/or eliminate under achievement, the quality of teaching should be improved.

The study focused on teaching practices in high school physics classrooms in NZ. Like many other countries, the education system in NZ has a three-tier structure that includes primary schools, secondary schools (high schools) and tertiary institutions (universities and polytechnics). In NZ, high schools are classified and rated into socio-economic bands called ‘deciles’. The decile rating of a school gives an indication as to the average family socio-economic backgrounds of the students at that school. In other words, deciles represent the average number of socially and economically disadvantaged students at a school. There are 10 deciles with decile 1-3 being the most disadvantaged and decile 8-10 the least.

Although deciles are a funding mechanism and in no way, reflect the quality of education offered in a school, evidence suggests that parents often judge schools on their decile rating and many at times associate deciles with the success of a school. Analysis of the National Certificate of Educational Achievement (NCEA) results shows that the least disadvantaged schools (decile 8-10) always outperform their counterparts (New Zealand Qualifications Authority[NZQA], 2012) This paper was conducted as part of a larger study (Buabeng, 2015) which investigated teaching and learning practices in physics classrooms and took account of the decile rating of the schools. The study was guided by the following research questions:

1. How do secondary teachers perceive their physics classroom interactions?
2. Is there any significant difference in classroom interactions between the decile ranked schools?

Theoretical Framework

The study was underpinned by two theories – constructivism and the cognitive apprenticeship model (CAM). Constructivism is characterized by the view that knowledge is not transmitted directly from one person to another, but is actively built up by the learner (Cobern, 1998; Driver, Asoko, Leach, Scott, & Mortimer, 1994). Cobern argues that a constructivist classroom is one in which people are working together to learn. To him, such a classroom will be a place where inquiry is conducted. Discourse will be the mode by which participants engage in negotiations of meaning. Cognitive, social and cultural differences among students will be honoured and alternative world-views respected (Cobern). Constructivist classroom is a learner-centred environment which acknowledges and brings to the fore the past experience of students (Conner, 2014). She articulates that in constructivist classrooms, learning is "reflective, interactive, inductive and collaborative, and questions are valued as a source for curiosity and focus for finding out information" (p. 3). In such classrooms, the teacher acts as a facilitator or mediator of learning rather than someone who only takes on the role of imparting knowledge.

The cognitive apprenticeship model also presumes that learners should be exposed to the teaching methods that give students the chance to observe, engage in, invent, or discover expert strategies in context (Berryman, 1991; Collins, Brown, & Holum, 1991). According to Berryman, the teaching methods should "systematically encourage student exploration and independence" (p. 5). Berryman stresses that teachers only coach – "offering hints, feedback, and reminders; provide 'scaffolding' (support for students as they learn to carry out tasks); and 'fade' – gradually handing over control of the learning process to the student" (p. 5). More so, the learning environment should reproduce the technological, social, time, and motivational characteristics of real world situations with varying levels of difficulty to enable students to work with their peers in finding solutions to problems as experienced in the real world (Berryman; Chandra & Watters, 2012).

Empirical studies show that the cognitive apprenticeship model and/or constructivist theory is an accurate description of how learning occurs and the instructional strategies can be designed into formal learning contexts with positive effect (Chandra & Watters, 2012; Conner, 2014; Vanessa Paz Dennen, 2004; Vanessa P Dennen & Burner, 2007; Keser, Akdeniz, & Yyu, 2010). With these two theories (constructivist and cognitive apprenticeship model) teachers acknowledge they cannot mandate what students learn. They design learning activities that are informed by what students already know and believe, and actively encourage students to reflect on and manage their own learning.

Methodology

All secondary schools in New Zealand were offered the opportunity to participate in this study through a national survey of high school physics teachers. The sample from all high schools who responded and completed the survey comprised 104 physics teachers. Data from teachers' survey questionnaires were analysed using descriptive statistical methods (including percentages, means, standard deviations and graphs where appropriate) and inferential statistics – multivariate analysis of variance (MANOVA).

The questionnaire (the online survey) asked physics teachers to indicate on a five-point Likert scale how often particular teaching strategies and practices occur in their physics classrooms. The teachers' responses were coded and ranked on a five-point Likert scale format with 'Never'=1; 'Not Often'=2; 'Sometimes'=3; 'Most of the Time'=4; and 'Always'=5 respectively. The practices were grouped under the headings: teaching approaches, teacher feedback and guidance, and ICT usage in physics teaching.

Findings

This section reports the findings of the physics teacher's responses to the rating-scale items on the physics classroom interactions – teaching approaches, teacher feedback and guidance and ICT usage in physics teaching.

Physics Classroom Interactions

Teaching Approaches

As can be seen in Table 1, the teachers responded to many points about what actually takes place in the physics classroom regarding their teaching methods. The overall mean scores and standard deviations on this sub-scale were: decile 1-3 (M = 3.31, SD = 0.75); decile 4-7 (M = 3.41, SD = 0.75); and decile 8-10 (M = 3.37, SD = 0.75) respectively. These give an indication that physics teachers sometimes use the said teaching strategies indicated in Table 1. It can be seen that presentation of new concepts and problem solving are most often done on the white board. Teachers from decile 1-3 and 4-7 schools most of the time emphasized mathematical presentation of concepts more than their colleagues in decile 8-10 schools. Teachers from decile 4-7 and 8-10 schools on the other hand, recorded high mean scores (3.82 and 3.90) on qualitative thinking and presentation of concepts – an essential feature of teaching by inquiry.

Teachers from decile 4-7 and 8-10 schools also reported high mean scores (3.73 and 4.04 respectively) for the use of demonstrations and discussions to illustrate concepts/phenomena. Almost all of the teachers indicated that teaching and learning was rarely student-centred. In addition, students' ideas and suggestions were not often used in teaching. Also, students were not likely to have opportunities to plan and carry out their own designs for experiments, as most often they would perform experiments by following teacher instructions rather than student inquiry-based approaches.

Table 1.

Means and Standard Deviation Scores of Items on Teaching Approaches by Schools' Decile Ranking

Statements	Decile ranking					
	1-3 (N=9)		4-7 (N=44)		8-10 (N=51)	
	Mean	SD	Mean	SD	Mean	SD
I present new materials on the white board	3.22	0.67	3.55	0.98	3.61	0.83
I demonstrate problem-solving on the white board	3.89	0.78	3.91	0.77	3.88	0.74
I place emphasis on mathematical presentation of concepts	3.56	1.13	3.73	0.92	3.35	0.93
I place emphasis on qualitative thinking and presentation of concepts	3.33	0.87	3.82	0.79	3.90	0.81
I use demonstrations and discussions to illustrate concepts/phenomena	3.44	0.73	3.73	0.59	4.04	0.80
Teaching and learning is teacher-centred	3.44	0.53	3.50	0.63	3.51	0.61
Teaching and learning is student-centred	2.89	0.78	2.80	0.55	2.76	0.68
I use students' suggestions and ideas in teaching	3.33	0.71	3.34	0.81	3.22	0.76
I engage students in context based-activities	3.56	0.88	3.23	0.71	3.27	0.80
Students work with physics problems individually	3.11	0.78	3.23	0.74	3.33	0.59
Students work with physics problems in groups	3.56	0.53	3.30	0.67	3.16	0.58
Students have opportunity to explain their own ideas	3.56	0.88	3.70	0.70	3.51	0.81
Students do experiments by following instructions from the teacher	3.00	0.71	3.23	0.81	3.39	0.70
Students plan and do their own experiments	2.44	0.53	2.64	0.89	2.49	0.86
Average scores	3.31	0.75	3.41	0.75	3.39	0.75

Teacher Feedback and Guidance

Items on this category were used to find out how physics teachers related to, encouraged, motivated and showed interest in their students' learning. The mean scores and standard deviations of the items by decile ranking are shown in Table 2. The overall mean scores and standard deviations for the teachers on teacher feedback and guidance were as follows: decile 1-3 (M = 3.78, SD = 0.87); decile 4-7 (M = 3.83, SD = 0.74); and decile 8-10 (M = 3.79, SD = 0.73). This indicates that teachers in the survey perceived their response and assistance to students to be important. That is, most of the time, teachers showed interest in their students' learning and provided the needed motivation and encouragement to students. The item "I use language that is easy to understand" for example, was rated to be the most positive with mean value of 4.44 and standard deviation of 0.53 for teachers of decile 1-3 schools, mean value of 4.20 and standard deviation of 0.59 for teachers of decile 4-7 schools and mean value of 4.24 and standard deviation of 0.68 for teachers of decile 8-10 schools.

Table 2.
Means and Standard Deviation Scores of Items on Teacher Feedback and Guidance

Statements	Decile ranking					
	1-3 (N=9)		4-7 (N=44)		8-10 (N=51)	
	Mean	SD	Mean	SD	Mean	SD
I tell students how they can improve their performance	4.22	0.83	3.93	0.66	3.90	0.67
I give quizzes that I mark to see how students are performing	2.33	1.12	2.89	0.84	3.00	0.66
I talk to students about how they are getting on in physics	3.78	0.83	3.82	0.82	3.55	0.78
I mark students' work and give it back quickly	3.78	0.97	4.07	0.76	3.92	0.82
I use language that is easy to understand	4.44	0.53	4.20	0.59	4.24	0.68
I show students how new concepts in physics relate to what we have already done	4.11	0.93	4.09	0.74	4.14	0.77
Average scores	3.78	0.87	3.83	0.74	3.79	0.73

Likewise, items “I tell students how they can improve their performance” and “I show students how new concepts in physics relate to what we have already done” were also rated highly by the teachers. On the other hand, formative types of assessment in classrooms, such as giving quizzes and marking them to see how students are performing rarely happened, as almost all the teachers reported low rankings on this item. A low mean score of 2.33 and standard deviation of 1.12 were recorded for teachers of decile 1-3 schools; 2.89 and 0.84 mean and standard deviation values for decile 4-7; and 3.00 and 0.66 mean and standard deviation values for decile 8-10 school teachers. The mean values were far below the average mean score for the category, as indicated in Table 2.

ICT Usage in Physics Teaching

The third category was used to find out how often physics teachers use ICT tools to enhance the teaching and learning of physics. As shown in Table 3, the overall mean scores and standard deviations for the teachers by their schools’ decile ranking were as follows: M = 2.47 and SD = 0.83, M = 2.60 and SD = 0.90, and M = 2.80 and SD = 0.81 for decile 1-3, 4-7, and 8-10 schools respectively. The mean scores for all five questions related to the use of ICT indicated that the majority of physics teachers used ICT tools sporadically or rarely at all.

Table 3.
Means and Standard Deviation Scores of Items on ICT Usage in Physics Teaching

Statements	Decile ranking					
	1-3 (N=9)		4-7 (N=44)		8-10 (N=51)	
	Mean	SD	Mean	SD	Mean	SD
Use computers for laboratory simulations	2.44	1.01	2.70	0.95	3.00	0.78
We look for information on the internet at school	2.89	0.78	2.95	0.96	2.80	0.72
Use computers to collect and/or analyze data	2.22	0.67	2.39	0.90	2.65	0.96
Use computers to demonstrate physics principles	2.89	0.78	2.84	0.71	3.00	0.63
Students use their phones to search for information at school	1.89	0.93	2.11	0.97	2.55	0.95
Average scores	2. 47	0.83	2.60	0.90	2.80	0.81

Differences in Classroom Interactions between the Decile Ranking Schools

To find out whether the mean scores observed in Table 1, Table 2 and Table 3 were statistically significant between the decile ranking schools, a one-way analysis between groups multivariate analysis of variance (MANOVA) was conducted after initial testing of assumptions was performed. Preliminary evaluation of assumptions of univariate and multivariate normality, linearity, homogeneity of variance-covariance matrices, equality of variance and multicollinearity were satisfactory, with no serious violations identified. However, one variable, usage of ICT in physics teaching, recorded a significance value of 0.03 under the Levene's Test of Equality of Error Variance. Since this value (0.03) is less than 0.05 the said variable (usage of ICT in physics teaching) did not meet the assumption of equality of variance. In such situations, Tabachnick and Fidell (2007) recommend that Pillai's trace criterion should be reported for the combined test of significance because it is "more robust for small sample sizes, uneven N values and violation of assumptions" (Pallant, 2007, p. 286)

With the use of Pillai's trace criterion, as shown in Table 4, the results of the combined dependent variables (teaching approaches, teacher feedback and guidance and ICT usage in physics teaching) were not statistically significant for the decile ranking schools, F (6, 200) = 0.98, p = 0.44; partial eta squared = 0.03.

Table 4.
Multivariate Test of Significance for Combined Classroom Interactions

Grouping variable	Effect statistics	Value	F	df	Error df	p-value	Partial eta squared
Decile ranking of schools	Pillai's Trace	0.057	0.976	6.00	200.00	0.442*	0.028
	Wilk's Lambda	0.943	0.975	6.00	198.00	0.444	0.029
	Hotelling's Trace	0.060	0.973	6.00	196.00	0.445	0.029
	Roy's Largest Root	0.052	1.747	3.00	100.00	0.162	0.050

*Not significant, $p > 0.05$

This means that physics teachers across the schools do not differ in terms of their classroom interactions. They have similar teaching approaches and also related to students in a similar manner. The estimated marginal means indicated in Table 5 further show that the means scores on each construct were almost the same for all schools.

Table 5.
Estimated Marginal Mean Scores for the Classroom Interactions

Construct	Decile ranking	Mean	Std. dev.
Teaching approaches	1-3	3.31	0.34
	4-7	3.41	0.32
	8-10	3.39	0.29
Teacher feedback and guidance	1-3	3.78	0.67
	4-7	3.83	0.45
	8-10	3.79	0.43
ICT usage in teaching physics	1-3	2.47	0.57
	4-7	2.60	0.65
	8-10	2.80	0.44

Discussion and Implications

The findings from the study revealed that no significant difference existed between teaching in the various decile rankings (Table 4). This suggests that teaching accross the school was almost similar. The findings buttress the point that decile ratings are for funding purposes only and they are not, in any way, an indication of the performance or quality of education delivered at a school. Parents should therefore not judge schools on their decile by associating deciles with the success of a school.

In other hand, the findings from the study indicate that physics classroom dialogue tended not to support constructivist epistemology, problem-based learning or inquiry-based teaching and learning, which is emphasised in the New Zealand Curriculum (NZC) (Ministry of Education, 2007). Thus, what is occurring in the physics classrooms is contrary to the aspirations of the NZC (Ministry of Education). It can be inferred that teachers have not embraced or aligned with the cognitive apprenticeship model (CAM) which suggests that learners should be exposed to teaching methods that give them the chance to observe, engage in, invent, or discover expert strategies in context (Berryman, 1991; Collins et al., 1991).

The CAM stresses that teaching methods should systematically encourage student exploration and independence and that teachers should only coach – "offering hints, feedbacks, and reminders; provide scaffolding (support for students as they learn to carry out tasks); and fade gradually, handing over control of the learning process to the student) (Berryman, p. 5). The teachers' survey data, as presented in Table 1, revealed that student-centred instructional approaches were not common in many physics classes. In most cases, teachers across all decile rankings decided on what happened in the senior physics classrooms and students' ideas and suggestions played little role in the planning of teaching and learning processes.

Formative types of assessment in classrooms, such as giving quizzes and providing feedback to show students how well they are performing rarely happened in all schools. Almost all the teachers reported low scores on this item. This finding is comparable to the findings by (Sunal et al., 2015) who reported that formative assessment was rarely observed in physics lessons in Alabama State in the U.S.A as most often physics teachers resorted to the use of summative assessment. As indicated by Black (1998) formative assessment is diagnostic in nature and it is intended to provide the teacher with feedback about teaching and learning processes. The results from formative assessment inform the teacher about students' performance abilities and the teacher uses the information to reform his/her teaching. Formative assessment also provides an indication of progress to both students and teachers and "assessment results provide valuable information that guide subsequent teaching-learning planning" (Conner, 2013, p. 157). The practice of formative assessment must therefore be integrated into physics teaching and learning since it's essential to quality teaching.

It can be inferred from the findings (Table 1) that students rarely had the opportunity to plan and implement their own designs for experiments as most often students carried out experiments by following pre-determined instructions from teachers. Students' questionnaire data and focus group interviews further corroborated the teachers' questionnaire data (Buabeng, 2015; Buabeng, Conner, & Winter, 2016). As reported by Berry, Gunstone, Loughran, and Mulhall (2001), such an approach to teaching is an ineffective way of developing students' understanding of science concepts, and it also presents a wrong impression of how scientific knowledge develops.

Findings from the study (Table 3) revealed that physics teachers rarely used ICT tools for physics teaching. This finding is consistent with other findings conducted in educational settings regarding the use of ICT to support physics teaching and learning (Eteokleous, 2008; Koehler & Mishra, 2009; Shih-Hsiung, 2011; Smeets, 2005). Teachers' lack of use of interactive instructional approaches in physics classrooms on a frequent and regular basis may largely be attributed to limiting factors – assessment demands, time constraints, teacher work-load etc. identified by the teachers (Buabeng, Conner, & Winter, 2015; 2017).

Also, because of the age of the teachers and when they did their initial teacher training (Buabeng, 2015; Buabeng et al., 2016), student-centred pedagogies and the use of ICT, critical thinking, inquiry etc., were not necessarily emphasised as much as now. That is, their teacher education was appropriate for that time, but is no longer adequate (Buabeng et al.), indicating the need for on-going professional learning opportunities. The challenge for teacher educators is to ensure that today's teacher preparation programmes are responsive to the needs of physics graduates who aspire to be effective teachers.

Recommendation

The revelation that physics teachers in this study rarely used ICT tools for physics teaching is disconcerting and should be an area for future professional development for teachers. Professional learning programmes should support teachers to deepen their pedagogical content knowledge to make learning for their students interesting and relevant. Teacher educators should develop a closer association or work more closely with university physics departments so that they can include more interactive approaches to learning. Since teachers' understanding of physics is mainly gained through learning within undergraduate physics courses, it is important that lecturers teaching these courses model effective approaches for teaching and learning.

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