# PROBLEM-BASED AND SCHOOL-TYPE AS CONTRIBUTORY FACTORS TO THE SENIOR SECONDARY SCHOOL STUDENTS' PRACTICAL SKILLS IN CHEMISTRY

Modupe M. Osokoya and Chinwe C. Nwazota
Institute of Education, University of Ibadan, Ibadan, Nigeria

**Abstract**: *The study assessed effects of problem-based learning approach on senior secondary school students' practical skills in chemistry and the role of school type as a moderating variable. A pretest, posttest control group quasiexperimental setting with non-equivalent groups design was adopted. A total of 124 students (54 from coeducational and 70 from single-sex) of federal government colleges in Lagos and Oyo states of Nigeria participated in the study. A 33-item Chemistry Manipulative Skills Scale (CHEMMSS) with Cronbach alpha of 0.87 was used along with the treatment manuals as instruments. Findings show that students exposed to problem-based learning approach performed better in practical chemistry than those taught using conventional method. The result also revealed that students from single-sex colleges had higher mean score gain in practical skills in chemistry than those from coeducational colleges. Chemistry teachers are therefore enjoined to adopt problem-based learning approach in the teaching of practical chemistry and that teachers in coeducational schools should motivate and encourage their students so as to benefit meaningfully in the approach.*

**Keywords:** problem-based learning, chemistry teaching, school type, practical skills

## Introduction

Chemistry is a branch of science which teaches about elements as the constituents of matter, their existence, and their interactions. These interactions manifest in what is seen today as new discoveries. The Nigerian National Policy on Education stipulates that education should aim at producing self-reliant citizens through innovations (Federal Republic of Nigeria [FRN], 2013). So, educational activities should be centred on the learner for maximum self-development, self-fulfilment, and self-confidence. Secondary education has its contributions to achieving this through its comprehensive core curriculum which includes chemistry as an almost indispensable subject towards the development of science and technology. It has been identified as one of the veritable tools for solving socio-economic problems as it contributes immensely to both individual and national development (Adewunmi, 2006; Akinola, 2007; Williams, 2003). Chemistry, being an experimental science, is full of activities which enhance the acquisition of certain skills and competences that can make an individual become scientifically literate and self-adaptive.

Through adequate exposure to practical exercises, discoveries are made, and new things are invented. The practical nature of chemistry cannot easily be overlooked because it even enhances the understanding of the theory aspect of the school subject and builds up manipulative skills necessary for cognitive development. The examining bodies in Nigeria such as West African Examinations Council (WAEC) and National Examinations Council (NECO) emphasize this importance of practical chemistry and apportion a remarkable part of the overall candidates' scores in their examinations, 25% and 24% respectively to practical chemistry (Osokoya, 2015). Despite this, there has been a continuous underachievement and low performance by the students in practical chemistry over the years. The chief examiners' reports from 2004-2010 continuously had comments such as: "inadequate and insufficient exposure of students to practical exercises; inability to link theoretical knowledge with actual practical work; inconsistent burette readings; inadequate knowledge of the properties of common salts, etc." as some of the weaknesses observed from the students' performances (WAEC, 2013, 2014). The general performance of students in this aspect of chemistry has great impact on their success in the subject.

Research studies have revealed major learning difficulties in practical chemistry, and the main causes are insufficient qualified teachers, ill equipped laboratories, students' study habits, and students' attitudes among others (Adesoji & Olatunbosun, 2007; Ezeasor, 2003; Osokoya & Opateye, 2009). It is believed that many of the difficulties in learning and understanding chemistry in general and practical chemistry in particular are caused by how instruction is passed across to the learners. Methods of instruction such as problem-solving techniques, laboratory skills method in practical skills teaching (Sikiru, 2004) had been used to teach practical chemistry in order to enhance the performance of students but not much improvement was noticed.

Problem-based learning (PBL) is a student-centred method based on the principle of using a problem as a starting point for the acquisition of new knowledge (Vasconcelos, 2010). PBL is also an investigative approach whereby learners in their small groups are needed to proffer solutions or suggestions to tasks or problems in their environment using acquired or current knowledge in chemistry. PBL originated in the 1960s at the medical school at McMaster University, Hamilton, Ontario, Canada and has since diffused into many other professional fields including education, law, economics, architecture, chemical, and civil engineering. In education, aspects of the approach were applied to K-12 classrooms by Bruner, Dewey, and Piaget among others as early as the 1920s (Dochy, Segers, Van den Bossche, & Giejbels, 2003). Paige and Smith (2013) required nursing students' collaboration to develop strategies to resolve problems, consider alternative solutions, and justify their solution to others. One of the benefits of PBL strategy is the potential to enhance retention and recall concept learned. The approach aims to bridge the gap between the stated problem and various solutions by using what has been learned previously and being learned currently to solve the prevailing pressing need and thereby learn more. In other words, PBL approach requires that the learner uses the previously learned principles together with the presently taught or discovered facts to figure out solutions to the problem at hand in academics or real-life situations (Chukwuka, 2006; Orji, 1998).

PBL is an active learning strategy which gives students opportunities to become aware and determine their problem-solving abilities and learning needs thus making knowledge operative and perform in group work especially when faced with real life problem (Akingolu & Tandogan, 2007). The students become each other's teachers and make use of self-selected resource materials such as textbooks, journals, and libraries' online resources and discuss more among one another than in the traditional classroom settings (Vernon & Blake, 1993). The lack of problem-solving abilities of students has been identified as one of the reasons for students' poor performance in science, especially when the question required application of skills to answer (Adewale, 2002; Akuche, 2007). As earlier stated, PBL is student-centred and activity focused; therefore, practical work thrives more in it as it encourages students' participation. Students' ability to handle different apparatus for practical chemistry counts a lot because they would not know how to use these apparatuses if they were not exposed and allowed to use them adequately enough to establish mastery. It should also be noted that the teaching of practical chemistry focuses on the development of appropriate skills, abilities, and competences related to the psychomotor domain of the student. The objective of this aspect of chemistry study synchronizes with the purpose of self-reliance advocated in the national policy on education (FRN, 2013). As the cognitive and the psychomotor aspects of the child are developed, the affective would naturally be motivated to give the child self-confidence in handling challenges and interest in the study of practical chemistry. This study, therefore, investigated the effects of exposing chemistry students to the use of the PBL approach on their learning outcomes.

In Nigeria, there are two categories of schools: same/single sex school and coeducational school. These categories or arrangements may influence learning outcomes because there might be some characteristic behaviours exhibited by students in same-sex schools that may not be prominent in coeducational set-up and vice versa. It is pertinent to note that the influence of gender is always considered important in the process of learning and has been proved by various studies to be a strong predictor of human behaviour (Mbah, 2003; Onuebunwa, 2000; Tatarinceva, 2005). Attitudes, behaviours, and achievements of males and females most times differ towards different subject areas or fields of study (Adeagbo, 2004; Adeyinka, 2005). Various research works have been carried out to ascertain whether there are disparities in the academic performance and behaviours of students in single-sex school and those in coeducational school settings (Butler, 2000; Chanlin, 2001; Collins, McLeod, & Kenway, 2000; Webb & Macdonald, 2007). Mulholland, Hansen, and Kaminski (2004) compared performances of students in single-sex and coeducational schools. Their analysis demonstrated that both boys and girls who were educated in single-sex classrooms scored higher than boys and girls in coeducational settings. The report also speculated that boys and girls in single-sex schools would behave better, find learning more interesting, and the curriculum more relevant than their counterparts in coeducational schools.

Consequently, there seems to be some peculiar challenges inherent in same-sex educational set up that never occur in a coeducational setting, which are capable of affecting learning. Hence, the inclusion of school type as a moderator variable in this study and assessment of its effect on learning outcomes in practical chemistry.

## Statement of the Problem

Chemistry, though an experimental subject, is generally being taught and learnt theoretically in most schools in Nigeria. This makes the abstract nature of the subject very prominent and understanding of the concepts difficult for learners. The method of teaching practical chemistry becomes pertinent so as to arrest and sustain the interest of the students and enhance understanding and better performance. Using real problems as a starting point for new learning in practical chemistry may create in different types of schools a fertile ground for students' committed participation. This study, therefore, seeks to determine the effects of PBL approach and school type and their interactions on students' achievement in practical chemistry.

## Research Question/Hypotheses

In view of the above stated problem, the following research question was answered and three hypotheses were tested in the study. This study sought to answer the following question:

> What are the mean differences in pre-test and post-test scores of students' achievement in practical chemistry by (a) treatment? and (b) school type?

The study was based on the following three hypotheses:

$Ho_1$ – There is no significant main effect of treatment (problem-based learning approach) on students' practical skills in chemistry.

$Ho_2$ – There is no significant main effect of school type on students' practical skills in chemistry.

$Ho_3$ – There is no significant interaction effect of treatment and school type on students' practical skills in chemistry.

## Methodology

### Research Design

This study adopted a pretest, posttest, control group quasiexperimental setting. The layout of the design is as shown:
Experimental group – $O_1$ $X_1$ $O_2$
Control group – $O_1$ $X_2$ $O_2$
Defined as follows:
$O_1$ = represents pre-test achievement in practical chemistry for each group.
$O_2$ = represents post-test achievement in practical chemistry for each group.
$X_1$ = represents group taught with problem-based approach
$X_2$ = represents group taught with conventional method (control group)

### Sampling Procedure and Sample

Two states, Lagos and Oyo, out of the six in the southwest educational zone in Nigeria were randomly selected, and two federal government colleges were selected from each state. One single-sex and one coeducational were purposively selected out of a minimum of three in each of the states to make a total of four schools for the study. A male’s only school was selected from one state (Lagos) while a female’s only school was selected from the other state (Oyo). One single-sex and one coeducational school were used as experimental while the other pair served as control. Simple random sampling was again used to get one intact chemistry class each from the participating schools. One male’s only school class of 42 boys, and a coeducational school class of 29 students (16 boys, 13 girls) made up the experimental group, while one female’s only class of 28 students and a coeducational of 25 students (14 boys, 11 girls) participated as the conventional group (control) in their respective schools. These numbers gave an average number of thirty-one students per class.

Table 1 shows a 2 X 2 factorial design of the study with treatment operating at two levels in which there is an experimental group of PBL approach and the conventional method of teaching which served as control. Type of school is also operating at two levels namely single-sex and co-educational.

Table 1
*Factorial Design*

| Treatment | School Type | |
|---|---|---|
| | Single-sex | Co-educational |
| Problem-based approach | 42 | 29 |
| Conventional method of teaching | 28 | 25 |

## Instrumentation and Data Collection

The researchers developed and validated one instrument used for collection of data and two treatment manuals. This instrument is the *Chemistry Manipulative Skill Scale* (CHEMMSS) used for both the pretest and posttest. The two treatment manuals are (a) *Operational Manual of Instruction on Problem-based Learning Approach* (OMIPBLA) and (b) *Operational Manual of Instruction on Conventional Method of Teaching* (OMICMT). Both are defined in *Chemistry Treatment Manual* (CHEMTM)].

**Chemistry Manipulative Skill Scale (CHEMMSS).** The researchers developed this instrument used to measure the knowledge and manipulative abilities of the students towards the use of basic chemistry practical apparatus in the laboratory and understanding of the procedural steps required. The practical aspect of focus is “Introduction to Volumetric Analysis” according to senior secondary school class 2 (SS2) scheme of work for the term. The proctors used the prepared 33-items scale to test the students. A 4-point Likert scale response options of very good (VG), good (G), fairly good (FG), and fair (F) was used. The skills are listed and value scores of 4-1, respectively, were apportioned or awarded for different levels of mastery by the research assistants. The face and content validities of the items were established by having them vetted by experienced chemistry teachers. Further validation was done to ascertain the psychometric properties by trial testing it on 34 SS2 chemistry students of a public secondary school in Surulere, Lagos. Cronbach alpha was used to estimate the reliability coefficient value of 0.87.

**Chemistry Treatment Manual (CHEMTM).** The researchers developed this manual that was used by the research assistants. This manual was meant to ensure conformity of depth of coverage. The categories for application of the instrument are (a) experimental group exposed to problem-based approach; (b) then the control group was taught using the conventional method. The research assistants were the trained chemistry teachers of the intact class randomly selected for treatment in the schools of study along with their respective laboratory attendants. They administered the pretest and posttest manipulative skill scale, which required observations and scoring.

**Operational Manual of Instruction on Problem-Based Learning Approach (OMIPBLA).** This manual prepared by the researchers was to guide the teachers and the students on the various steps applied while using the PBL approach. Because the focus was more on students' participation, the activities they performed were highlighted in an orderly manner and in very explicit language. The OMIPBA was a guide for practical chemistry.

**Operational Manual of Instruction on Conventional Method of Learning (OMICML).** The conventional method is the prevailing and the traditional teaching and learning method known and commonly used by the teachers and students in schools. It involves lecture, talk and chalk, an occasional demonstration because of the experimental nature of chemistry, and students listening and watching.

## Research Procedure

The study lasted for a period of five weeks. The first two weeks were used for the training of research assistants, students’ orientation, and administering of the pretest. The remaining three weeks were used for the treatments, that is, implementing the new approach in the classroom and for posttests immediately after the treatments using the developed instrument – CHEMMSS.

**Training of participating research assistants**. The training was organized to provide step-by-step explanations on the use of the treatment manuals and the learning guides for the treatments as well as the manipulative skill tests. This training was conducted by the researchers for the participants in their respective schools due to the distance between the schools. One week was used for these trainings.

Necessary corrections and amendments were made at this stage in the treatment manuals and learning guides. These changes were majorly with respect to the sequence of some steps and the need for more elaborate descriptions of certain steps. The researchers thus benefited from the experience of the teachers who subsequently served as research assistants. The manipulative skill raters, who were also the monitoring and implementing group of five, were trained together to ensure high interrater reliability, a value of 0.79 was obtained using Cronbach alpha, this indicates uniformity of operation. The same pilot school in Surulere, Lagos was used for this step.

**Data analysis.** The statistical tools used to establish the pretest and posttest mean difference as well as the main effect and the interaction effects of the independent on the dependent variable for this study were descriptive statistics and analysis of covariance (ANCOVA) respectively.

## Results and Discussion

To answer the research question, a pretest and posttest were given to discover the students' achievement in practical chemistry by treatment and by school type. The CHEMMSS had a maximum of 132 points (33 test items with a 4-point Likert scale).

Table 2 shows that PBL group had higher posttest mean score in practical skills (X=110.75) than conventional method group (X=81.47). When the posttest mean scores are compared with corresponding pretest mean scores, the PBL group had higher mean gain practical skill scores 62.96 than conventional method group, which had a mean gain score of 41.77, indicating better learning with PBL approach.

This difference in increased mean scores can be deduced from the submission of Ausubel (1968) that meaningful learning can only take place when a person consciously and explicitly ties new knowledge with relevant concepts or propositions they already possess or are able to discover in the process of trying to solve a problem. This idea provides evidence that the individual has been able to internalize a new stimulus and is reflected in the ability to apply the new knowledge to other situations. In contrast, rote learning (memorisation), which mostly characterises the traditional lecture method of teaching (conventional method) even in practical lessons, only arbitrarily results in new knowledge. This type of new knowledge, which only arises when it is randomly incorporated into the cognitive structure of the students, cannot be applied to relevant new situations. Both groups, however, have higher posttest practical skill mean scores than pretest scores.

Table 2
*Summary of Mean Difference of Students' Practical Skills in Chemistry by Treatment*

| Treatment | n | Pretest | | Posttest | | Mean Gain |
|---|---|---|---|---|---|---|
| | | Mean | *SD* | Mean | *SD* | |
| PBL | 71 | 47.79 | 5.042 | 110.75 | 8.817 | 62.96 |
| Conventional | 53 | 39.70 | 4.213 | 81.47 | 7.347 | 41.77 |

Table 3 reveals that the posttest students' practical skills mean scores in chemistry is higher in single-sex colleges (X=112.28) than those from coeducational colleges with posttest practical skills mean score of 102.55. Also, students from single-sex colleges have a greater mean gain score (63.59) than their coeducational colleges' counterpart with mean gain score of 58.71.

Table 3
*Summary of Mean Difference of Students' Practical Skills in Chemistry by School Type*

| School Type | n | Pretest | | Posttest | | Mean Gain |
|---|---|---|---|---|---|---|
| | | Mean | *SD* | Mean | *SD* | |
| Single-sex | 70 | 48.69 | 5.033 | 112.28 | 7.177 | 63.59 |
| Coeducational | 54 | 43.84 | 5.218 | 102.55 | 19.56 | 58.71 |

**Results and Discussion for $Ho_1$**

Table 4 presents the results of analysis of covariance (ANCOVA) for main effect of treatment (PBL and conventional) approaches on students' practical skills in chemistry. Having adjusted covariate, the results show that there was a significant main effect of learning approaches on students' practical skills in chemistry — $F(2,126) = 211.59$, $p < .05$. The covariate was the pretest score of respective students. The *p* value ($p = .000$) is less than 0.05, so $Ho_1$ (there is no significant main effect of treatment [PBL approach] on students' practical skills in chemistry) is rejected. From the adjusted *R* squared value of 0.814, the independent variable accounted for 81.4% of the variation observed in students' practical skills in chemistry. The partial eta-squared estimated for treatment was 0.708; this shows that treatment (PBL approach) accounted for 70.8% of the variance observed in students' practical skills in chemistry.

These results are similar to those found in the exploration stage biological science curriculum study (BSCS) model of five "E's" (engage, explore, explain, elaborate, and evaluate), which revealed the advantage of the students having the opportunity to get directly involved with the phenomena and materials during the practical application process (BSCS & IBM, 1989). From the modified description of 5E phases, the exploration phase involves students in exploring objects, observing, identifying variables, and establishing relationships. The teacher at this stage serves as the facilitator (Bybee et al., 2006). The process of taking students through the PBL approach to acquire practical skills in chemistry in general can be likened to engaging, exploring, explaining, elaborating, and evaluating as they interact with the teaching-learning materials, the teacher and among themselves. Involving students in these activities makes them to develop a grounding of experience with the phenomenon and as they work together in teams, they build a base of common experience which assists them in the process of sharing and communicating for better performance.

Table 4
*Analysis of Covariance (ANCOVA) of Posttest Mean Score of Students' Practical Skills in Chemistry by Treatment and School Type*

| Source of Variation | Type III Sum of Squares | *df* | *MS* | *F* | *P*-Value | Eta-Squared |
|---|---|---|---|---|---|---|
| Corrected Model | 8386.992 | 3 | 2795.664 | 68.859 | .000 | .826 |
| Intercept | 17578.186 | 1 | 17578.186 | 432.963 | .000 | .623 |
| Pre-Practical Skills | 664.571 | 1 | 664.571 | 16.369 | .000 | .059 |
| Treatment | 8590.552 | 1 | 8590.552 | 211.591 | .000 | .708 |
| School Type | 1554.625 | 1 | 1554.625 | 38.292 | .000 | .128 |
| Treatment & School Type | 342.004 | 1 | 342.004 | 8.424 | .004 | .031 |
| Errors | 5115.600 | 126 | 40.600 | | | |
| Total | 33420.000 | 124 | | | | |
| Corrected Total | 6095.981 | 123 | | | | |

Note: $R^2$ = 0.789 (Adjusted $R^2$ = 0.814)
p < .05

The above results imply that the treatment improved the students' practical skills in chemistry with PBL approach showing a more pronounced contribution to this improvement on the students' practical skills. The reason could be because during the intervention, while in their groups, the students were allowed to use the chemistry practical apparatus individually up to the point of mastery. This practice boosted their confidence and interest; the result of which showed in their improved performance in practical chemistry posttest scores. Because the students were allowed to use the apparatus to carry out the practical instructions long enough and given ample opportunity to practice with them, they developed some characteristic expertise in operating them, making it easier for the students to use during chemistry practical tests/examinations. On the other hand, the results also address and solve the problem expressed by the chief examiners reports of NECO and WAEC (2004-2006), which state that students do not have a firm grip of the use of chemistry practical apparatuses and cannot relate them to their functions. The skill they now acquired would then enable them to use any of those apparatus or a related one anywhere anytime.

The result also reflects the findings of Hmelo-Silver (2004) and Hmelo-Silver and Barrows (2006), which emphasized the monitoring duty of the facilitator (chemistry teacher) to ensure that all students are involved and encourage them to externalize their own thinking and to comment on each other's thinking concerning their discoveries. The teachers' effective monitoring during the treatment sessions resulted in this improved performance in practical chemistry.

**Results and Discussion for $Ho_2$**

Table 3 shows that students from single-sex colleges had higher mean gain score (X=63.59) in practical skills in chemistry compared to their co-educational counterparts with mean gain practical skills score of (X = 58.71). This result implies that students from single-sex colleges are better in chemistry practical skills in chemistry $F(1,126) = 38.29$, $p < .05$. In view of this result, hypothesis $Ho_2$ (there is no significant main effect of school type on students' practical skills in chemistry) was rejected because school type has significant main effect on students' practical skills in chemistry. The partial eta-square value of 0.128 indicates that school type accounted for 12.8%

of the variance observed in the posttest students' practical skills in chemistry which was significant enough to make a difference.

Further analysis of the result revealed that students from single-sex colleges had higher mean gain scores in practical skills in chemistry than their counterparts in coeducational colleges, meaning that they performed better in practical skills than the students from coeducational colleges after the treatment. The reason could be that of gender sensitivity where female students in coeducational colleges are less active in their heterogeneous group leaving the male students to do most of the practical works, thereby slowing down the activity rate which may lead to incomplete exercise consequent to slow perception and low scores. Whereas, in a single-sex school there is no such gender sensitivity; everyone is there on his or her own right for the chemistry practical and participate fully at every stage of the exercise. This full and unreserved participation leads to better performance in practical skills in chemistry in a single-sex school shown in the result above. So, chemistry teachers in single-sex colleges can freely use the PBL approach to teach practical chemistry for a more positive response, irrespective of being boys only or girls only school.

## Results and Discussion for $Ho_3$

Table 4 shows that there is significant interaction effect of treatment (PBL and Conventional) approaches and school type (single-sex and coeducational) on students' practical skills in chemistry $F(1,126) = 8.42$, $p < .05$. $Ho_3$ (there is no significant interaction effect of treatment and school type on students' practical skills in chemistry) is then rejected. This result depicts that school type (single-sex or coeducational) of students has effect on the treatments (learning approaches) used in this study. Chemistry teachers could use the learning approaches by considering the type of school, whether single-sex or coeducational, for greater effectiveness. This result is also in agreement with the study of the British Office for Standards in Education (OFSTED, 1998) whose studies also found that students in single-sex schools have a significantly more positive attitude towards manipulative skills than their coeducation counterpart.

## Conclusion and Recommendations

The findings of this study show the following implications in the teaching and learning of practical chemistry in federal government colleges in Nigeria. The positive effects of PBL approach on students' practical skills in chemistry is an indication that learning takes place easier and better when a problem is used as a starting point for new knowledge. Students learn better when given opportunity to interact among themselves in small groups, and when learning topics are structured to solve real life problems, students find it easier to relate apparatus with functions and theory with practice in practical chemistry. Furthermore, because they worked in groups and the teacher acted as a facilitator, students freely expressed their fears and ignorance to their fellow students and then by exchange of knowledge, they helped one another to understand better. Studying becomes a cooperative affair and learning is facilitated and internalized. This structure yields more encouraging learning outcomes for the students.

The study also reveals that school type, specifically single-sex colleges benefit more on practical skills after being exposed to the PBL approach. This result is an indication that single-sex arrangement has the ability to instil high levels of self confidence in their students, making them participate fully in practical chemistry, irrespective of the sex, either boys only or girls only than the coeducational colleges. Consequently, chemistry teachers in coeducational colleges using this PBL approach should motivate and encourage their students well enough during practical chemistry for a positive response. The society is made up of both male and female students who are ready to acquire similar knowledge and skills from various learning experiences provided by school; school counsellors should therefore be around to guide in this direction.

## References

Adeagbo, J. C. (2004). *Educational challenges in a gender-sensitive environment: The way out*. (Unpublished doctoral thesis). University of Nigeria Nsukka, Nsukka, Nigeria.

Adesoji, F. A., & Olatunmbosun, S. M. (2008). Student, teacher and school environment factors as determinants of achievement in senior secondary school chemistry in Oyo state, Nigeria. *The Journal of International Social Research, 1/2*(Winter), 13–34.

Adewale, J. G. (2002). Modern trends in physics teaching at secondary school level. In S. O. Ayodele (Ed.), *Teaching strategies for Nigerian secondary schools* (pp. 230–241). Ibadan, Nigeria: Powerhouse Press and Publishers.

Adewunmi, M. B. (2006). *Science education: The bedrock to realistic, scientific and technological development in Nigeria*. Paper presented at the 47th Annual Conference of Science Teachers Association of Nigeria.

Adeyinka, N. B. (2005). *Gender, location and class size as determinants of instructional needs among secondary school teachers in Nigeria* (Unpublished doctoral thesis). University of Lagos, Akoka, Nigeria.

Akinoglu, O., & Tandogan, R. O. (2007). The effects of problem-based active learning in science education on students' academic achievement, attitude and concept learning. *Eurasia Journal of Mathematics, Science & Technology Education, 3*(1), 71–81.

Akinola, A. B. (2007). *Scholastic aptitude and study habit as predictor of achievements in chemistry among selected secondary school students in Agege* (Unpublished doctoral thesis). University of Lagos, Akoka, Nigeria.

Akuche, E. U. (2007). Effects of three instructional strategies on students' learning outcomes in practical physics. (Unpublished doctoral thesis). University of lbadan, Ibadan, Nigeria.

Ausubel, D. P. (1968). *Educational psychology: A cognitive view*. New York: Holt. Rinehart, and Winston.

BSCS and IBM. (1989). *New designs for elementary science and health: A cooperative project between Biological Sciences Curriculum Study (BSCS) and International Business Machines (IBM).* Dubuque, IA: Kendall/Hunt Publishing Company.

Butler, D. (2000). Gender, girls, and computer technology: What's the status now? *Clearing House, 73*(4), 225–230.

Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (2006). *The BSCS 5E instructional model: Origins and effectiveness.* Colorado Springs, Co: *BSCS, 5*, 88–98. Retrieved from https://bscs.org/sites/default/files/_media/about/downloads/BSCS_5E_Full_Report.pdf

Chanlin, L. J. (2001). The effects of gender and presentation format in computer-based learning. *Educational Media International*, *38*(1), 61–65.

Chukwuka, L. (2006). Counselling children with special needs in an inclusive classroom setting. *Journal of Counselling Psychology, 9*(8), 33–36.

Collins, C.W., McLeod, J. and Kenway, J., 2000. Factors influencing the educational performance of males and females in school and their initial destinations after leaving school Canberra: Department of Education, Training and Youth Affairs.

Dochy, F., Segers, M., Van den Bossche, P., & Giejbels, D. (2003). Effects of problem-based learning: A meta-analysis. *Learning and Instruction*, *13*, 533–568.

Ezeasor, M. E. N. (2003). *School environment and teacher effectiveness as determinants of student achievement in biology: A case study of selected secondary schools in Ibadan.* (Unpublished doctoral thesis). University of lbadan, Ibadan, Nigeria.

Federal Republic Nigeria [FRN]. (2013). *National Policy on Education* (6th ed., revised). Abuja, Nigeria: Federal Ministry of Education.

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review*, *16*(3), 235–266. doi: 10.1023/B:EDPR.0000034022.16470.f3

Hmelo-Silver, C. E., & Barrows, H. S. (2006). Goals and strategies of a problem-based learning facilitator. *The Interdisciplinary Journal of Problem-based Learning*, *1*(1), 21–39. doi: 10.7771/1541-5015.1004

Mbah, P. E. (2003). *Effects of two teaching methods, personal and social factors on JSS I home economic students' academic performance in selected secondary schools in Lagos state.* (Unpublished doctoral thesis). University of Benin, Benin City, Nigeria.

Mulholland, J., Hansen, P., & Kaminski, E. (2004). Do single-gender classrooms in coeducational settings address boys' underachievement?: An Australian study. *Education Studies*, *30*(1), 19–32.

Office for Standards of Education. (1998). The annual report of Her Majesty's chief inspector of schools - standards and quality in education 1997/98. [Online]. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/265506/129.pdf

Onuebunwa, B. N. (2000). Gender barriers, challenges and opportunities in technical and scientific advancement: A challenge to women in the 21st century. *Journal of Women in Colleges of Education, 4*, 159–163.

Orji, A. B. (1998). *Effect of problem-solving and concept mapping instructional strategies on students' learning outcomes in physics.* (Unpublished doctoral thesis). University of lbadan, Ibadan, Nigeria.

Osokoya, M. M. (2015, January 30). *Comparative assessment of practical test in selected O-level chemistry examination.* A paper presented at the WAEC monthly seminar held at WAEC International WAEC International Office, Lagos. Published by the West African Examination Council.

Osokoya, M. M., & Opateye, J. A. (2009). Action-based testing and test anxiety as determinants of secondary school students' achievement in electrochemistry. *Journal of the Science Teachers Association of Nigeria, 44*(1&2), 42–49.

Paige, J. B., & Smith, R. O. (2013). Nurse faculty experiences in problem-based learning: An interpretative phenomenologic analysis. *Nursing Education Perspective*, *34*(4) 233–238.

Sikiru, V. C. (2004). *Discovering the students' major difficult areas in senior secondary school certificate chemistry: A case study of selected private secondary schools in Nsukka*. (Unpublished doctoral thesis). University of Nigeria Nsukka, Nsukka, Nigeria.

Tatarinceva, A. (2005). *The relationship among a student's learning style and achievement in foreign language learning.* (Unpublished doctoral dissertation). University of Latvia, Riga, Latvia.

Vasconcelos, S. C. (2010). Teaching environmental education through PBL: Evaluation of a teaching intervention program**.** *Research in Science Education, 42*(2), 219–232. doi: 10.1007/s11165-010-9192-3

Vernon, D. T., & Blake, R. L. (1993). Does problem-based learning work? A meta-analysis of evaluative research. *Academic Medicine, 68*(7), 550–563.

Webb, L., & Macdonald, D. (2007). Dualing with gender: Teachers' work, careers and leadership in physical education. *Gender and Education*, *19*(4), 491–512. doi: 10.1080/ 09540250701442674

West African Examination Council (2013): Chief Examiners' Report.

West African Examination Council (2014): Chief Examiners' Report.

## Authors

**Modupe M. Osokoya,** Ph.D., is a reader (associate professor) in the Institute of Education, University of Ibadan, Ibadan, Nigeria. Her research interest is on assessment of factors relating to students' achievement in science, curriculum development, and evaluation of educational programmes.

**Chinwe C. Nwazota,** Ph.D., is a lecturer in educational management at Saint Augustine's College of Education, Akoka, Lagos, and vice-principal with the Federal Ministry of Education, Abuja, Nigeria. Her field of interest is on how teaching/learning can be enhanced for outstanding performances by the learner.