# Pedagogic Transformation: Blending of Reinforcement and Inquiry Learning in Innovative Science as Resilience Technique

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## ABSTRACT

In this paper, blending reinforcement and inquiry learning in innovative science (technological approaches) as resilience technique was presented. The study was designed to determine the effectiveness of these innovative approaches in improving students' performance. The views about reinforcement and inquiry methods were used as data collection instrument. To this end two research questions were raised and two research hypotheses were formulated to answer the research questions. The study adopted the quasi-experimental design of pre-test post-test non-equivalent control groups. Sixty 100Level undergraduate students of National Open University of Nigeria (NOUN) were used. After four weeks of online facilitation of quantitative and qualitative techniques, acid-base reaction and determination of radicals, a-20 item questions which was well validated and had reliability coefficient of 0.80 were administered to the students before and after application of the teaching strategies on the students. After that the students were reinforced and tested with the same questions. Mean, Standard Deviation and t.test were the statistical tools used to analysis the data. The result of the study shows that students with the blend of guided inquiry and reinforcement learning performed significantly well than students with only guided inquiry learning. In addition, the types of degree (BSc/BSc. (Ed.)) has significant influence on students' performance in favour of BSc. Students. Based on the findings of this study, it was recommended among others that university lecturers should be encouraged to blend guided inquiry with reinforcement as a teaching method in delivery of their lessons especially in the teaching of some concepts in chemistry.

Keywords: chemistry, guided inquiry, Academic performance, Reinforcement, Blended learning

## Introduction

Science and technology in the 21st century have witness rapid scientific innovation and technological advancements that have been the key factor in national economic, education, culture and politics. Abdullahi (2007) argued that the development of any society depends on its scientific and technological achievements. Therefore, there is need for learning of science to adequately prepare our students for 21st century skills to overcome challenges and be able to participate in and contribute to national development.

The concept of innovative science has its root from three perspective of the definition of innovation. Innovation as a concept by itself can be viewed from three dimensions-- product, process, and application; first and most common is when viewed as a product, that is when it refers to the "locus" of innovation- an object of analysis to be improved through innovative activity. Second, when viewed as process, that is from cognitive frame, of which it implies a facilitator to the comprehension of conditions and actions that

lead to innovation. Third, when viewed from application dimension, which is as used in educational settings, business environment, and non-profit motivated pursuits. The first dimension has shifted overtime from product centred that is the placing of importance on ‘‘solution’’ novelty and differentiation to study of ‘‘problems’’ and focus on ‘‘users’’. For example, product innovation to multipurpose technology or user centered design. The second dimension on the other hand equally shifted from the perspective of differentiation between nature and nurture to the study of heuristics and to formalized discipline of creativity.

The definition of innovation in relation to the teaching and learning of basic science involves the combination of the first two dimensions, thus, defining innovation to be specific approaches to finding solution to problem with emphasis on scientific method and emergent thinking. In line with this definition, ‘‘Innovative science’’ implies science relating to what is referred to as ‘‘Core sciences’’ such as Biology, Chemistry, Computer science, Mathematics, Physics and their related fields.

There are two major factors that influence the teaching learning of innovative science-based courses.

(1) influence based on the three main paradigms of educational pedagogy- behaviorism, cognitivism, and constructivism;

(2) influence due to the digitalization of education.

Teaching-Learning Method based on Educational Paradigms

Learning theories developed in the three psychological paradigms explaining how children acquire skills and knowledge have been adopted by teachers in the teaching of science courses. Behaviourism paradigm’s focus was on observable hahavior, therefore, learning was defined in line with acquisition of new behavior based on environmental conditions. This paradigm gave priority to practice as a tool to ensuring knowledge acquisition as against higher- order skills like understanding, interpretation and application, thus promoted remedial instruction.

Cognitivism focuses on organization and adaptation-in learning. Organization implies that all cognitive structures are interrelated, and that new knowledge must be fitted into the existing system. Adaptation on the other hand implies organism’s ability to fit into its environment in ways that promote survival. This led to the four-stage model of development- sensory motor stage (0-2 years), pre-operational stage (2-7 years), concrete operational stage (7-11 years), and formal operational stage (11 years and above). Therefore, the paradigm theories implores teachers to make knowledge meaningful and help learners organize new information in s/he cognitive schema. Among the strategies of cognitive theories are use of mapping and advanced organizers and use of analogies and metaphors. The method of teaching-learning of science under this paradigm are Activity-based teaching and Inquiry method of teaching-learning. The activity-based teaching was focused on developing laboratory skills so that students can design and perform experiments individually. The inquiry method focuses on creating puzzling situations for students to start enquiring. Further, students are allowed or encourage to engage in self-learning rather than being given answers by their teachers, and teachers interacting closely with the students to assist in analyzing their inquiry strategies a and find answers to their questions.

The inquiry method as a mode of teaching favours greatly the teaching of science because of the abstract nature of the subject matters that require asking questions and pondering about natural phenomena.

Constructivism as educational paradigm focuses on that knowledge is constructed through personal experiences and interaction with the environment. It therefore views the learner as a constructor of knowledge and the teacher as the facilitator of the constructed knowledge. Constructivism is divided into two: Social constructivism- this takes the socio-cultural context into account and advocate teacher-pupil interaction as an important aspect of learning and Cognitive constructivism- in which knowledge is considered to be constructed by assimilation or accommodation. For assimilation, incoming information does not match the existing schema, it therefore changes to accommodate this effect. As a whole, constructivism is recommended when students take control of learning situation. For example in problem-based learning

Digitaliztion of Education as an influence on teaching learning method

The advancement in digital technology have greatly impacted teaching –learning of science coursesespecially in the way learners make meaning of information available to them. This include the switch to virtual classroom via zoom as replacement to conventional face-to-face classroom.

All the changes in teaching-learning methods resulting due to the influences aforementioned, have forced educationists to quest for appropriate teaching learning method to be adopted in different situation. In view of this, the study looks into devising the appropriate teaching –learning method to be adopted in circumstance of unpredicted event as a resilience strategy for teaching-learning of innovative science courses.

Digital education is otherwise termed Technology Enhanced Learning (TEL), e-learning, or digital learning and involves use of modern technology in teaching-learning. Example include use of virtual classroom like zoom, and online teaching. Although the concept has been in existence but became more pronounced with the natural phenomenon of COVID 19. During the pandemic, the face-to-face teaching-learning was replaced with digital education, thus replacing traditional education process of talk and chalk. The use of zoom and online asynchronous learning via internet is therefore a combination of technology, innovative learning and digital content. among the advantages of digital education are: promotion of individualized learning experience, students becoming smarter, unlimited information, smart classrooms, Digitally Updated and high engagement learning, ease of sharing, accountability in students. All these advantages notwithstanding, digital education has its limitations that makes it not too adequate for the teaching-learning of innovative science. Among these limitations are: creation of a sense of isolation, self-discipline requirement, requirement of additional training for instructors, being prone to technical issues. All these limitations impede on teaching-learning of innovative science by virtue of its abstractness. Thus, the need to quest into better teaching-learning techniques via digital education to serve as resilience technique for innovative science teaching-learning.

The pandemic event changed drastically everything including teaching-learning, with the lockdown and stay at home, teaching-learning shifted from block and mortal classroom system to pure online based system. This shift, which was sudden and without prior knowledge serves as the resilience technique for education system. It serves as resilience because resilience implies ability to continue to function or operate as effectively as before a change (Raghunathan , Singh & Sharma, 2022). Though, digital education was a resilient for education as a whole, but has limitation as resilient for innovative science because of its abstractness as earlier explained. In view of this, the present study looks into complementary resilience technique (using blended pedagogic approach) for teaching-learning of innovative science amidst the limitations of the general education resilience technique-Online/digital education.

The rating of the effectiveness of different teaching/leaning methods is determined using students' academic performance. Students' academic performance is the extent to which students achieve their short or long-term educational goals. This is commonly measured through external or internal examination as well as continuous assessment in form of tests, assignments, projects, debates, practical as well as term papers. Two forms of evaluations are used to assess students' academic performance: formative and summative evaluations. Continuous assessment is a form of formative evaluation = provides early indications of the performance of students. Continuous assessment - provides students with information that can be used to improve their academic achievement.

Among innovative science courses chemistry subject matters are abstract and requires special resilience technique. Teague (2016) asserts that chemistry is a content driven subject and is an accepted body of knowledge, often recommended to be taught using discovery/inquiry method of teaching/learning. The inquiry method involves structured or unstructured exploration of chemistry subject matters involving mental processes such as observing, measuring, classifying, hypothesizing, etc. It encourages independence and aids retention, recall and transfer of knowledge is facilitated. Despite the aforementioned advantages of inquiry method, it has limitation if is to serve as a teaching/learning method for resilience situation. The abstract nature of chemistry subject matter discourages students from reading except when compelled. During unforeseen circumstances requiring resilience learners need to learn all alone, and by this, often neglect the learning of innovative science course due to lack of compelling on the part of the teacher. Dienye and Gbamanja (1990) in Nwanekezi and Arokoyu (2014) defines guided inquiry as a teaching method whereby the teacher asks the students to formulate problem for investigation, state the purpose, design experiment, predict results, identify procedures to collect data and to perform the investigation as well as study to learn from the activities.

As a result of the limitation of recommended pedagogic teaching/learning method of science, it is viewed that a pedagogic transformation involving the blending of two pedagogic methods could serve better as resilience technique for education. The pedagogic transformation could be a blending of constructivism and behaviourism methods, cognitivism and constructivism methods or a blend of any of pedagogic method with digital education. We view a combination of inquiry

and reinforcement methods would be a better resilience technique for innovative science education.

Reinforcement method is a behavioural psychology, which when applied strengthen an organism's future behaviour. Reinforcement as an operant conditioning term refers to anything that increases the likelihood that a response will occur. Examples of reinforcement indication include praise, scores in form of marks, token rewards and fun activities. It could be positive or negative, and by positive it implies timely encouragement which is gentle and effective at the same time. The actions and inactions of a teacher can make or mar the academic performance of students by using any of the type of reinforcement. In view of the aforementioned this study intend looking into the use of blending of pedagogical teaching/learning methods combined with digital education. By blending, we mean combining formal classroom methods (e.g., Discussion, Demonstration, Inquiry, Project-based, Reinforcement approaches) with e-learning. This approach has three components: the teacher, online learning materials, and the skills developed during the classroom experience. Although some researchers report that a blended learning approach is more effective (Dowling, Godfrey & Gyles, 2003), others state that it does not change students' understanding of science concepts (Anderson & May, 2010; Larson & Chung-Hsien, 2009). The present study focus on blending Inquiry and Reinforcement learning with technology. This is to encourage teachers and students to think and work on activity-based learning environment in order to develop Pedagogical Content Knowledge for Guided Inquiry and Reinforcement instructions. In view of the aforementioned, this study intend looking into use of blended inquiry, reinforcement and online learning. As an educational resilience technique, we will like to answer the following questions and test the formulated hypotheses.

**Research Questions**

Consequently, to give direction to this investigation the following research questions were posed to guide the study:

The following research questions were posed to guide the study:

1. What are the mean performance scores of students taught chemistry using inquiry method and those taught using online facilitation?
2. To what does the performance of students taught chemistry with guided inquiry and reinforcement learning differ from those taught with online facilitation?
3. What is the difference in academic performance between BSc. degree students taught the concept of chemistry and those of BSc. (Ed.) degree students?

**Null Hypotheses**

The following null hypotheses were formulated and tested at $p \leq 0.05$ level of significance to answer the research questions

$H_{O1}$: There is no significant difference in the mean achievement scores of the students taught chemistry using inquiry learning and those taught using online facilitation.

$H_{O2}$**:** There is no significant difference in the mean achievement scores of the students taught chemistry using inquiry learning/reinforcement learning and those taught using online facilitation.

$H_{O3}$: There is no significant difference in the mean performance scores between BSc. Degree students taught the concepts of chemistry and those taught the same concept for BSc.(Ed.) degree.

**Methodology**

This study adopted the pretest-posttest-post-posttest quasi-experimental-control group design. Sixty, 100 Level undergraduate students. Chemistry students of National Open University of Nigeria, were selected and assigned into two groups, thirty students for experimental group (guided inquiry/reinforcement) and the other thirty students for the control group (online facilitation). Three research questions were raised and three null hypotheses guided the study. After four weeks of the teaching of the chemistry concepts, a test instrument named Chemistry Performance Test (CPT) which is a-20 multiple choice objective test questions which was well validated and had reliability coefficient of 0.80 on Cronbach alpha technique were administered to the students in the two groups before and after the application of the teaching strategies on the two groups. Mean, standard deviation and t-test were the statistical tools used for data analysis. Inquiry and reinforcement were used in teaching the experimental group while the control group was taught the same chemistry concepts using online facilitation method of teaching.

The population of this study consisted of all chemistry undergraduate students of National Open University of Nigeria The total number of students 8206, distributed across Nigeria. A group of students was purposively selected as an experimental group because of the number and mode of education in NOUN.

The number of the subjects is considered adequate and reasonable as the representative of the population considering the design of study.

**Instrumentation**

The (CPT) was developed by the researchers to measure students' performance in chemistry practical and validated by science educators. The performance test (CPT) was based on the stated objectives of the topic selected from the curriculum 100 Level Chemistry undergraduate. Questions related to qualitative and quantitative analyses were adapted from the past question papers and NOUN chemistry course materials to ensure the standard of the questions based on the contents taught in the lesson which were derived from the curriculum. CPT is a-20 item multiple-choice test with one correct answer and three distracters for each set. Each correct response attracts a score of one mark. The students were asked to select the correct option by ticking the letter bearing it. The reliability index of 0.80 was obtained for CPT using Pearson Product Moment Correlation Coefficient (PPMC) statistical technique after a trial testing.

**Administration of Instrument**

The CPT was administered to the experimental and control groups before treatment as pretest. Each of the groups was given the pretest in the first week before the commencement of instruction (treatment). The teaching in both experimental and control groups then commenced which lasted for four consecutive weeks. Blended inquiry and reinforcement teaching method was used for teaching experimental group and the online facilitation method for the control group. In the experimental group the students were allowed to handle the apparatus by themselves which require them to observe or manipulate the apparatus by themselves. The students were allowed to discuss among themselves. At the end of the four weeks, CPT was administered to the experimental and control groups in normal classroom situations as posttest. The posttest was conducted to determine the students' academic performance of chemistry concept. The instrument was administered within one and half hours. The subjects were allowed to peruse the instructions and item statements in order to identify any problem before starting. The researcher and the research assistant went round to assist the subjects in accordance with the instructions. The papers were collected at the end of the test. The test scores for the instrument were recorded and computed, these were used for data analysis.

| Variables | Reinforcement learning | Inquiry learning | Blending (reinforcement and inquiry) | Control (self online learning) |
|---|---|---|---|---|
| Mean | 13.83 | 10.07 | 23.90 | 11.70 |
| SD | 9.97 | 2.01 | 10.74 | 1.82 |
| SE | 1.820 | 0.37 | 1.96 | 0.33 |
| Confident int. | 95.0% (10.11) | 95.0% (9.31) | 95 (19.89) | 95.0% (11.01) |
| t-value | 3.20 | -13.40 | 4.54 | -9.92 |

**Data Analysis**

Research Question 1: What are the mean performance scores of students taught chemistry using Guide inquiry method and those taught using online facilitation?

**Table 1: Results of t-test Analysis of the Posttest Mean Performance Scores of the Experimental and Control Groups**

| Groups | N | $\bar{X}$ | SD | SE | Df | t-value | p-value |
|---|---|---|---|---|---|---|---|
| Inquiry Method | 30 | 10.07 | 2.01 | 0.37 | | -13.40 | |
| | | | | | 29 | | 0.01 |
| Online Facilitation | 30 | 11.70 | 1.82 | 0.33 | | -9.92 | |

*Significant at $p \leq 0.05$

Table 1 shows the mean scores and standard deviation of students in the Inquiry Group and Online Facilitationcontrol groups. The mean achievement scores of the students taught chemistry using Guided Inquiry and those taught using online facilitation were shown in Table 1. The Table shows that the mean performance score of the experimental group ($\bar{X}$=10.07) exposed to Guided Inquiry method is higher than the mean performance score of the control group ($\bar{X}$=11.70) exposed to online facilitation of teaching chemistry. From the result presented, it is evident that students taught with Guided Inquiry method had higher performance score than those taught with the online facilitation. t-test statistics was used for further analysis.

**Null Hypothesis 1:** There is no significant difference in the mean performance scores of the students taught chemistry using Blended inquiry and reinforcement learning and those taught using online facilitation.

To test this hypothesis, the posttest scores for both the experimental and the control groups were analysed using t-test statistics. From Table 1, the p-value of 0.01 is less than 0.05 level of significance set which is an indication that there is a significant difference in the achievement mean scores between the experimental group taught the chemistry concepts using Blended method and the control group taught the same chemistry concepts using online facilitation in favour of the experimental group. Based on this result, the null hypothesis is thus rejected. This result showed that the subjects in the experimental group had significantly higher academic achievement compared to their counterparts in the control group. Blended menthod therefore seems more effective in enhancing the subjects' performance in teaching and learning of stoichiometry than the online facilitation of teaching.

**Research Question 2:** To what does the performance of students taught chemistry with blended inquiry and reinforcement learning differ from those taught with online facilitation?

**Table 2: Results of t-test Analysis of the Posttest Mean Performance Scores of the Experimental and Control Groups**

| Groups | N | $\bar{X}$ | SD | SE | Df | t-value | p-value |
|---|---|---|---|---|---|---|---|

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Experimental Group | 30 | 23.90 | 10.74 | 1.96 | | 4.54 | |
| | | | | | 29 | | 0.01 |
| Control Group | 30 | 11.70 | 1.82 | 0.33 | | -9.92 | |

*Significant at $p \leq 0.05$

Table 2 shows the mean scores and standard deviation of students in the experimental and control groups. The mean achievement scores of the students taught chemistry using Blended Inquiry and Reinforcement and those taught using online facilitation were shown in Table 2. The Table shows that the mean performance score of the experimental group ($\overline{X}$=23.90) exposed to Blended method is higher than the mean performance score of the control group ($\overline{X}$=11.70) exposed to online facilitation of teaching chemistry. From the result presented, it is evident that students taught with Blended method had higher performance score than those taught with the online facilitation. t-test statistics was used for further analysis.

**Null Hypothesis 2:** There is no significant difference in the mean performance scores of the students taught chemistry using inquiry learning/reinforcement learning and those taught using online facilitation.

To test this hypothesis, the posttest scores for both the experimental and the control groups were analysed using t-test statistics. From Table 1, the p-value of 0.01 is less than 0.05 level of significance set which is an indication that there is a significant difference in the achievement mean scores between the experimental group taught the chemistry concepts using Blended method and the control group taught the same chemistry concepts using online facilitation in favour of the experimental group. Based on this result, the null hypothesis is thus rejected. This result showed that the subjects in the experimental group had significantly higher academic achievement compared to their counterparts in the control group. Blended menthod therefore seems more effective in enhancing the subjects' performance in teaching and learning of stoichiometry than the online facilitation of teaching.

Research Question 3: What is the difference in academic performance between BSc. degree students taught the concept of chemistry and those of BSc. (Ed.) degree students?

**Table 3: Results of t-test Analysis of the Posttest Mean Performance Scores of the BSc. Degree and BSc. (Ed.) Degree**

| Groups | N | $\overline{X}$ | SD | SE | Df | t-value | p-value |
|---|---|---|---|---|---|---|---|
| BSc. Degree | 20 | 13.83 | 9.97 | 1.82 | | 3.20 | |
| | | | | | 29 | | 0.01 |

| | | | | | |
|---|---|---|---|---|---|
| BSc.(Ed.) Degree | 10 | 10.07 | 2.01 | 0.37 | -13.40 |

*Significant at $p \leq 0.05$

Table 3 shows the mean scores and standard deviation of students in the experimental and control groups. The mean achievement scores of the students taught chemistry using Blended method and those taught using Online Facilitation method were shown in Table 3. The Table shows that the mean achievement score of the experimental group ($\overline{X}$=13.83) exposed to Blended is higher than the mean achievement score of the control group ($\overline{X}$=10.07) exposed to Online method of teaching chemistry. From the result presented, it is evident that students taught with Blended had higher achievement score than those taught with the Online method. t-test statistics was used for further analysis.

**Null Hypothesis 3:** There is no significant difference in the mean performance scores between BSc. Degree students taught the concepts of chemistry and those taught the same concept for BSc.(Ed.) degree

To test this hypothesis, the posttest scores for both the experimental and the control groups were analysed using t-test statistics. From Table 1, the p-value of 0.01 is less than 0.05 level of significance set which is an indication that there is a significant difference in the achievement mean scores between the experimental group taught the chemistry concepts using Blended and the control group taught the same chemistry concepts using online method in favour of the experimental group. Based on this result, the null hypothesis is thus rejected. This result showed that the subjects in the experimental group had significantly higher academic achievement compared to their counterparts in the control group. Blended therefore seems more effective in enhancing the subjects' achievement in teaching and learning of stoichiometry than the online method of teaching.

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**Discussion of Findings**

Teachers of science often complain that students are unable to understand emerging queries, think critically, ask good questions, or analyze scientific knowledge. Despite these challenges among students, teaching science by blending inquiry and reinforcement can help effectively develop

21st-century skills, such as critical thinking, collaboration, creativity, problem solving, and productivity, and improve students' views of practical chemistry.
Based on the findings above, blended inquiry and reinforcement instruction can improve not only science teachers' knowledge of science more than traditional science instruction but also their PCK for teaching science. These findings confirm those of previous studies (Gibson & Chase, 2002; Marincovich, 2000; Shimoda et al., 2002; Welch et al., 1981)
that showed that blended PBL and HOS approaches can enhance teachers' affective domains of learning and help them ably transfer these domains to their classroom practices to make their students scientifically literate in terms of 21st-century skills (Bransford, Brown, & Cocking, 2000; Sandoval & Reiser, 2004).

The findings of this study revealed that blending inquiry and reinforcement learning has significant effect on students' performance. Students who were reinforced positively performed better than those taught using online facilitation. The findings of this study are also consistent with earlier studies of

The result of this study however, contradicts the conclusion of

## CONCLUSION AND RECOMMENDATION

The study investigated Chemistry by guided inquiry and students' academic performance in National Open University of Nigeria (NOUN). Guided inquiry and Reinforcement learning is a learner centered strategy where the teacher helps the learner to develop their cognitive and psychomotor abilities. It is a constructive instructional design model that combines principles from discovery learning and radical constructivism with the principles from cognitivist instructional design theory. The study reveals that guided inquiry method is more effective than online facilitation teaching and learning method in undergraduate students understanding of the Practical Chemistry which leads to attainment of academic performance. In addition, the degrees of study do influence students' performance and understanding of practical Chemistry. It is therefore recommended that:

- Guided inquiry should be adopted by university lecturers in delivery their lessons especially in the teaching of concepts such as qualitative and quantitative analyses.
- The curriculum contents of the B.Sc.Ed degree programme should be enriched by curriculum planners with themes and concepts that promote the study of Chemistry in all its ramifications.
- Teachers should be encouraged to blend methods of classroom instructions. Blende learning is still a novelty in schools in Nigeria.
- Inquiry and Reinforcement Learning should, therefore be incorporated into the main stream of pedagogy in the teaching of chemistry in institutions of higher learning.

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