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Comparative Effect of Three Instructional Strategies on Pre-Service Teachers' Learning Outcomes in Chemistry Practical in Niger State, Nigeria

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ABSTRACT

Chemistry is an activity-oriented subject; however, students' achievement over the years has remained unsatisfactory. Among the factors responsible for poor performance is the use of ineffective instructional strategies. This study examined the effects of guided inquiry (GI), guided inquiry with demonstration (GID), and lecture-demonstration (LD) on pre-service teachers' cognitive attainment and practical skills acquisition in stoichiometry and chemical reactions. A quasi-experimental design was adopted. A total of 300 pre-service teachers were purposively selected from chemistry and integrated science departments and assigned to two experimental and control groups. Data were collected using the Test of Cognitive Attainment (TCA) and Test of Practical Skills (TPS). Reliability coefficients of 0.73 and 0.69 were obtained, respectively. Data were analysed using means, standard deviations, t-tests, and one-way ANOVA. Findings revealed that both GI and GID significantly improved students' cognitive attainment and practical skills compared to LD. GID produced the highest gains in practical skills acquisition. The study recommends the adoption of inquiry-based instructional strategies in chemistry teaching

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INTRODUCTION

Chemistry science is regarded among senior secondary school subjects in Nigeria as one which requires intellectual skills to collect data for analysis in order to solve problems. Science process skills therefore act as requisites for integrated processes taught in the subject. Like other science disciplines, practical work in Chemistry has become the nucleus of its Curriculum reform initiative as observed by Gott and Duggan (2007: 271) worldwide. The inclusion of practical component in Chemistry curriculum stemmed from the acknowledgement that practical skills are reliably pivotal to learning Chemistry which inculcates critical competencies in students as activity-oriented subject. In sustained effort to maximize gains in the learning of Chemistry, pre-service teachers training programmes are provided at Colleges of Education as well as Education faculty in the Universities in Nigeria.

A number of instructional approaches have been proposed by educators to be adopted singly or integrated for effective curriculum contents delivery. Such approaches employed by teachers in presenting scientific knowledge and skills include conventional lecture, laboratory work, demonstration, guided discovery and inquiry, discussion, project, field trip, concept mapping and game-based methods among others. Proliferation of approaches notwithstanding, specifics is germane for mental recognition and cognitive attainment of pre-service teachers in stoichiometry and chemical reactions of practical Chemistry. Since stoichiometry requires the application of quantitative ability, it demands the use of problem-solving approach in the teaching and learning of the concept in Chemistry.

To achieve successful preparation of pre-service teachers who are to expose Secondary school learners to the fundamentals of the subject, guided discovery has been recommended by Upahi (2015) as one out of many competing instructional approaches to be explored by teachers. Three types of inquiry studies have been stated as guided-inquiry, less structure guided inquiry and free inquiry (Carin, 1993) as cited in Asnidar, Khabibah and Sulaiman (2018). An aspect of practical activity in the curriculum lays sentimental emphasis on the exploitation of local resources; this according to Yusuf (2015) is meant for students to imbibe the spirit of enquiry

in his or her use of multiple representations in the understanding of chemical concepts. Others like Akuche (2008) contrasted the effect of guided inquiry and demonstration strategies in Physics classes while cooperative instructional methods were investigated by Abdulwahab, Oyelekan and Olorundare (2016).

Guided inquiry is viewed as the use of series of structured, sequential scientific investigation which integrate appropriate processes and information chosen through research to fashion meaningful experiences tor students (Davis, 2005 as cited in Osokoya, 2017). Guided-inquiry method of teaching as advocated by Gialamas, Cherif, Keller and Hansen (2001) promotes students' active participation in the leaning process. The use of inquiry-based learning according to Camenzuli and Buhagiar (2014) in Mathematics class indicated that students benefited in facial, social, emotional and behavioural difficulties through a number of ways. While Arends (2012) viewed inquiry learning as a model of instruction that has been developed for the purpose of teaching students how to think. Sanjaya (2014) viewed inquiry learning model as a series of learning activities that emphasize the thinking process of searching and finding answers to a questionable problem.

Demonstration method as revealed in the study of Buncick, Bettes and Horgan (2001) is effective in capturing students' attention and as such can be used to stretch the cognitive spectrum of learners. It is a method that involves illustrating a point in a lesson by means or something other than routine visual aids or other means of instruction (Ahmad, Muhamad, Naji & Avi, 2017). Relating demonstration to Chemistry teaching Taylor (1985) opined that demonstration in chemistry is a pedagogical event whose objective is for illustrating a scientific concept.

To substantiate these views Osokoya (2017) established that demonstration involves a display to students how to carry out a specific activity; it could as well be to illustrate a scientific principle in a lecture by other means different from the conventional visual-aid apparatus. In an effort to keep the pace of achieving educational objectives despite incongruence of resources and students ever daily population increase, demonstration is not only necessary but a better resort. The use of demonstration in Chemistry classroom has been discussed many times in literature (Thompson & Soyibo, 2002). Price and Brooks (2012) and Odom and Bell (2015) have maintained that "although lecture demonstrations have been conducted in Chemistry classrooms for a long time, little research exists that documents the frequency that such demonstrations are employed or their effect on learners' motivation and performance.

Educationally, the place of theoretical framework in selecting a mixture of instructional strategies to impact knowledge is crucial. Bruner's theory of instruction which hinges on the fact that learning is an active process in which learners construct new 1deas based on their past or current knowledge was adapted. From the constructivist point of view, this theory provides avenue for learners to select and transform information, construct hypotheses, and make decisions, relying much on a cognitive structure to do so (Arowolo, 2012). The theory is of three components viz: enactive (learning through practice); iconic (learning through visualization of image or picture) and symbolic (acquiring knowledge through the use of language).

Literature has it on record that numerous moderator variables contributed in no small measure to the effect of independent variables on dependent variables. Studies have it that family background, home environment; parental socio-economic factors and the like affect academic achievement of learners. The gender of pre-service teachers in pre-service training programme is considered in this study as critical for cognitive attainment and practical skills acquisition in practical Chemistry. It is vital for pre-service teachers to develop deep knowledge of whatever content area of their field of study: just as courses about pedagogy are equally vital. Such course as spelt out by UNESCO (2013) are most effective when teacher educators demonstrate and implement varied pedagogical approaches in the course rather than merely lecture about Pedagogy. In addition, teachers' development of academic content related fluency in the 1anguage of instruction is very important, and might vary according to gender.

Similarly, in education for entrepreneurship, a variety of approaches and pedagogical methods are applied in other to transmit useful knowledge to individuals and help them to develop entrepreneurial skills, aptitudes, attitudes and wisdom. Therefore, the focus on experimental learning and action oriented educational practices is necessary to foster entrepreneurial thinking and behavior (Jain., Jain, & Jain, 2017).

THEORETICAL FRAMEWORK

The theoretical framework for this study is grounded in several key educational theories that inform teaching methodologies and address the learning dynamics in chemistry education. The constructivist theory posits that learners construct their own understanding and knowledge of the world, through experiencing things and reflecting on those experiences. In the context of chemistry education, guided inquiry approaches allow students to build on their prior knowledge actively, fostering a deeper understanding of complex concepts, such as stoichiometry and chemical reactions. The work of Piaget and Vygotsky highlights the importance of social interactions and collaborative learning, which align with the collaborative nature of guided inquiry. Also, the Experiential Learning Theory developed by Kolb, emphasizes learning through experience, suggesting that concrete experiences followed by reflective observation improve learning outcomes. The use of both guided inquiry and demonstration as teaching strategies encourages students to engage in hands-on experiments, thereby enhancing their practical skills. Proponents of this theory emphasize the role of experimentation and feedback in the learning process, making it particularly relevant for practical chemistry.

In addition, Sweller's cognitive load theory helps to explain how the complexity of information affects learning outcomes. When students are exposed to demonstration while learning conventional methods, their cognitive load can become overwhelming. In contrast, guided inquiry methods may provide structured support that reduces cognitive overload, allowing students to focus on critical concepts without unnecessary distraction. This study investigates how different instructional strategies can optimize cognitive processing and, consequently, improve learning outcomes.

Building on Vygotsky's ideas, social constructivism emphasizes the significance of social interaction in learning. The collaborative nature of guided inquiry promotes discussion among peers, enhancing understanding through shared insights. By engaging students in discussions and cooperative learning, this framework posits that students are better able to internalize knowledge and develop essential skills in a social context. This theoretical framework supports the investigation into how different teaching strategies influence cognitive attainment and practical skills acquisition in chemistry. By integrating elements from these educational theories, the study aims to highlight the significance of instructional strategies in enhancing learning outcomes for pre-service teachers. Overall, the relationships among these theories provide a comprehensive backdrop to understand the implications of guided inquiry and demonstration methods within the context of chemistry education, guiding the research questions and methodology employed in this study.

STATEMENT OF THE PROBLEM

The researcher has taught pre-service teachers practical Chemistry classes and the teaching of stoichiometry and chemical reactions this far has prompted variety of actions and inactions. The pre-service student teachers have nonetheless displayed reasonably well a range of learning outcomes which awakens some rude level of concerns. We could share the plight of the pre-service student teachers in their confusion of the complexity of integrating mathematical ability in handling quantitative aspects of practical Chemistry.

On realizing this predicament, it was felt that to really read into what students are reflecting and thinking of, they needed to be asked some thought-provoking questions and their models needed to be patient to listen attentively to their responses. Despite concerted struggle for deep reflection to encourage pre-service teachers on how to pencil down their grey capability areas it remained problematic how pre-service teachers related quantitative ability with equations of reactions in Chemistry as well as practical skills acquisition. This was the premise which prompted the researchers to begin to re-assess the pedagogies adopted in imparting the cognitive attainment and practical skills of pre-service teachers in stoichiometry and chemical reactions of practical Chemistry.

RESEARCH QUESTIONS

1. What is the relative impact of the strategies adopted by the teachers on the practical skills acquisition of pre-service teachers in Chemistry?
2. What is the relative impact of the strategies adopted by the teachers on the cognitive attainment of pre-service teachers in Chemistry?

RESEARCH HYPOTHESES

1. There 1s no significant main effect of strategies adopted by teachers on pre-service teachers' practical skills acquisition in Chemistry based on course combination.
2. There is no significant main effect of strategies adopted by teachers on pre-service teachers' cognitive attainment in Chemistry based on course combination.

METHODS

The research design adopted in this study is the quasi-experimental. This is because the design provides a procedure for determining the effect of independent on dependent variables. The targeted population of 310 and 234 from the departments of chemistry and integrated science respectively for the study was pre-service teachers offering a course that required practical activities for cognitive attainment and practical skills acquisition in stoichiometry and chemical reactions in Federal College of Education Kontagora, Niger State in the 2024/2025 session. Sample selection was purposively based and stratified on the three strategies considered. 300 students were randomly selected from all of the three levels of the two departments. 100 level students in both departments were assigned lecture with demonstration (LD) method, while the 200 level students were engaged in guided inquiry with demonstration (GID) method and the 300 level students were assigned only to guided inquiry (GI). To determine the learning outcomes of the pre-service teachers, 50 students were randomly selected from each level of each of the departments to make 100 for each of the groups with equal gender representation respectively.

Three stimulus instruments were developed and used each for a group; these include: Practical Manual for Guided Inquiry (PMGI), Practical Manual for Guided Inquiry with Demonstration (PMGID) and Laboratory Instruction for Lecture with Demonstration

(LILD). Each of the stimulus instruments was used in the second semester of 2020/2021 (May - August) for specific courses where quantitative ability of stoichiometry and chemical reactions are related. Two other instruments were developed for data generation. These are the Test of Practical Skills (TPS) and Test of Cognitive Attainment (TCA) in Chemistry courses. 1he two response instruments were pruned with the validation criteria, after which their reliability were determined. TPS was subjected to scorer reliability computation which yielded .69 while TCA yielded .73 reliability coefficients through split-half computation respectively. The data generated were analyzed using SPSS version 25 for descriptive (mean and standard deviation) and inferential (t-test and ANOVA) statistics respectively.

RESULTS

Summary of the results are presented according to the research questions and hypotheses in tables

Table 1: Mean scores on Chemistry TCA and TPS by Treatment Groups

Level	Group	N	TCA		TPS	
			$\bar{x}$	Std Dev.	$\bar{x}$	Std Dev.
300	GI (E1)	100	22.08	6.081	5.48	1.313
200	GID (E2)	100	24.36	6.154	6.42	1.357
100	LD(C)	100	18.28	5.038	3.52	1.092

Table 1 displays the mean scores of students in TCA and TPS in the three treatment groups investigated in this study. It shows that pre-service teachers in the experimental group 2 (GID) had the highest mean scores of 24.36 (Std dev. = 6.154) and 6.42 (Std dev. = 1.357) on TCA and TPS respectively. This group was followed by those in the experimental group 1 (GI) with mean scores of 22.08 (std dev.= 6.0S1) and 5.48 (Std dev. = 1.313) on TCA and TPS respectively. The control group (LD) had the lowest mean scores of 18.28 (Std dev, = 5.038) and 3.52 (Std dev. = 1.092) on TCA and TPS respectively. This shows that the experimental groups had better learning outcomes in cognitive attainment and practical skills acquisition than in the control in stoichiometry and chemical reactions of practical Chemistry and similar course in Integrated science.

Table 2: T-test of Learning Outcomes of the Experimental Groups (GI and GID)

	Group	N	$\bar{x}$	Std Dev	df	t	sig(2tailed)
TCA:	G1 (E1)	100	22.08	6.081	198	-1.864	.065
	GID (E2)	100	24.36	6.154			
TPS:	GI (E1)	100	5.48	1.313	198	-3.521	.004*
	GID (E2)	100	6.42	1.357			

Table 2 provided the result of t-test statistics of pre-service teachers learning outcomes in the two experimental groups. The result reveals a no significant difference between GI and GID on cognitive attainment ($t_{(98)}$ = -1.804 at p>.05) but a significant difference existed on practical skills acquisition ($t_{(98)}$ = -3.521 at p< .05) in chemistry for which GID had a higher mean score. This implies that both treatments (strategies) were adequately reliable for pre-service teachers' cognitive attainment whereas, GID was a better option for practical skills acquisition in stoichiometry and chemical reactions of practical Chemistry and similar course in Integrated science.

Table 3: t-test of Learning Outcomes of Experimental Group 1 (GI) and the Control (LD)

	Group	N	$\bar{x}$	Std Dev	df	t	sig(2tailed)
TCA:	G1 (E1)	100	22.08	6.081	198	3.313	.001*
	LD (C)	100	18.38	5.038			
TPS:	GI (E1)	100	5.48	1.313	198	8.114	.000*
	LD (C)	100	3.52	1.092			

Table 3 indicates that there was a significant difference both in cognitive attainment ($t_{(98)}$ = -3.313 at ps,05) and practical skills acquisition ($t_{(98)}$ = 8.114 at p<.05) of pre-service teachers in chemistry between GI and LD. This implies that GI was by far better over LD for pre service teachers' learning outcomes in stoichiometry and chemical reactions of practical Chemistry and similar course in Integrated science.

Table 4: t-test of learning outcomes of Experimental Group 2 (GID) and the Control (LD)

	Group	N	$\bar{x}$	Std Dev	df	t	sig(2tailed)
TCA:	G1D (E2)	100	24.36	6.154	198	5.317	.000*
	LD (C)	100	18.38	5.038			
TPS:	GID (E2)	100	6.42	1.357	198	11.773	.000*
	LD (C)	100	3.52	1.092			

Table 4 reveals that there existed a significant difference both in pre-service teachers' cognitive attainment ($t_{(98)}$ = 5.317 at p<.05) and their practical skills acquisition ($t_{(98)}$ = 11.773 at p<05) in chemistry between GID and LD. This implies as well that GID was much better a strategy for imparting knowledge in stoichiometry and chemical reactions of practical Chemistry and similar course in Integrated science than using LD.

Table 5: ANOVA of Learning Outcomes by Treatment Groups

Sources of variance		Sum of Squares	df	Mean Square	F	Sig
TCA:	Between Groups (Combined)	910.813	2	445.407	13.632	.000*
	Within groups	4910.980	147	33.408		
	Total					
TPS:	Between Groups (Combined)	218.920	2	109.460	69.017	.000*
	Within groups	233.140	147	1.586		
	Total	452.060				

Table 5 gives the ANOVA of the pre-service teachers scores in both cognitive attainment and practical skills acquisition in chemistry for the three treatments (Strategies) examined in this Study. The result shows a significant mean difference among the groups (strategies) of pre-service teachers chemistry cognitive attainment ($F_{(2, 147)}$ = 13.632 at p<.05) and practical skills acquisition ($F_{(2, 147)}$ = 69.017 at p<.05). These significant differences in the learning outcomes have been shown on table 1. The hypotheses of no significant difference were therefore rejected. This means that stoichiometry and chemical reactions of practical Chemistry and similar concept in Integrated science are better leaned by pre-service teachers when GI and GID are used over LD.

DISCUSSION

The finding in this study shows that the experimental groups had better learning outcomes in chemistry practical skills acquisition and cognitive attainment than in the control. This means that there was relative impact of the strategies adopted by lecturers on the practical skills acquisition as well as the cognitive attainment of pre-service teachers in Chemistry. This result showed the learning activities with guided-inquiry with or without demonstration have fulfilled a number of effectiveness indicators presented by Nieveen (1999) such as ability of teachers to manage the learning that fulfilled the minimum criterion of good category as well as students' responses to the devices and the learning activities (practical skills acquisition and cognitive attainment) that were positive. Though, both GI and GID were adequately reliable for pre-service teachers' cognitive attainment, GID was a better option for practical skills acquisition in chemistry. This buttressed the position of Gott and Duggan (2007) that the inclusion of practical component in Chemistry curriculum stemmed from the acknowledgement that practical skills are reliably pivotal to learning Chemistry which inculcates critical competencies in students as activity oriented subject. GID could have shown this attribute because the pre-service teachers in this group combined inquiry with demonstration which involved a two-in-one intensive activity, whereas, GI was just a single activity at once. Despite this disparity, both groups showed positive development which reflected the submission of Asnidar, Khabibah and Sulaiman (2018) that guided learning is effective to teach comparison topics.

Likewise, as GI was by far better over LD for chemistry learning outcomes so was GID much better a strategy for imparting chemistry knowledge than LD. Similarly, a significant mean difference existed among the groups (strategies) on pre-service teachers practical Skills acquisition and cognitive attainment in chemistry which means that chemistry concepts are better learned by pre-service teachers' when GI and GID are adopted by lecturers over LD. This finding tows the line of the submission of Camenzuli and Buhagiar (2014) that the use of inquiry-based learning in Mathematics class indicated that students benefited in facial, social, emotional and behavioral difficulties through a number of ways.

Also, with the view of Sanjaya (2014) inquiry learning model is a series of learning activities that emphasize the thinking process of searching and finding answers to a questionable problem. Similarly, Gialamas et al (2001) had advocated that guided-inquiry method of teaching promotes students' active participation in the learning process. Likewise, the combination of demonstration with

guided inquiry harnessed the finding of Buncick et al (2001) that demonstration method is effective in capturing student's attention and as such can be used to stretch the cognitive spectrum of learners. This also added value to the submission of Osokoya (2013) who established that demonstration involves a display to students how to carry out a specific activity different from the conventional visual-aid apparatus as cultured in conventional lecture method.

This could have been the combining strength of GID strategy in improving pre-service teachers learning outcomes over others since there seemed a sort of synergy operated among the three domains of learning outcomes. Just as Kuntzleman, Rohrer and Sehultz (2012) observed that experiments and demonstrations that confirm a physicochemical phenomenon such as illustrating chemical processes by light-sticks can be used to facilitate understanding certain chemical concepts like acid-base reactions, redox reactions and thermodynamics among others.

RECOMMENDATIONS

1. Chemistry/Integrated Science Lecturers in Colleges of Education should adopt the use of guided-inquiry with demonstration and guided inquiry for imparting knowledge of stoichiometry and chemical reactions of Chemistry and similar concepts in Integrated science that require practical skills acquisition and cognitive attainment.
2. Active participation of students should be paramount in learning chemistry concepts since this will instill critical competencies in students and the zeal to accept chemistry as activity-oriented subject.
3. The adoption of guided-inquiry with or without demonstration by teachers or students to learn concepts in chemistry should be non-negotiable since they synergize learners' psychomotor and affective domains with cognitive domain in disguise for outstanding achievement.
4. To properly blend the three domains of learning outcomes in learners' chemistry concepts learning, school chemistry and integrated science laboratories should be adequately equipped with basic equipment, apparatus and gears.

CONCLUSION

This paper has justified the consideration of Chemistry as an activity-oriented subject examined the effects of guided-inquiry with or without demonstration, and demonstration with conventional approach on pre-service teachers' cognitive attainment and practical skills acquisition in stoichiometry and chemical reactions of practical chemistry. Guided inquiry with or without demonstration strategies was found to enhance pre-service teachers learning outcomes in chemistry than with the adoption of demonstration with conventional approach. It is therefore crystal clear that the adoption of guided-inquiry cither with or without demonstration is advocated for all stakeholders in the teaching and learning of chemistry concepts to enhance performance and development of relevant entrepreneurial skills.

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