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Fostering science process skills through constructivist-based module among form two students of different cognitive levels

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ABSTRACT

The present study was undertaken to investigate the 7E-inquiry integrated module (7E-IIM) effect in fostering form two junior secondary school students' science process skills (SPS). This study employed pre-test, post-test, and delayed post-test quasi-experimental design. 73 students aged 12 years on average constitute the sample of this study. The science process skills test was used to measure the participants' process skills; meanwhile, the Lawson classroom test of scientific reasoning was administered to classify the participants into the concrete and formal cognitive developmental levels. Repeated measure ANOVA and independent Mann-Whitney U test were used for data analysis. The repeated measure ANOVA findings indicated a significant mean difference between experimental and control groups ($p<0.05$). However, no significant difference existed in student's SPS between concrete and formal cognitive levels in the experimental group ($p>0.05$). On the contrary, there is a significant difference in student's SPS between concrete and formal cognitive levels in the control group ($p<0.05$). Overall, the 7E-IIM effectively promotes students' SPS regardless of their cognitive developmental level. Instructors are therefore recommended to adopt the 7E-IIM in fostering students' process skills to close the gap in students' learning differences and difficulties.

Keywords: science process skills, cognitive level, constructivism, the 7E-inquiry integrated module

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INTRODUCTION

According to the American Association for the Advancement of Science's (AAAS) Science Literacy: Project 2061, all pupils must be able to grasp science, technology, and mathematics by the end of grades two, five, and 12 (AAAS, 1994). These benchmarks are necessary for educators to describe the levels of comprehension and abilities of different students in order to make sure that they become science literate (Bete, 2020). Teaching and learning is not limited to knowing *what* but also about learning *how.* Teaching and learning about science is much more than just imparting scientific knowledge; it also improves students' problem-solving skills (Duda et al., 2019). The science process skills (SPS) can be developed through experimental activities in the school laboratory or classroom. It is curial to understand that science as an inquiry involved applying SPS. SPS are one of the 21st century skills and hence the need for science teachers to teach these SPS to students. It is believed that knowledge and skills are major ingredients in the economic development of a country (Bete, 2020). Accordingly, Turiman et al. (2020) the 21st century skills are required for future global advancement driven by knowledge, technology, and innovation. Individual manipulative ability, active involvement, and meaningful learning are all enhanced by SPS (Turkmen & Usta, 2007). Similarly, Ozgelen (2012) described SPS as capacities, possibilities, and specialized expertise created in a child and can be utilized to do the mental and physical tasks in science class. For decades studies on SPS in science education have been conducted internationally (Abd Rauf et al., 2013; Amansoi & Basseyii, 2017; Gagné, 1967; Ozgelen, 2012; Ozturk et al., 2010) and in Nigeria (Amansoi & Basseyii, 2017; Jack, 2013; Oloyede & Adeoye, 2012) focusing its relation to academic achievement of students. According to an American psychologist Gagné (1965), the major purpose of scientific training should be to teach SPS. Gagné's (1965) vision of SPS, according to Finley (1983), has affected and inspired academics, curriculum creators, and scientific educators for decades.

Researchers have defined SPS in different ways. For instance, they are regarded as abilities that aid students in interpreting the natural environment (Ozgelen, 2012; Tan & Temiz, 2003). Furthermore, Oloyede and Adeoye (2012) described SPS as the ability to reason intelligently and tackle problems more effectively. Also, Ozturk et al. (2010) defined SPS as the ability to learn by doing and associating science experience with daily life. SPS, according to Wilke and Straits (2005), help students succeed both inside and outside of the classroom; thus, developing these skills is critical. Chongo et al. (2021) affirm that

SPS in science are crucial, hence the need for educators to embed hands-on activities in teaching science to promote student's SPS. There are two types of SPS (basic science process and integrated SPS). The present study examined six basic SPS: *observation, classification, measurement, communication, inferring and predicting.* The SPS are believed to enhance learning and retention of ideas. Students must be actively involved in their activities while developing these skills through inquiry learning. (Aydin-Gunbatar et al., 2019).

SPS are crucial in both teaching and studying science (Jack, 2013; Jegede & Okebukola, 1991). It has been established that science teaching and learning relied heavily on SPS (Ergul et al., 2011). Studies have reported that the new science curriculum worldwide stresses SPS and emphasizes higher cognitive skills through the student-centred approach (Ozgelen, 2012). The search for a more practical teaching and learning science approach that enhances process skills acquisition has persisted over the years (Jack, 2013). Constructivism is thought to be the most accurate scientific approach of teaching Demirbas and Tanriverdi (2012), because it focuses on a far more efficient student-centered curriculum than a teacher-centered one (Yin et al., 2020).

It is believed that general skills acquisition enhances learning in different ways (Bruner, 1985). According to Koksal and Berberoglu (2014), teaching SPS is important since it encourages students to utilise them in scientific investigations both in and out of classroom. Ibe and Nwosu (2017) believed acquisition of SPS support students in exploring their world and overcoming environmental challenges. Therefore, looking at the role SPS play on students' achievement, it is imperative to foster students' SPS. For students to act like a real scientist, there is a need for appropriate science SPS at all educational institutions (Aktamis & Ergin, 2008). The importance of SPS was further confirmed by Aktamis et al. (2016), Feyzioglu (2009), and Saputro et al. (2019). The authors affirmed the positive relationship between SPS and academic achievement in elementary, chemistry and science education. Accordingly, students are expected to acquire SPS that invariably improve their performance in and outside the classroom. SPS acquisition is at the heart of constructivism and is explicitly linked to the 7E learning cycle approach, where students are expected to explore information themselves. At the same time, the teacher serves as a facilitator with constant scaffolding. The primary aim of this study is to determine the relative influence of the 7E-inquiry integrated module (7E-IIM) on students' acquisition of SPS.

Making observations, measuring, classifying, communicating, inferring, and predicting are all essential SPS, according to Longo (2012). However, in this present study, the teacher as facilitator ensures students acquisition of SPS by engaging them into hands-on activities that required them to measure, observe, classify, and make prediction. The teacher, as a facilitator, plays a crucial role in making sure students acquire the proper process skills. Ango (2002) believes that learners can observe, explore the environment, and handle things; thus, students develop their ideas, manipulative skills. It has been reported that constructivist learning cycles promote the acquisition of SPS. Jack (2013) sees cognitive and psychomotor skills as key employed in solving problems.

In general, SPS are the skills that facilitate learning in physical sciences, ensure active student participation, and have students develop a sense of undertaking responsibility in their learning, increase the permanence of knowledge, and have students acquire research ways and methods (Samuel et al., 2018). This present study adopts a 7E learning cycle to develop a 7E-IIM for teaching grade 6 (form two) students. The 7E-IIM provides students with collaborative, problem-solving and hands-on activities to explore a given phenomenon, which invariably promotes students' SPS and ensure meaningful learning.

Considering that SPS are the ingredient for students understanding of science, there is inevitably the need for students at the lower level to acquire SPS in science classes. Jack (2013) suggests that SPS are the key and primary source for students to explore science differently. However, despite the importance of SPS, there is still a disturbing report on students' poor SPS (Akani, 2015; Amansoi & Basseyii, 2017; Bete, 2020; Kimba et al., 2018). Jack (2013) in his study affirmed the low acquisitions of students' SPS to the students' massive failure in the public examinations. It may not be out of context to conclude that it is critical to determine students' knowledge and learning SPS in order to meet their requirements and capacities (Bete, 2020).

In light of the aforesaid, the present study investigates how the SPS of form two students of different cognitive levels can be improved through the constructivist-based module. In other words, the main thrust of this study is to investigate the effect of the 7E-IIM on promoting the SPS of form two students. Teaching these skills to ensure children use them in their everyday life in future is necessary.

Objectives

1. To investigate the difference between the 7E-IIM and conventional method of instruction (CMI) on form two students' SPS at phase1, phase2, and phase3.
2. To investigate the difference between concrete and formal form two students' SPS at phase1, phase2, and phase3.

THE 7E-INQUIRY INTEGRATED MODULE CONCEPTUAL FRAMEWORK

According to Australian teachers and academics, there are five stages model for meaningful learning to occur. These include

1. engagement,
2. exploration,
3. transformation,
4. presentation, and
5. reflection (Pritchard, 2017).

The Australian stakeholders place engagement at the beginning of learning, which agrees completely with the constructivism approach to teaching and learning and the adopted approach to this current study. One of the problems teachers faces is selecting an appropriate approach to teaching a certain kind of knowledge (Scoular et al., 2020). The 7E-IIM integrates multiple methods such as inquiry learning, game-based learning, and problem-solving learning approach with states of matter topic across the 7E learning cycle. This module is developed based on the Dick and Carey instructional design model and underpinned by the theory of constructivism. The Dick and Carey model has been effective and suitable in designing teaching and learning (Hartman, 2017; Perinpasingam & Balapumi, 2017).

The rationale for developing this module arose from the literature indicating the need for innovative teaching and learning different from the current approach of using textbooks and assignments (Ayodele, 2016; Idowu, 2011; Osuolale, 2014; Samuel, 2017). A module is defined

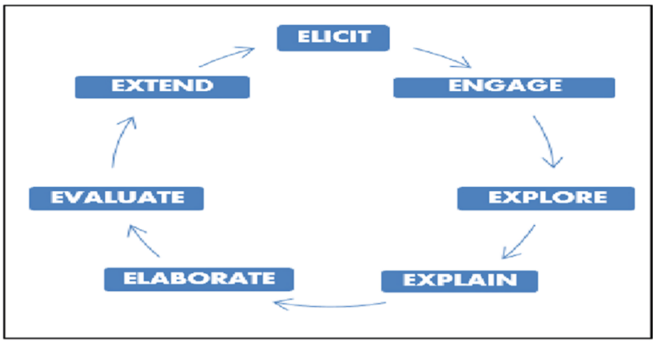

Figure 1. Diagrammatical representation of 7E learning cycle (George, 2016)

as an individual, self-contained unit of a designed series of learning activities to help students achieve specific, well-defined goals (Guido, 2014). The module is an instructional learning series of activities well-coordinated that is relatively short and precise, with content arranged to achieve the learning objectives (Telaumbanua et al., 2017). This module was designed to assist students in understanding abstract concepts while making observations, measurement, classifying and predicting states of matter transformations. Scale content validation index (S-CVI=0.81) from the opinion selected science teachers showed that the module is suitable for teaching form two students basic science. Ibe and Nwosu (2017) argued that SPS could only be promoted through the appropriate method of instruction based on strong theory like Piaget (1976) cognitive theory. The authors further assert that instructions that do not bridge the gap between prior knowledge of students and the new learning content do not improve the child's cognitive (mental) and psychomotor (skills) skills. The teacher engages students in a challenging task in the 7E-IIM Constructivist classroom. This task is according to their mental ability and provides opportunities for discussion. Students will get the opportunity to share their views with others, enhance their observation and communication skills, and expand their knowledge through interaction. This module was designed with hands-on and mind-on activities conducted by individual students and in the group. At the same time, the teacher acted as a facilitator with constant feedback in making sure students reach the zone of proximal development (ZPD). This module is structured with a task sheet that engages students in problem-solving activities. The 7E-IIM required students to carry out activities individually and in groups. The module is very engaging, well detailed and self-explanatory.

According to Piaget (1976), the ability of a person to explore information and experience occurs in his or her schemata (Chongo et al., 2021). Children response or manipulative skills reflect the internal structure, which Piaget (1976) refers to as schema. The 7E-IIM is designed to reflect the schemata of form two students. The researchers are conscious of Piaget's (1976) belief that children's schemata change based on mental development (Wadsworth, 1979). The 7E-IIM is developed to ensure individuals assimilate or accommodate information at eliciting or engage stage of the module. In the second stage of the 7E-IIM, students are presented with a task sheet to identify and solve a given problem. The module is also designed to help students develop a deep, meaningful understanding of states of matter transformation related to SPS involved in hands-on activities. The 7E-IIM is designed to emphasize transfer of learning and importance of prior knowledge. It is crucial to contribute to knowledge in providing suitable and quality pedagogical instructions that enable students to learn actively and motivate students' learning, increasing students' achievement and SPS.

Consequently, developing an instructional module by adopting constructivist Eisenkraft (2003) 7E learning cycle and employing Dick and Carey instructional design model to improve student SPS is imperative. The 7E-IIM is a paradigm of learning that can foster SPS. Constructivist, meaningful, and inquiry-based learning concepts underpin this module. The module's specifics were established outside and inside the classroom in order to provide aspiring teachers with a guide and syntax to follow. The seven syntaxes of the 7E-IIM learning model are eliciting, engage, explore, explain elaborate, evaluate, and extend (Eisenkraft, 2003). As illustrated in **Figure 1**, the implementation of the seven syntaxes is done in cycles and in a sequential order.

THEORETICAL UNDERPINNING

According to Piaget's (1976) cognitive development theory, school education should empower both men and women to do new things through creativity, invention, and discovery (Bete,2020). However, since learning is an individual active activity, where learners search experience themselves then teaching and learning requires the knowledge of constructivism. This study was supported by two theories, namely cognitive constructivist theory of learning from Piaget (1976) and Vygotsky's (1978) theory of social construction. Keeping a comprehensive understanding of all components of the system to be studied on the central principles of student learning is crucial. The theories of cognitive and social education agree that students generate or make meaning from experience (Colburn, 2000). Therefore, Piaget (1976) and Vygotsky's (1978) learning theories support this study in guiding and developing appropriate learning activities that foster SPS. According to Piaget's (1976) theory of intellectual development, a child's active engagement with his environment is what causes cognitive development.

According to Piaget's (1976) theory, learning starts with a child interacting with their physical and social environment. For learning to take place, according to Piaget (1976), a child must interact with the things in his or her surroundings (Wadsworth, 1979). Students shouldn't just be passive listeners; they should actively participate in their education. The child's active participation could take the shape of physical manipulations, visual observations, or internal or mental movement or change.

According to Piaget (1976), the mental activity of the child is organized into structures. The teacher provides the background information, but it is up to the student to explore a given phenomenon themselves to identify the relevant information, to quantify it, to generate a hypothesis, and finally to go through the process of interpretation and predictions verification of their investigation, by way of deducting or inducting. It is also believed that student interaction with peers and teachers helps facilitate learning improve communication and share ideas. Vygotsky (1978) believe that cognitive development is influenced heavily by other people and external factor. Individuals must first build, understand, and remember what they learned (cognitive processing of information), then practise and apply their new skills and knowledge to make it more natural and efficient, as well as a permanent part of their practise (behavioural) this is the view of constructivist theory (Liu & Chen, 2010; Woolfolk Hoy et al., 2013).

Table 1. Sample based on developmental cognitive level

S/N	Teaching method	Concrete	Formal	Total
1	7E-IIM	22	17	39
2	CMI	18	16	34
Total		40	33	73

All learning processes are socially and culturally intertwined, and if either of these processes is absent, learning will fail (Woolfolk Hoy et al., 2013). Theorists attempted to explain how learning occurred in students and emphasised the importance of condition selection and mental development to which learning should be considered. Concluding that all learning is based on a given theory is problematic. In this regard, Powell and Kalina (2009) argued that they need to employ cognitive and social constructivism for teachers to have constructivist classes. There is a belief that no single theory can adequately explain learning (Woolfolk Hoy et al., 2013). In this study, the selected theories have a crucial role in teaching unique and successful in addressing learning difficulties in understanding the concepts and acquisition of SPS.

Despite the fact that the social cognition theory views learning as an inclusive process of negotiation and dialogue that emphasises collaboration and knowledge exchange, scaffolding holds that persons in similar settings obtain different understanding. It highlights the importance of teachers assisting students with their learning tasks by scaffolding them. In this situation, the instructor or peers may provide scaffolding via 7E learning cycle's learning phases or in a face-to-face learning setting. In this study, researchers ensure that the teacher for the experimental group provided the necessary assistance for students to move to the zone at which they can learn without teacher directives. Vygotsky (1978) describes this zone as the ZPD at this stage, students can assimilate or accommodate. In this study while students observe, measure, and predict information, the teacher as a facilitator continue to provide feedback and ensure student reach the level they can learn. Allowing the student to interact with peers, as suggested by Vygotsky (1978) according to Powell and Kalina (2009), making it easy for students to develop their communication skills and internalized learning. Many studies have reported the positive effect of 7E learning cycle in enhancing students' science process (Celik et al., 2013; Gok, 2014). Gagné (1965) proposed that the required knowledge for the concepts and principles in the hierarchy could only be achieved if the students had mastered specific underlying skills in their theory of learning structure-learning hierarchy and learning requirement. These abilities according to Gagné (1965) are known as intellectual skills or science processes, and they are required for pupils to practice and understand science.

METHODOLOGY

The purpose of this study is to see how the 7E-IIM affects form two students' SPS at various cognitive levels. On non-equivalent groups, this study is a quasi-experimental pre-test, post-test, and delayed post-test. The study was conducted at two randomly selected public schools, with a total sample size of 73 children, all of whom were 12 years old on average and were split into experimental (39) and control (34) groups (**Table 1**).

Two classes were randomly selected, the entire class was maintained, in another word, the traditional method of instruction (CMI) and the 7E-IIM were the two teaching approaches that were randomly assigned to the two intact classrooms. Students in both groups were taught the same material in both classes, despite the fact that the two treatments could involve various times and activities. The experimental group received instruction from the 7E-IIM, whereas the control group received CMI which involves the use of textbooks, classroom assignment and homework. Two science teachers were involved for teaching of experimental and control group. The science teacher for experimental group follow the developed module. Classes in the experimental group received the 7E-IIM whereas those in the control group underwent CMI. Students in grade the 7E-IIM were exposed to practical tasks, which tickles their interest and gives them first-hand knowledge of a certain phenomenon. The applications from the textbook that the control group used included questioning, information, discussion, and some tasks. Throughout the seven weeks, the research assistant makes use of the module that the researcher designed. Each lesson takes one week to complete with tasks. The schools allotted two sessions to each student each week, as was already established. In contrast to the other week, which is dedicated to practical, hands-on learning, one week is devoted to theoretical instruction. The validated and modified science process skills test (SPST) was administered to students to classify the participants into concrete 40 (54.80%) and formal 33 (45.20%) cognitive levels (**Table 1**). The SPST was administered before the treatment as a pre-test and readminister after treatment and six weeks after treatment.. Students in grade the 7E-IIM were exposed to practical tasks, which tickles their interest and gives them first-hand knowledge of a certain phenomenon. The applications from the textbook that the control group used included questioning, information, discussion, and some tasks. Throughout the seven weeks, the research assistant makes use of the module that the researcher designed. Each lesson takes one week to complete with tasks. The schools allotted two sessions to each student each week, as was already established. In contrast to the other week, which is dedicated to practical, hands-on learning, one week is devoted to theoretical instruction. The treatment lasted for seven weeks period. Each week has two periods of 45 minutes each.

Instrumentation

Paper and pen written test were the method applied in data collection. This study used the SPST and the Lawson classroom test of scientific seasoning (LCTSR). The two instruments were adopted. In ascertaining children's cognitive development, Piagetian stage of intellectual development was measured by a modified version of the LCTSR revised edition, August 2000 by Anton E. Lawson, Arizona State University, based on Lawson, 1978 (Han, 2013). The original version comprises 24 items. After the pilot study, 10 items were adopted. The LCTSR was administered to groups of approximately 73 junior secondary school II students ranged in age from 11 to 14 years, mean age is 12 years; as stated earlier, the purpose of the LCTSR is to classify the students as concrete or formal developmental cognitive level.

Students were grouped into concrete and formal cognitive developmental levels according to their LCTSR pre-test scores. Each correct answer in the LCTSR is scored one, and the wrong answer is zero. Based upon the cut-off points used by Acar and Patton (2016), Han (2013), and Lawson et al. (2007), the present form two basic science students were scored between 0-5 and categorized as concrete developmental cognitive level, and those who scored between 6-10 were grouped as formal developmental cognitive level. Therefore, 40 students are classified as concrete developmental cognitive level and 33 as a formal developmental cognitive level.

Also, the SPST is adapted instrument. The original version comprises 60 items. However, the present study adapted 25 items based on feedback from expert validation and a pilot study. Most of the items in the original version are not suitable and not within the content of the junior secondary school curriculum. These instruments access students' cognitive developmental levels and SPS. The reliability of SPST and LCTSR is KR=0.89 and KR=0.85, respectively. Students were asked to fill out a test booklet that contained questions, multiple-choice answer possibilities, and blanks for each question.

Treatment (7E-IIM vs CMI)

Going by the specified objective, seven weeks was observed for the full implementation of the experiment during the first term of the 2019/2020 academic session. The state of matter unit was taught to Form Two basic science students as part of the standard curriculum. The study was attended by 73 students from two intact classrooms and two basic science teachers. Two periods a week were allocated to form two basic science classes with 45 minutes per lesson. The experimental group classes received the 7E-IIM while the control group go through CMI. Students under the 7E-IIM were exposed to hands-on activities, which invariably increases their curiosity and provide them with first-hand information on a given phenomenon. The control group followed the textbook's applications, including questioning, discussion, information, and some activities. The research assistant uses the researchers developed module throughout the seven weeks. Each module is completed in a week with practical activities. As already mentioned, the schools allocated two periods each per week. One week is used for theoretical class, while the other period is utilized for practical hands-on activities. This is because the researchers have understood that process skills can only be improved through laboratory activities (Feyzioglu, 2009).

Despite the curriculum suggesting the student-centre method, which is in line with the constructivist perspective, the strategy employed in science classes force students to explore concepts themselves with limited support from the textbooks and teachers. Observation has indicated that most of the students resort to using the textbooks provided by schools, which lacks details of concepts, especially the concepts of matter and its states. To ensure compliance with the full implementation of the experiment or when the research assistant needed the researcher's attention on a given activity, the researcher got involved in the instruction of the experimental group. However, there was not much interference in the teaching of the control group. During the intervention, participants from the experimental group are introduced to hands and mind-on activities. These involve practical activities that require students to observe, classify, measure, record, and make predictions based on his or her findings. These activities improve their process skills. But from time to time on weekly, the researcher holds meetings with the research assistant to ensure full implementation of the 7E-IIM. These meetings were often aimed at maintaining contact during treatment and reducing conflicts resulting from learning activities.

Data Collection Procedure

The SPST was used to collect data in three phases: pre-test, post-test, and delayed post-test (SPST). The instruments were given out before the treatment, with the goal of comparing the SPS of the control and experimental groups. LCTSR, on the other hand, was administered at pre-test to determine the participants' cognitive developmental levels. Following the pre-test, both groups were given treatment; the control group followed the CMI while the 7E-IIM was used on the experimental group. After which, the SPST was administered as a post-test to the two comparison groups to measure their SPS acquisition. However, three weeks later, a delayed post-test was administered through the SPST. Throughout the research, pre-test, post-test, and delayed post-tests were referred to as phase1, phase2, and phase3 on SPS (SPST). The data collected were subjected to mixed between-within-subject repeated measure ANOVA and independent Mann-Whitney U test.

Table 2. Tests of between-subjects effects results for SPST

Source	Type 111 SS	df	F	Sig. (p)*	Partial μ^2
7EIIM/CMI	589.33	1	12.30	0.01	0.15

Note. *Analysis was performed with the significance level of α=0.05

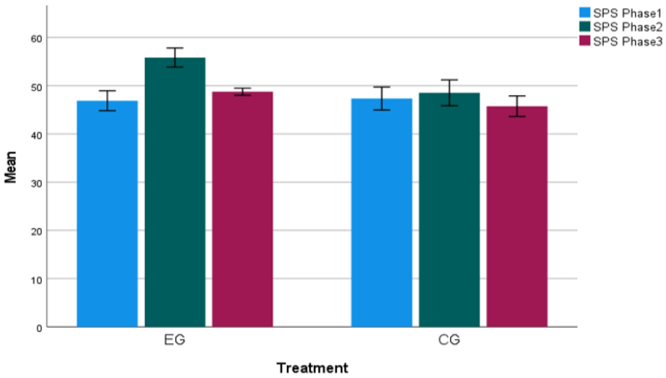

Figure 2. Means of groups with respect to phase for SPST (Source: Authors)

RESULTS

The sphericity assumption is checked; this assumption includes the equality of variances of all the comparisons calculated from differential scores. This is tested by Mauchly's test of sphericity $X^2(2)$=.750, p=.00. However, this assumption has been violated. Having violated the assumption, the results should be interpreted via multivariate test data analysis (Field, 2009).

1. *Is there is a significant difference between 7E-IIM and CMI on form two students' SPS at phase1, phase2, and phase3?*

First, the significant difference between groups was investigated and the multivariate analysis of variance revealed that the treatment's main effect (7E-IIM and CMI) is significant. This implies that a statistically significant mean difference is found between experimental and control groups F(1, 71)=12.30, p= 0.00 favoring the experimental group (**Table 2**). The partial μ^2 value of 0.15 indicating that 15% variance of dependent variables is explained by treatment effect, 15% partial μ^2, according to Cohen (1988) as cited in Pallant (2020), is moderate effect size.

A pairwise comparison was conducted to pinpoint the significant difference between the 7E-IIM and the CMI (**Figure 2** and **Table 3**). Therefore, to pinpoint these differences, the syntax was extended, and

Table 3. Pairwise comparisons of groups by phase for SPST

Phase	(I) Treatment	(J) Treatment	Mean difference (I-J)	Standard error	Sig.b
Phase1	EG	CG	-.456	1.548	.769
	CG	EG	.456	1.548	.769
Phase2	EG	CG	7.317*	1.614	.000
	CG	EG	-7.317*	1.614	.000
Phase3	EG	CG	3.005	1.055	.006
	CG	EG	-3.005	1.055	.006

FooterWillBeHere

Table 4. Mann-Whitney U test analysis for SPST ranks of concrete and formal students in experimental group

Phase	Cognitive level	n	Mean rank	U	p-value
Phase1	Concrete	22	20.82	169.00	.62
	Formal	17	18.94		
Phase2	Concrete	22	17.23	248.00	.09
	Formal	17	23.59		
Phase3	Concrete	22	17.52	241.50	.49
	Formal	17	23.21		

Table 5. Mann-Whitney U test analysis for SPST ranks of concrete and formal students in control group

Phase	Cognitive level	n	Mean rank	U	p-value
Phase1	Concrete	18	15.00	221.00	.13
	Formal	16	20.31		
Phase2	Concrete	18	14.22	203.00	.04
	Formal	16	21.19		
Phase3	Concrete	18	13.22	189.00	.01
	Formal	16	22.31		

Bonferroni adjustment was used on statistical package for social sciences (SPSS) to decrease the type 1 error on multiple comparisons.

As shown in **Figure 2**, at the beginning of the intervention (phase1), a statistically significant mean difference does not exist between the two groups regarding students' SPS ($p>.05$). However, there was a statistically significant mean difference between the experimental group ($M=55.85$) and the control group ($M=48.53$) ($p<.05$) after the intervention (phase2). The significant difference found between groups after the intervention arose from the treatment effect favouring the experimental group ($M=55.85$). Similarly, three weeks later (phase3), there is a statistically significant mean difference between the two groups experimental groups ($M=48.77$) and the control group (45.76). This finding implies that SPS acquired were significant across the groups ($p<.05$). In other words, students exposed to 7E-IIM attain and stored the acquired SPS better than students under CMI.

2. *Is there is a significant difference between concrete and formal cognitive developmental level form two students' SPS?*

Research question 2 was analyzed independently based on each group (7E-IIM and CMI). The result is presented separately.

2.1. Is there any significant difference in the mean score SPS between formal and concrete cognitive developmental level students exposed to 7E-IIM at phase1, phase 2, and phase3?

In answering research question 2.1., the SPST scores of concrete and formal students under 7E-IIM were subjected to the independent Mann-Whitney U test. The summary of the analysis is presented in **Table 4**.

Independent sample Mann-Whitney U test indicated that there is no statistically significant difference in SPS mean scores of students at phase1 U(concrete=20.82, formal=18.94)=169.00, $p>0.05$); phase2 U(concrete=17.23, formal=23.59)=248.00, $p>0.05$), and phase3 U(concrete=17.52, formal 23.21)=241.00, $p>0.05$). It can be concluded that there is no significant difference in the pre-test, post-test, and delayed post-test SPST of concrete and formal students in the experimental group. This shows that the 7E-IIM had positively promoted students' SPS regardless of their cognitive level in the experimental group. This has indicated the strength of 7E-IIM in enhancing students' SPS in concrete cognitive and formal cognitive levels.

2.2. Is there any difference in the mean SPS of formal and concrete development level students exposed to CMI at phase1, phase 2, and phase3?

In answering research question 2.2., the SPST scores of concrete and formal students under CMI were subjected to the Mann-Whitney U test. The summary of the analysis is presented in **Table 5**.

The independent sample-Mann Whitney U test indicated no statistically significant difference in SPS mean scores of students at phase1 U(concrete=15.00, formal=20.31)=221.00, $p>0.05$). On the other hand, the results of the independent sample Mann-Whitney statistically shown a significant mean difference in the SPS of concrete and formal students at phase2 and phase3 U(concrete=14.22, formal=21.19)=203.00, $p<0.05$) and U (concrete=13.22, formal=22.31)=189.00, $p<0.05$) respectively. Thus, it can be concluded that there is a significant difference in the post-test and delayed post-test SPS of concrete and formal students in the control group in favour of formal cognitive level. This implies that the CMI lacks the strength to positively influence students' acquisition of SPS at the concrete cognitive developmental level.

Finding from the present study showed that 7E-IIM successfully enhances students' SPS. The mixed between-within ANOVA significance p-value implies differences between the experimental and control groups with respect to their mean pre-test, post-test, and delayed post-test on SPS test scores. These findings are similar to the results of the other 7E learning cycle studies by Gok (2014) though there was insufficient evidence that the 7E learning cycle improves the science-process skills of middle school students. On the other hand, his results did not reveal a negative effect of 7E instruction in the learning cycle. Instead, the student scores increased slightly in parallel with the student comparison group scores.

Similarly, the present study's finding agrees with Wijayanti et al. (2014) results. Wijayanti et al. (2014) researched the effectiveness of 7E inquiry-based instruction on students' acquisition of the SPS. The authors found students under the 7E learning cycle acquired more process skills than those under the conventional approach. The study's findings revealed that students who learned the topic through the 7E learning cycle approach substantially outperform other students. Another related study also reported a high mean score gain in favour of the experimental group. This was evidenced by Nwagbo and Chukelu (2011) studies and Ukoh (2012), reporting students better performances concerning these skills.

The 7E-IIM is prepared to include practical activities. Students under the experimental group who experience the use of the module participated in practical activities. Students' practical activities in all the seven modules might be why the student acquired and retained their SPS. According to Animashaun (2015), students' application of process skills increases the permanence of learning. Similarly, Njoku (2002) opined that the SPS are retained after the cognitive knowledge of science has been forgotten. The previous studies did not use the constructivist module in their studies, which could be why subjects could not attain significant changes and retention of SPS. Our finding has shown that there is a need for science teachers to carefully prepared instruction that promote the SPS of the learner. Our finding agrees with the work of Renken et al. (2016), who suggested that teachers need to select strategies that support student learning and skills.

However, examining the Independent Mann-Whitney U test results indicated no significant difference $p>0.05$ in the mean score of concrete and formal experimental group students. The pahse2 SPS test mean rank score of concrete and formal both improved significantly. This implies that the experimental group students functioned and performed at the same level despite the cognitive level difference. Though students' mean rank at the formal developmental level is slightly higher than students' concrete developmental level. This result is in contradiction with the work of Mari and Gumel (2015), who in their findings, reported that students who are formal reasoners were significantly better in their academic achievement than students who were concrete reasoners exposed to the use of cooperative learning strategy. Although, the formal students mean score is slightly higher than that of the concrete student. Cantu and Herron (1978) believed that no matter the type of instructional approach students experience, one should expect the success of formal operational students to be greater than the success of concrete operational students. This result is encouraging in teacher education programs because it demonstrates that it is possible to achieve scientific reasoning equity through continuous scaffolding and providing opportunities to all students regardless of their reasoning abilities as professionals. Students need to be allowed to design and perform experiments to practice applying various SPS. On the contrary, the Independent Mann-Whitney U test result for the control group student's SPS score indicated that there is a significant difference in the mean score of concrete and formal students $p<0.05$. The phase2 and phase3 of student's SPS mean score of concrete is below the mean score of formal. This difference may be on the instructional approach that failed to stimulate the concrete developmental level students' SPS.

The findings shed light on which instructional strategy made a difference in fostering process skills to students across the two cognitive developmental levels. According to this result, there were no statistical mean differences among the concrete and formal developmental cognitive level regarding SPS which signifies the strength of the 7E-IIM in providing opportunities for students regardless of their mental ability. In other words, the positive features of the 7E-IIM have ensured students acquired process skills regardless of their cognitive level. This is because students understood the concept of states of matter using the constructivist-based module, specifically the 7E-IIM. However, the previous research results did not directly respond to whether providing equity to students with different cognitive development levels is possible. The present study's result is promising for ensuring equity and equality of SPS among Form Two students with different developmental levels. The current results are contrary to the finding of Lewis and Lewis (2008), who conclude that it is impossible to reduce attainment gaps among students with different reasoning abilities in college. The authors argue that it is likely not possible to provide equity in student learning with different mental abilities. However, the present results have indicated that it is possible to close the attainment gap between students of different backgrounds or mental structures. The current result has shown that providing a level playing ground for all individuals to ensure equity and equality in student's SPS is double and achievable.

Major Findings

1. The study provides a better understanding of constructivism and reconfirms the effectiveness of modular teaching.
2. What is novel in this research is that the findings shed light on which instructional strategy made a difference in fostering students' SPS across the two cognitive developmental levels (concrete and formal).
3. This study's overarching conclusion showed that instruction based on the 7E-IIM leads to better acquisition of SPS concepts and deepens understanding.

Implication

Considering the number of studies that adopt social and cognitive constructivist learning theory on how students can be guided to explore knowledge and skills is of major concern. Our study has confirmed the findings of previous studies on the need for science teachers to adopt a collaborative, problem-solving and hands-on strategy for students to explore their own experience and build the process skills for future application. The current finding has a few practical implications for science teachers. The finding indicated the need for science teachers to identify and align individual differences with a suitable approach for meaningful learning to occur. According to cognitive constructivist, in any classroom, there are students with different mental structure and failure to prepare instruction that fit the cognitive structure of learner result to not limited rote learning, but learning is likely to be less successful. Individual strategies to cognitive development differ greatly, and some may appear confusing and challenging to one person while appearing clear and straightforward to another (Pritchard, 2017).

This study has proven that individuals can perform and achieve better scores if provided with opportunities to explore their potentials. The results indicated that providing equity in classroom ensure equality of outcome across students of different cognitive developmental level. Observations from this study suggested that a certain approach is preferable for the level of cognitive development of students, if not quite necessary, for them to acquire necessary SPS. Furthermore, the findings of the study implied that to promote students' SPS through the 7E-IIM careful attention should be given to the design and development of the activities. These activities need to connect to their prior information (elicit stage), foster the students to trade ideas in their own words (engage stage), to develop students appropriate concrete experience to support their opinions by discussions with peers and teachers (explore), to provide hands and minds on engagements (elaborate Phase). For example, by asking students to test whether the volume of the water is changing when place in a different container, these and more related activities improve the understanding of scientific knowledge and knowing. Similarly, students should be engaged with more experimental situations to adopting a scientific process. They need to be allowed to design and perform experiments in which they can practice in applying various SPS. It can be suggested to develop activities that students able to experience the process of a real scientist in which they can realize how to construct the scientific knowledge through employing the necessary scientific skills such as observing, inferring, identifying variables, designing investigations, and communicating with the peers. The exploration and explanation phases of the 7E-IIM are suitable to embed this and more related activities which may benefit students to enhances the acquisition of SPS. Therefore, it is recommended that curriculum planners should take into cognizance the practical activities of students, providing hands and mind on activities.

CONCLUSION AND RECOMMENDATION

The overarching conclusion of this study showed that instruction based on the 7E-IIM leads to better acquisition of science concepts and promotes student's SPS. In educational system around the world, teachers are expected to guide students to explore knowledge and skills themselves. However, one of the challenges teachers face is selecting the appropriate strategies that suit the schema of individuals. Our adoption of 7E model as a strategy in developing the module has indicated significant effect in improving student's process skills. The findings of this study implied that promoting students' SPS required careful and systematic attention to the design and development of instruction. The instructions need to connect to individual prior information (elicit stage), foster the students to trade ideas in their own words (engage stage). The instruction also develops students appropriate concrete experience to support students' opinions by discussions with peers and teachers (explore), to provide hands and minds on engagements (elaborate phase). Students should be allowed to design and perform experiments to practice by applying various SPS. It can be suggested to develop activities that students can experience as real scientists to realize how to construct scientific knowledge by employing the necessary scientific skills such as observing, inferring, identifying variables, designing investigations, and communicating with peers.

The exploration and explanation phases of the 7E-IIM are suitable for embedding this and more related activities that may benefit students to enhance the acquisition of SPS. Therefore, it is recommended that curriculum planners take into cognizance the practical activities of students, providing hands and mind on activities. This study also established that instructors are required to identify the mental operation of their student in preparing the instruction. Identifying individual operational levels will bridge the gap of presenting information, not within the students' level of understanding and avoid assimilation or accommodation failure by individuals.

The overarching conclusion of this study showed that moduler teaching leads to better acquisition of science concepts and promote students SPS than the conventional approach. This study has also affirmed the effectiveness of modular teaching in promoting learning. This finding agrees with the work of (Ali et al., 2010; Matanluk et al., 2013; Nor, 2014). The authors report the suitability and effectiveness of modular teaching. Although previous studies have provided different teaching approaches, the present study's findings have indicated some gaps with the current practice in helping students explore knowledge and invariably promote their process skills. Thus, there is a need for curriculum developers to consider the findings and recommendations of the present study related to the practical outcomes of the curriculum to decide and carry out necessary revisions.

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Declaration of interest: Authors declare no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

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