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# INQUIRY MODELS-BASED INSTRUCTIONAL ACTIVITIES' EFFICACY AND GENDER OF JUNIOR SECONDARY SCHOOLS SCIENCE STUDENTS' PROCESS SKILLS IN BASIC SCIENCE AND TECHNOLOGY

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# Inquiry Models-based Instructional Activities' Efficacy and Gender of Junior Secondary Schools Science Students' Process Skills in Basic Science and Technology

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**Abstract**

*This study examined the effects of inquiry-based instructional strategies on student's science process skills in junior secondary school basic science and technology in Gombe Local Government Area of Gombe State. Simple random sampling technique was employed to select 180 Junior Secondary School two students from six schools in Gombe Local Governments, Nigeria for the study. Participants were randomly assigned to conventional (cookbooks laboratory), structured and guided inquiry-based instructional activities. The treatment lasted for 7 weeks. One main instrument was developed by the researchers, validated and used; Science Process Skills Test (r = 0.85). Two hypotheses were raised to test the significant difference between cookbooks laboratory, structured and guided inquiry-based instructional activities in basic science and technology and significant difference between gender and students' science process in basic science and technology in selected concepts. The two hypotheses were tested at 0.05 level of significance. Data were analysed using Analysis of Variance (ANOVA) and t -test analysis. The study revealed that there was significant difference in the students' science skills between students exposed to cookbooks laboratory, structured and guided inquiry-based instructional activities. The finding also indicated that there was significant difference in the science process skills of male and female students It was therefore recommended that basic science and technology teacher should be encouraged to inculcate science process skills in learners in involving students in inquiry-based learning activities.*

## Introduction

In Nigeria, the revised National Policy on Education (FRN, 2014, p. 12-14) stated that the need for scientific and technological progress of Nigeria as a nation necessitates the inculcation of the spirit of enquiry and continuity in the child through the exploration of nature and local environment from the pre-primary level so that, by the time the child would have passed through the primary school, a solid foundation for scientific and reflective thinking would have been laid. In addition, the policy emphasized the goals of science education to include the development of scientific literacy in the citizens. Hence, the significance of basic science and technology in both primary and junior secondary schools cannot be overemphasized.

Basic Science and Technology Curriculum is the production of a re-aligned, re-structured and revised curricula for Primary Science and Junior Secondary School Integrated Science. The overall objectives of this curriculum are to enable the learners to: develop interest in science and technology, acquire basic knowledge in science and technology and apply their scientific and technological knowledge and skills to meet societal needs. Other objectives include: it will enable the learners to take advantage of the numerous career opportunities offered by science and technology, become prepared for further studies in science and technology, develop learners' literacy and process skills, among others (NERDC, 2007, p. 4).

For the attainment of the stated objectives, Nigerian Educational Research and Development Council (NERDC, 2007, p. 4) recommended instructional strategies for the curriculum implementation such as open-ended laboratory, discovery method demonstration field trips, project, among others. The teaching of basic science and technology should not only concern with the teaching and learning of facts and theories in science, but researches on teaching that would enhance learners' science literacy and process skills in particular (Adodo & Ogundare, 2016, p. 35).

Science process skills are those that need to be acquired, practiced and demonstrated by students and to actualize this, requires specific instructional strategies. Science process skills are the foundation for scientific inquiry and intellectual development necessary to learn scientific concepts (Akerson & Hanuscin, 2007, p. 671). Kim and

McKinney (2007, p. 26) noted that developing science process skills facilitates daily students' problem-solving, critical thinking and making decisions. Science process skills acquisition is therefore the foundation for the meaningful learning of science even at the primary or basic level of education because it helps the learner to perceive the relevance of science in everyday life. Hill (2011, p. 112) described science process skills as the basic and fundamental skills which govern the scientific method. In other words, science process skills are used to gather information and facts about nature, hence, learners should learn by doing in order to maximize the learning of the nature of science. To be actively involved in learning may be actualized by inquiry-based instructional strategies which might enhance students' skills of observing, inferring, predicting, asking questions, constructing hypothesis and applying concepts and principles to solve daily problems (Hill, 2011, p.113).
Bell (2008, p. 10) sees these process skills as tools which scientists use to do science and that if children are properly introduced early to science through Process skills acquisition, will find the skills useful throughout life. He contends further that it is possible to easily forget science content(s) learnt but process skills learnt tend to remain with individuals for a longer period. Unfortunately, these process skills have been imparted to learners through conventional lecture methods for many years. Traditional/conventional methods of passing instruction in the classroom has been old as education itself which has resulted to memorization of scientific facts and rote learning and this has not been able to adequately enhance learners' science literacy and science process skills (Adodo & Ogundare 2016, p. 33).

As knowledge relating to learning and human development has increased rapidly, this also has led to the growth and modification of effective educational practices globally. As a result of this, demands integrating more insights across diverse instructional strategies that facilitate active learning, students' science literacy, science process skills and performance. Among such innovative educational practices and instructional strategies are inquiry-based learning, project-based learning, among others (Aliyu, 2015, p.71).
Inquiry activities are centre in the heart of scientific undertaken, therefore demands primary position in science instruction and learning. Inquiry refers to activities of learners by which they develop knowledge and understanding of scientific ideas and how understanding of scientists investigates the natural world (National Science Education Standards, National Research Council, Washington, DC, 1996, p. 32).
Involving learners in scientific inquiry activities helps them develop scientific literacy and give the students ample opportunity to practice important science process skills, critical thinking and problem -solving skills. Added to this, studies suggest that students participating in scientific inquiry activities can lead to achievement gains in science concepts, critical thinking and problem-solving skills (Banchi & Bell, 2008). The researchers are interested in testing the efficacy of two model's inquiry-based learning strategies thus: structured and guided inquiry-based learning. The study adapted the inquiry-based model of Bell, Smetana and Binns (2005, p. 25).

| | | How much information is given to the student? | | |
|---|---|---|---|---|
| | Level of Inquiry | Question? | Methods? | Solution? |
| Teacher-Directed | 1- Confirmation | √ | √ | √ |
| | 2- Structured | √ | √ | |
| | 3- Guided | √ | | |
| | 4- Open | | | |
| Student-Directed | | | | |

Figure 1: Four-level model of inquiry (Bell, Smetana & Binns, 2005, p. 25)

This model of inquiry instruction indicates how inquiry-based activities can vary from highly teacher-directed to highly student directed, based on the amount of information provided to the learner.
Level 1 is referred to as "cookbook laboratories," or conventional activity in that the procedure is typically laid out for students in a step-by-step sequence. It provides students with the research question and the method through which the research question should be answered. The expected answer to the research question is known in advance. In these activities, students are establishing what is already known.
Level 2 is referred to as structured inquiry in which students are given a research question and the prescribed procedure, but the answer to the research question is not known in advance.
Level 3 (guided inquiry activities) and Level 4 (open inquiry activities) are characterized as "high level" inquiry activities, as they require significant cognitive demand on the part of the student. In Level 3 inquiry activities, students are presented with a teacher-posed research question, but students devise their own methods and solutions to answer the question. In this "guided inquiry," students practice research design.

Level 4 inquiry activities are those in which students are responsible for choosing the research question, designing their own procedure for answering the question, and developing their own solutions to the research question.
Structured inquiry-based instruction is where students engage in a student driven inquiry process, teacher provided the method but without answers to investigation questions (Peters, 2009, p. 79). He claimed that an instructional strategy like project-based learning, which is structured, allows for many of the parameters in learning environments to exist. Students learn in authentic contexts, do chosen tasks of their own, collaborate with others, and have access to peers who share expertise ideas. Since students were allowed to work in groups of their peers; students were more motivated to learn new material because they had the opportunity to bounce ideas off of each other in a collaborative effort. This intervention allowed students to become motivated because inquiry-based learning uses authentic problems to solve.

Peters (2008, p.30) described structured inquiry-based teaching method as "a learning approach based on students working for a period of time in order to intensively investigate the real-world issues or problems in an interdisciplinary approach so as to produce something concrete through individual efforts or group work. Students try to resolve the encountered problems cooperatively, become decision makers on their successes, life is brought into the classroom and the classroom is transferred to life (Pandey, 2017, p. 72).

Luft, Bell and Gess-Newsome (2008, p. 65) in their work of structured inquiry-based learning on elementary school student's science process skills acquisition in elementary sciences asserted that structured inquiry activities had a significant effect on science process skills acquisition. It also revealed that gender was not a significant factor in student's science process skills acquisition in elementary science. In a similar study, Peters (2009, p. 74) in a study of shifting to a student-centered science classroom instruction, in Virginia discovered that structured model of inquiry-based students' learning activities enhanced critical thinking and students' science process skills acquisition.

Guided inquiry-based instruction enables the teacher to give research problem to learners, students design their experiment or method and find solution to the problem (Peters, 2009, p. 70). In this method, students solve problems and make decisions by being given or creating specific situations and complex problems.
Wachanga (2014, p. 366) a study on effects of guided inquiry-based learning on secondary school student's science process skills in chemistry in Nyado District, Kenya observed that guided-based learning enhanced student's science process skills in chemistry. Added to this, Bell, Smetana and Binns (2005, p. 36) in a study on simplifying inquiry instructions activities in the classroom/laboratory setting in Virginia noted that guided inquiry-based instruction activities promoted students' acquisition of science literacy and science process skills.

Cookbook laboratories or conventional learning activity refers to the procedure that is typically laid out for students in a step-by-step sequence. It provides students with the research question and the method through which the research question should be answered. The expected answer to the research question is known in advance. In these activities, students are establishing what is already known. This is the method of teaching that emphasizes "talk and chalk" to the teaching of science subjects. More than 70% of scientific information and principles are delivered as lectures. Science teachers embraced this method for easy coverage of the school syllabus. It is characterized by the one-way flow of information. The lecture method has been criticized for not promoting higher order skills such as conceptual understanding, independent learning, and problem-solving which are better seen as fostered by more innovative instructional methods like problem-based learning (Adodo & Ogundare, 2016, p. 32).
However, the influence of gender on students' science literacy in science has for a long time been a concern to many researchers and science educators. Studies carried out in the United States overwhelmingly show the image of a scientist as a white, bespectacled male wearing a laboratory coat and holding a test tube. Most of the illustrative diagrams and pictures in the science textbooks show males doing experiments (Edgar, 2014, p. 61).
Owo and Glory (2019, p. 327) of their gender differences in basic science performance in private secondary schools in Abio/Akpor Local Government Area of Rivers State showed that female students preferred inquiry-based learning to competitive one. It is therefore possible that interaction between boys and girls in coeducational schools may enhance students' academic performance leading to science learning among the girls in co-educational schools than in single girls' schools. Ekon and Eni (2015, p. 99) a study on gender differences in basic science achievement and the acquisition of science process skills among in private secondary schools in Abio/Akpor Local Government Area of Rivers State found out that gender did not significantly influence the acquisition of science process skills at the upper basic level of universal basic education. This study therefore, investigated the effects of inquiry-based instructional strategies on student's science process skills in junior secondary school basic science in Gombe Local Government Area of Gombe State.

**Statement of the Problem**

The objectives of Basic science are clearly stated in the National Policy of Education (NPE, 2014, p. 12-13). Federal Minister of Education (2020, p. 9) noted that the objectives are still far from being achieved. Among the primary objective is students' acquisition of science process skills that will promote learners' scientific literacy. This might account for the gap created by learning and teaching processes of basic science in Junior Secondary Schools (JSS) as a result of basic science teachers' curriculum delivery. Omorogbe (2013, p. 60) observed that most teachings in basic science at elementary schools emphasized theory rather than practical aspects of the subject and most of them lack adequate acquisition of learners' science process skills. Omebe and Omiko, (2015, p. 175) remarked that various instructional strategies such as discovery, problem-solving, open-ended field trips collaborative and laboratory among others had been employed to enhance learners' acquisition of science process skills in the basic science curriculum instruction for several years, yet learners' acquisition of science process skill is still low. Hence, the researchers are interested in finding out whether inquiry-based instructional strategies would facilitate learners' science process skills. Therefore, this study focuses on the effects of two model inquiry-based instructional strategies on Junior Secondary School (JSS) basic science and technology students on science process skills in Gombe Local Government Area of Gombe State, Nigeria.

**Purpose of the Study**

The purpose of this study is to examine the effects of two model inquiry-based instructional strategies on student's science process skills in junior secondary school basic science and technology in Gombe Local Government Area of Gombe State. Specifically, the objectives are to: investigate the effects of the two-model inquiry-based instructional strategies on learners' science process skills in basic science and technology, examine the effects of lecture method on acquisition of students' science process skills in basic science and technology and to determine the difference of male and female students' acquisition science process skills in basic science and technology.

**Research Hypotheses**

$H0_1$: There is no significant difference between mean score science process skills of students exposed to structured-based, guided inquiry-based and cookbook laboratory/conventional instructional strategies.

$H0_2$**:** There is no significant difference between gender and students' science process skills in basic science and technology.

**Methodology**

**Design and participants**

The population of the study consists of all nine hundred and seventy-three JSS II basic science and technology students in public Junior Secondary Schools in Gombe Local Government Area of Gombe State. A sample of 180 of JSS II basic science and technology students using intact class from six junior secondary schools randomly selected from Gombe Local Government Area of Gombe State, Nigeria participated in the study using quasi-experimental design. From the selected schools, each school was randomly assigned to treatment group. In all, two schools were exposed to structured inquiry-based learning activities made up of 60 students, two schools exposed to guided inquiry-based learning activities comprised 60 learners and two schools exposed to lecture method by the researchers comprising of 60 students made up of 93 male and 87 female participants.

**Instruments**

One main instrument was developed, validated and employed for data collection. The instrument titled Science Process Skills Test (SPST, r = 0.85) was used to test participants' science process skills in basic science and technology concepts, such as habitat, changing in living things, changing in non-living things, kinetic energy and thermal energy. It was made up of 20 multiple-choice based on basic science process skills such as observation, classifying and analysing of data, communicating, estimating, inferring, interpreting, measuring, observing and predicting. Each correct answer earned the participant 1 mark and wrong answer earned the participant zero (0) mark.

The validity and reliability of the instrument was established using experts' judgement in the Department of Science Education, Federal University of Kashere, Gombe State to ascertain that the instrument measured learners' science process skills in the selected concepts in basic science and technology. Kuder-Richardson 20 measure of internal consistency was employed to determine reliability for SPST multiple choice items yielding an alpha value of 0.85.

**Procedures**

Data collection comprised three stages: pretest stage lasted for one-week, experimental stage lasted for five weeks and posttest stage lasted for one week respectively.

**1. Experimental group I (Structured Inquiry-Based Instructional Activities Guide)**

Step 1 The teacher introduced the lesson to the students by asking questions from the students on the previous lesson for 5 minutes.
Step 2 The teacher asked questions from the students on their previous knowledge/entry behaviour to test their knowledge on the topics for 5 minutes.
Step 3 The teacher taught and explained the topic for the day for 10 minutes.
Step 4 The teacher stressed and explain the basic science process skills relating to the concepts taught for 5 minutes.
Step 5 The teacher grouped the students into five members of different ability for 5 minutes.
Step 6 The teacher gave the research questions to each group for 5 minutes
*Step 7 The teacher gave the method/prescribed procedure to the participants/groups to follow and find solutions on their own for 30 minutes
Step 8 The teacher moved round the class to monitor the activities of the students in each group with no interference.
Step 9 The students asked questions on their discoveries from the teacher for 5 minutes.
Step 10 Each group briefs the class on their discoveries for 5 minutes.
Step 11 The teacher took all the summaries and discoveries of each group and gave solutions to problems on the relevant topics for 5 minutes.
Step 12 Students took assignment from the teacher.

**2. Experimental Group II (Guided Inquiry-based Instructional Activities Guide)**

Step 1 The teacher introduced the lesson to the students by asking questions from the students on the previous lesson for 5 minutes.
Step 2 The teacher asked questions from the students on their previous knowledge/entry behaviour to test their knowledge on the topics for 5 minutes.
Step 3 The teacher taught and explained the topic for the day for 10 minutes.
Step 4 The teacher stressed and explain the basic science process skills relating to the concepts taught for 5 minutes.
Step 5 The teacher grouped the students into five members of different ability for 5 minutes.
Step 6 The teacher gave the research questions to each group for 5 minutes.
Step 7 Students/groups devise their own methods and find solutions to the question for 30 minutes.
Step 8 The teacher moved round the class to monitor the activities of the students in each group with no interference.
Step 9 Each group briefed the class on their findings for 5 minutes.
Step 10 The students asked questions on their findings from the teacher for 5 minutes.
Step 11 The teacher summarized the findings of each group and gave solutions to the problem on the relevant topic for 5 minutes.
Step 12 Students took assignment from the teacher.

**3. Control Group ("Cookbook Laboratory" Method Guide)**

Step 1 The teacher introduced the lesson to the students by asking questions from the students on the previous lesson.
Step 2 The teacher asked questions from the students on their previous knowledge/entry behaviour to test their knowledge on the topics.
Step 3 The teacher taught and explained the topic for the day, emphasizing the basic science Process skills to the students.
Step 4 The teacher asked questions from the students to test how far they understood the topic taught.
Step 5 The teacher raised the question, design the method/experiment and proffered solution to the research question.
Step 6 The teacher wrote notes on the chalkboard for the students to copy in their notebooks.
Step 7 The students copied notes written by the teacher from the chalkboard.
Step 8 The teacher gave assignment to the students to solve from home.
Step 9 The teacher evaluated the lesson by asking questions from the students on the topic taught.

Data collected were analyzed using mean and standard deviation inferential statistics such as Analysis of Variance (ANOVA) to determine the significant difference among the three groups and t-test to determine the significance difference participants' gender.

**Results**

$H0_1$: There is no significant difference between mean score science process skills of students exposed to structured-based, guided inquiry-based and cookbook laboratory/conventional instructional strategies.

**Table 1: One-way Analysis of Variance (ANOVA) of the Mean Score Science Process Skills of Basic Science and Technology Students exposed to Structured, Guided-based and Conventional Instructional Strategies.**

| Source | SS | Df | MS | F | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|
| Corrected Model | 292.133[a] | 2 | 146.07 | 16.60 | .000 | .153 |
| Intercept | 33211.25 | 1 | 32211.25 | 3774.00 | .0 00 | .955 |
| Experimental | 292.13 | 2 | 146.07 | 16.60 | .000 | .158 |
| Error | 1557.62 | 177 | 8.80 | | | |
| Total | 35061.00 | | 180 | | | |
| Corrected Total | 1849 | | 179 | | | |

a. R Squared = .158 (Adjusted R Squared = .148)

Table 1 reveals that there was a significant effect of treatment on students' science process skills in basic science and technology ($F_{(2,177)} = 16.60$, $P < .05$), $\eta^2 = 0.158$. Treatment accounted for 15.8% variation of students' science process skills in basic science and technology by simply multiplying 0.158 by 100. Hence, hypothesis 1 is rejected. In order to determine the magnitude of the posttest mean scores in science process skills across the treatment groups, the estimated mean scores are presented in Table 2.

**Table 2: Mean scores of Science Process Skills of Basic Science and Technology Students exposed to Structured, Guided-based and Conventional Instructional Strategies.**

| Experimental Group | N | Mean | Std. Deviation |
|---|---|---|---|
| Structured-based learning | 60 | 13.92 | 3.169 |
| Guided-based learning | 60 | 14.95 | 3.285 |
| Conventional Method | 60 | 11.88 | 2.358 |
| Total | 180 | 13.58 | 3.215 |

Table 2 reveals the mean science process skills of students exposed to structured-based, guided-based and conventional instructional strategies as 13.92, 14.92 and 11.88 respectively. The guided inquiry-based instructional strategy showed the highest mean score of 14.92 followed by structured inquiry-based instructional strategy with 13.92 and cookbook laboratory/conventional method with the least 11.88 respectively. This shows that the guided inquiry-based enhanced students' science process skills better than others in basic science and technology.

$H0_2$**:** There is no significant difference between gender and students. science process skills in basic science and technology.

**Table 3: t-test analysis of Mean scores of Male and Female Students Science Process Skills Exposed to Conventional and Inquiry-Based Instructional Activities in Basic Science and Technology.**

| Variable | N | Mean | SD | SE | DF | t-value | p | Remark |
|---|---|---|---|---|---|---|---|---|
| Male | 93 | 14.57 | 3.376 | .356 | | | | |
| Female | 87 | 12.60 | 2.276 | .287 | 178 | 4.300 | .000(2tailed) | *sig. |

Significant at $P \leq 0.05$

Table 3 reveals t-test analysis of mean scores of male and female students' science process skills exposed to structured, guided inquiry-based and conventional instructional strategies. It revealed that male and female students' science process skills had significant difference (mean of = 14.57 and 12.60) respectively. The mean difference between the two groups was 1.064 and 95% interval for the estimated population mean difference is between 1.064 and 2.869. The effect size was fairly large (d = 0.12). An independent sample t-test showed that the difference between the male and female students' science process skills achievement was significant (t = 4.300, df = 178, p = .000, two tailed). Therefore, hypothesis 2 is rejected.

**Discussion**

The findings in this study revealed that participants exposed inquiry-based strategies had better science process skills post mean scores than of conventional group (cookbooks laboratory). This may be as a result of the critical thinking and high inquiry activities inherent in the inquiry-based strategies which involved active participation of learners, critical thinking, high cognitive task and challenges it demand. This also gives further empirical support to other findings which indicate that inquiry-based activities are more effective in students' acquisition science process skills than the conventional methods (Luft, Bell and Gess-Newsome, 2008; Peters, 2009; & Wachanga, 2014).

The poor performance of the conventional/cookbooks laboratory activities method group in the posttest science process skills in selected concepts in basic science and technology when compared with those in structured and guided inquiry-based instructional strategies group may be traced to the fact that the group was taught with method that was teacher-centred. In addition, it may be connected with the fact of inadequate utilization of high cognitive level and critical thinking on the part of the participants which is an attribute of the conventional/cookbook activities method. The conventional method does not seem to actively involve learners in teaching and learning processes. It allows the students to passively listen to the teacher with little or no interaction with the teacher and other students, thus making students to resort to memorizing of facts. The poor performance in the conventional group corroborates the findings of Adodo and Ogundare (2016).

The result in Table1 showed that there were significantly main effects of gender on students' science process skills in basic science and technology. The estimated marginal means of scores of genders in Table 3 shows that male learners had the highest adjusted mean scores than their female counterparts in science process skill in basic science and technology. The results revealed that male students had highest adjusted mean scores than female in the post science process skills scores than their female counterparts across the groups. This finding might be linked with the fact that male learners are more inclined to critical thinking than their female counterparts, most especially, in inquiry-based learning activities that require dexterity to observe, handle, manipulate objects. This might also have had significant effect on the students' science process skills in basic science and technology. This result supports the findings of Owo and Glory (2019) who concurred that gender plays significant difference in the acquisition of science process skills of learners in favour of males. However, the finding negates the results of Ekon and Eni (2015) that discovered in their studies that there is no significant difference in students' science process skills of boys and girls in science subjects.

**Conclusion**

The study established the fact that guided inquiry-based instructional activities enhanced better students' science process skills than structured inquiry-based and conventional/cookbooks instructional activities. The reason for this was that participants exposed to guided inquiry-based strategy were able to use high cognitive level and critical thinking in finding solutions to problems. The study also established that male learners had highest adjusted mean scores in the post science process skills scores than their female counterparts across the groups. Arising from the foregoing, it is concluded that inquiry-based learning activities enhanced students' science process skills on one hand, while male learners outperformed their female counterparts exposed to the same learning conditions. This implies that female students still need to be encouraged by basic science and technology teachers in involving more in inquiry-based learning activities for science process skills acquisition.

**Recommendations**

Based on the findings of this study the following recommendations are therefore made.

1. The guided and structured inquiry-based instructional strategies are recommended for teaching basic science and technology at junior secondary schools for acquisition science process skills in basic science and technology.
2. At federal, state and local government levels, seminars, conferences, symposia among others should be organized for service and in-service teachers on the use of inquiry-based activities.

3. Curriculum planners and developers should incorporate and emphasize inquiry-based learning in the curricula at all levels in Nigeria. Teachers should be encouraged to use them.
4. Students should be allowed to perform all tasks simple, complex or abstract with inquiry-based in basic science and technology classroom instructions.
5. Educational institutions saddled with the responsibility of training teachers should train and emphasize inquiry-based activities in curriculum instructions This will assist the teachers to apply these inquiry-based instructional strategies in teaching.

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