Instrument Development: How to Measuring Inquiry Skills

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Abstract. The literature study discusses how to measure inquiry skills. This literature study aims to determine and develop a form of measurement of inquiry skills. The method used is a systematic literature review. The initial literature obtained was selected based on predetermined criteria, namely: 1) English-language articles and international reputation; 2) Articles are collected from an electronic database (Google Scholar) using the following keywords: "inquiry skills"; 3) Search is limited to articles published from 2010 to 2022; and 4) The article contains a clear identity such as title, year, and type of assessment of the inquiry skills used. The results of the literature study: 1) Inquiry skills are skills needed to carry out the process of scientific inquiry; 2) The inquiry skills stage consists of identifying problems, formulating research questions, formulating hypotheses, planning experiments, conducting experiments, analyzing and interpreting results, and drawing conclusions; 3) Developing an assessment that refers to these stages to measure the accomplishment of inquiry skills; 4) The development of assessment instruments used to measure the stages of inquiry skills can refer to practicum planning activities, the form of essay questions that ask students to write answers about the design and conclusions of the practicum or experiment.

Keywords: inquiry skills; instrument inquiry skills, assessment inquiry skills

1 Introduction

Inquiry skills are a person's ability to formulate problems, and hypotheses, plan investigations, carry out investigations, to make conclusions in the form of explanations [1]. Inquiry skills can be applied by observation or experimentation to obtain information [2]. Inquiry skills are closely related to critical and logical thinking skills [3]. These critical and analytical thinking skills are used so that a person can master inquiry skills according to the stages.

Students need inquiry skills to investigate the object being studied and help construct students scientific knowledge. Inquiry skills are also required to carry out activities in the laboratory, which are essential and become an integral part of science learning [4]. Inquiry skills are trained through working collaboratively and communicating in teams [5].

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However, very few inquiry processes take place in science classes [6], so many students lack their inquiry skills, such as asking questions [7], designing experiments [8], collecting data, and drawing conclusions [9]. As a result, many teachers feel that students are underperforming, especially in the practice of inquiry. These findings suggest that students unfamiliar with direct inquiry, can only show relatively low skills. Therefore, inquiry skills need to be considered in research [6].

A way to assist teachers in understanding and to help students develop inquiry skills is by identifying strengths and weaknesses in their science inquiry skills. If the student wants to learn how science is carried out, then at least three important conditions are needed: 1) the teacher must understand the process of science itself; 2) students should have many opportunities to practice their skills; and 3) students must understand whether or not they are advancing in the achievement of their skills [10].

The factors identified as influencing inquiry skills to face difficulties in improving inquiry skills include: 1) the learning environment and the nature of the topic, namely lack of teaching materials, lack of visual representation, unplanned inquiry skills activities, abstract and complex topics; 2) problems related to teachers, namely if the teacher in the school is old, a knowledge provider and not a facilitator; 3) problems related to students, namely passive, boring, confusing [11]. In general, the learning environment, the nature of the topic, and problems related to teachers and students are the root causes of difficulties in student inquiry skills. Therefore, the right way is needed to measure inquiry skills so that students can meet each stage of inquiry skills. It is necessary to innovate the development of appropriate instruments to measure student inquiry skills.

2 Research Method

The method used is Systematic Literature Review (SLR). The guidelines used in the literature review of this study are PRISMA. PRISMA provides methodological standards for selecting literature that can be used. SLRs are performed to identify, analyze, and interpret all available information. The SLR stage begins with determining the formulation of the research problem. The research problem formulation is "how to develop the right assessment instruments to measure students' inquiry skills?"

Searching for literature is carried out by determining criteria related to inquiry skills. The initial literature obtained was selected based on predetermined criteria, namely: 1) English-language articles and international reputation; 2) Articles are collected from an electronic database (Google Scholar) using the following keywords: "inquiry skills"; 3) Search is limited to articles published from 2010 to 2022; and 4) The article contains a clear identity such as title, year, and type of assessment of the inquiry skills used.

Selecting articles that match the criteria is carried out by filtering titles, abstracts, and keywords. The literature results based on the requirements amounted to 97 articles. Still, after being analyzed based on research and discussion methods, 24 articles were finally selected that could be used as study materials following the research objectives.

The article discusses the explanation of inquiry skills, the stages of inquiry skills, types of assessment to measure inquiry skills, and innovations in assessment development to measure inquiry skills.

3 Result and Discussion

The results of this study obtained 24 articles that discussed assessment to measure inquiry skills. Articles are reviewed and extracted data, including year, author, title, and reviews. The data is shown in Table 1.

Table 1. Inquiry Skills Research Articles

No	Year	Author	Title	Review
1	2021	Elif Ozturk	The Effect of STEM Activities on the Scientific Inquiry Skills of Pre-service Primary School Teachers	Inquiry skills can be measured by the VASI (Views About Scientific Inquiry) instrument developed to identify students, prospective teachers, and scientists' views on inquiry and scientific understanding related to inquiry skills. The VASI instrument focuses on investigation skills that require the ability to think, criticize, and reason.
2	2020	Hasan Ozgur Kapici & Hakan Akcay	Enhancing preservice science teachers' inquiry skills in hands-on and virtual laboratory environments	The inquiry skills test is in the form of multiple choice developed by Çelik (2013). The test was given to prospective science teachers with 35 questions. The questions are related to the ability to compile hypotheses, infer, identify, control variables, and design and implement investigations.
3	2021	Setiono, Nuryani Y Rustaman , Adi Rahmat, & Sri Anggraeni	Inquiry skills for biology teacher candidates in plant anatomy practicum	Inquiry skills tests are developed based on indicators of inquiry skills (National Research Council, 2012).
4	2019	Evi Elisanti, Ratu Betta Rudibyani, Sajidan, Baskoro Adi Prayitno, Ryzal Perdana, K. F. Nuri Wulandari	Analysis of Students' Inquiry Skills in Senior High School Though Learning Based on the Hierarchy of Inquiry Model	The inquiry skills assessment instrument uses a test level of inquiry. Student skills are demonstrated with the student's level inquiry assessment instrument.
5	2018	Monde Kazeni, Eddy Baloyi & Estelle Gaigher	Effectiveness of individual and group investigations in developing integrated science inquiry skills	The instrument used to measure inquiry skills is the Test of Integrated Science Process Skills (TISPS), developed and validated by Kazeni (2005). The form question is in the form of multiple-choice. The test questions assess students' competence in Integrated Science Inquiry Skills (ISIS).
6	2018	Udomdeja Polyium, Tussatrin Wannagatesiri, Kulthida Nugultham	Effect of practical work on students' inquiry skills for hydrocarbon compounds classification tests	Inquiry skills are assessed using laboratory reports while students are studying in class. The laboratory report format is designed to meet the aspects of inquiry skills: introduction, materials and method, result, discussion, and conclusions.
7	2017	Safiye Aslan	Learning by Teaching: Can It	Instruments are used to measure inquiry skills using the Inquiry Skills Scale. Questions are categorized into

No	Year	Author	Title	Review
			Be Utilized to Develop Inquiry Skills?	three factors: acquisition of information, control of information, and self-confidence.
8	2017	U Hasanah, I Hamidah and S Utari	Trained Inquiry Skills on Heat and Temperature Concepts	The instrument was developed based on the aspect of inquiry skills which amounted to 15 multiple-choice questions that used reasoning.
9	2018	H Saputra, A Suhandi and A Setiawan	Profile of inquiry skills preservice physics teacher in Aceh	Data collection uses the Scientific Inquiry Literacy Test (ScInqLiT) developed by Wenning (2007). Questions take the form of multiple choices.
10	2018	Fatma Alkan & Canan Kocak Altundag	The Effect of Inquiry-Based Chemistry Experiments Practıces on Inquiry Skills and Scientific Creativity	The instrument for measuring inquiry skills uses a Likert scale developed by Aldan Karademir and Saracaloglu (2013), consisting of 14 questions. Questions were used regarding the acquisition of information, control, and self-confidence.
11	2018	Elena Čipková and Štefan Karolčík	Assessing Of Scientific Inquiry Skills Achieved By Future Biology Teachers	The research instrument for examining inquiry skills uses instruments that Fradd, Wenning, and Gormally have developed. The instrument focuses on the methods and procedures of science as well as the integrase of science into life.
12	2014	Hsin-Kai Wu & Chou-En Hsieh	Developing Sixth Graders' Inquiry Skills to Construct Explanations in Inquiry-based Learning Environments	The author developed the inquiry skills test with the basic concepts of The Test of Integrated Process Skills belonging to Burns, Okey, and Wise (1985) and TIMSS (2003). The level of inquiry skills assessed is identifying causal relationships and using data as evidence.
13	2015	Yiping Lou, Pamela Blanchard & Eugene Kennedy	Development and Validation of a Science Inquiry Skills Assessment	The six primary skills are: (1) identify questions for scientific investigations, (2) design scientific investigations, (3) use tools and techniques to gather data, (4) analyze and describe data, (5) explain results and conclude, and (6) recognize alternative explanations and predictions.
14	2021	Michael Leonard D. Lubiano, Marife S. Magpantay	Enhanced 7E Instructional Model towards Enriching Science Inquiry Skills	The inquiry skills test consists of 40 multiple choice question items containing statements about inquiry skills.
15	2013	Mary E. Arnold, Virginia D. Bourdeau, and Brooke D. Nott	Measuring Science Inquiry Skills in Youth Development Programs: The Science Process Skills Inventory	The research instrument uses The Science Process Skills Inventory with 11 items of 4-point Likert scale questions. Assessment of instruments focuses on the scientific step and the process of inquiry.
16	2017	Leo A. Siiman, Margus Pedaste, Mario Mäeots, Äli Leijen, Miia Rannikmäe,	Design and Evaluation of a Smart Device Science Lesson to Improve	Inquiry skills assessment uses a paper-based test in the form of multiple choice—the question item measures identifying variables as well as identifying and stating a hypothesis. The

No	Year	Author	Title	Review
		Zacharias C. Zacharia, Ton de Jong	Students' Inquiry Skills	tests used are the Test of The Integrated Science Process Skills (TIPS) and TIPS II.
17	2016	Burak Feyzioğlu	The role of inquiry-based self-efficacy, achievement goal orientation, and learning strategies on secondary-school students' inquiry skills	The test to measure inquiry skills was developed by Aydogdu (2012). The test consists of 27 multiple-choice questions.
18	2014	Margus Pedastea & Tago Sarapuu	Design principles for support in developing students' transformative inquiry skills in Web-based learning environments	The instrument used consists of 30 question items, which assess: students' ability to compile inquiry stages, identify correct research questions, evaluate formulating skills, formulate hypotheses, evaluate and read data, and make conclusions.
19	2013	Jinlu Wu	Mutation-Based Learning to Improve Student Autonomy and Scientific Inquiry Skills in a Large Genetics Laboratory Course	Inquiry skills are assessed by laboratory activities that are compiled into a report. Assessment rubrics that are assessed regarding content and performance. Rubric content includes: introduction, hypothesis, prediction, how it works, tools and materials, data result design and analysis, Rubric performance includes: work safety, punctuality, and preparation.
20	2015	Michal Zion, Tova Michalsky& Zemira R. Mevarech	The effects of metacognitive instruction embedded within an asynchronous learning network on scientific inquiry skills	The inquiry skills measurement instrument uses the Test of Domain-Specific Inquiry Skills (TODIS). The TODIS compiled refers to the PISA assessment, with two parts of the study. The first part consists of 10 open-ended questions requested to explain the scientific events presented, and the second part consists of 5 open-ended question items that ask students to design an experiment.
21	2017	Duongdearn Pinsuwan	The Development Of A Distance Training Package For Secondary School Teachers On The Topic Of Teaching To Develop Scientific Inquiry Skills	The instrument used to measure students' inquiry skills is in the form of displaying answer questions related to problems.
22	2019	Setiya Utari, Eka Cahya Prima	Designing Inquiry-based Laboratory on Concave Eyeglasses Experiment to exercise Student's Science Inquiry Skills	The instruments are designed to analyze student inquiry activities, such as how students understand problems, choose experiments, choose methods, structure procedures, analyze data, and draw conclusions.

No	Year	Author	Title	Review
23	2011	Mario Mäeots, Margus Pedaste, Tago Sarapuu	Interactions between inquiry processes in a web-based learning environment	The inquiry assessment is carried out through 5 stages. The assessment of the inquiry process consists of formulating research questions and hypotheses, planning an experiment, conducting it, and making inferences.
24	2020	Rumondang Purwati, Suci Paramitha Liestari, Tri Suwandi, Ana Ratna Wulan, Setiya Utari	Profile of Learning Experiences and Students' Scientific Inquiry Skills in Science Subjects	Inquiry skills measurement instrument in the form of a questionnaire of 5 scales consisting of 40 items. Questions on the questionnaire regarding learning motivation, frequency of practicum, preparation of investigations, implementation of investigations, investigative support activities, activities outside the classroom, learning resources, and facilities.

3.1 Inquiry Skills

Inquiry skills are defined as the ability of students to participate in scientific investigations [12]. Inquiry skills are skills needed to carry out the scientific inquiry process [5]. Inquiry skills are what students use to understand the world around them [13]. Inquiry skills are the basis for learning science content and allow students to apply and develop scientific practice skills [14]. Inquiry skills are needed to obtain information through observation or experimentation to solve a problem using critical and logical thinking skills, including identifying issues, formulating research questions, formulating hypotheses, designing experiments, conducting experiments, analyzing and interpreting results, and drawing conclusions [15]. Teaching methods commonly used to develop inquiry skills include demonstrations, individual practical work, group work, and computer simulation experiments [16].

Inquiry skills develop best in the context of rich practices in activities [17]. Each step of the practicum activity is designed so that students gain experience by conducting an inquiry to train students' inquiry skills and help students construct their knowledge [4]. Inquiry skills allow individuals to design and conduct scientific research to develop effective solutions to their problems as they interact with their environment [16]. The more often students plan their experiments and practicums, the higher the achievement of students' scientific inquiry skills [18]. The development of inquiry skills will not only allow students to build their understanding of the world around them but also to understand the nature of science, inquiry, and scientific reasoning [19].

3.2 Inquiry Skills Stages

Inquiry skills, according to Pedaste et al. (2012), consist of 7 stages, namely: 1) identifying the problem; 2) formulate research questions; 3) formulate hypotheses; 4) planning experiments; 5) conducting experiments; 6) analyzing and interpret the results, and 7) draw conclusions and present findings. The seven stages are interconnected and supportive in training students' inquiry skills. The seven stages of inquiry skills can be described as follows:

- Identifying the problem: students can identify the problem by paying attention to all the factors likely to have an effect.
- Formulating research questions: students can create research questions using the correct question word to construct problem formulations that correctly link between free variables and bound variables. Students can formulate problems logically, investigatable, focused, and detailed.
- Formulate hypotheses: students can draw up hypotheses that correspond to the formulation of the problem, devise hypotheses that can be tested through experimentation, make detailed and correct hypotheses in stating the relationship between free variables and bound variables, and draw up hypotheses in the form of statistical symbols.
- Plan an experiment: Students can determine the test and the number of test units and errors and determine materials and tools according to size. Students can define operational definitions of bound variables. Students can draw up experimental procedures/steps.
- Conducting experiments: students can correctly select materials and tools. Students can follow the correct procedure. Students can collect data and record it. Students can control disruptive variables.
- Analyze and interpret the results: students can determine the correct way the data is presented and the right reasons.
- Draw conclusions and present findings: students can answer the formulation of the problem, prove hypotheses that indicate the acceptance and rejection of hypotheses, and mention the error and recombination.

3.3 From of Assessment on Inquiry Skills

The points that are crucial strategies that can be applied in inquiry skills are: 1) providing opportunities for students to use inquiry skills in exploring materials and phenomena directly; 2) Asking questions that require the use of skills (and giving time to think and answer); 3) Provide opportunities for discussion in small groups as well as large groups; 4) Encourage a critical review of how activities have been carried out; 5) Provide the access and techniques needed to improve skills; 6) Involve the child in communicating in various forms and reflecting on his thoughts [19]. The strategy can be empowered with an appropriate assessment form to measure student inquiry skills. The form of assessment to measure inquiry skills can be questionnaires, interviews, multiple choice, report writing, scales, open-ended questions, and essay.

The form of questionnaires and interviews is more often used to find out the inquiry skills of students by giving questions to the teacher about the skills of their students at which level of inquiry [21]. The multiple-choice question form is the form of a question that is most often used to measure students' inquiry skills. Multiple choice assessment can be used to measure several indicators of inquiry skills, such as compiling hypothe-

ses, concluding, identifying, controlling variables, designing and implementing investigations [22]; identifying variables serta identifying and stating hypothesis [23]; observing, classifying, making inference, speculating, using space and time relationship, detecting problem, hypothesizing, determining and controlling variables, doing an experiment, and acquiring data skills [24]; formulating a hypothesis, identifying and managing variables, operationally defining variables, designing and conducting experiments, graphing, and interpreting data [16].

Report writing is a form of assessment used to measure student inquiry skills. Reports written by students must be to be described by students. Some examples of report sequences are as follows: introduction, materials and method, result, discussion, and conclusions [13]; introduction, hypothesis, prediction, how it works, tools and materials, design of data results and analysis, in addition to assessing student activities through occupational safety, punctuality, and preparation [25]. The scale is often used to measure students' inquiry skills. The scale used is the Likert scale. Some of the indicators assessed using a scale include: acquisition of information, control of information, and self-confidence [26]; science steps and inquiry process [27]; learning motivation, practicum frequency, investigation preparation, implementation of investigations, investigation support activities, activities outside the classroom, learning resources, and facilities [18].

The provision of assessment in the form of open-ended questions is a form of assessment that can be used to measure students' inquiry skills; through open-ended questions, students are asked to explain the scientific events presented and design experiments [28]. The form of an assessment essay or long answer is almost the same as open-ended questions that ask students to explain an event [29].

3.4 Develop Assessment to Measure Inquiry Skills

An assessment form that can be used appropriately to determine the achievement of the inquiry skills stage is to compile a report following the inquiry skills stage. Reports can be assembled correctly if students analyze practicum activities or planning [30]. Inquiry skills develop best in the context of practice planning [17]. Each step of the practicum activity is designed so that students gain experience by conducting an inquiry to train students' inquiry skills and help students construct their knowledge [4]. Inquiry skills allow individuals to design and conduct scientific research to develop effective solutions to their problems as they interact with their environment [16]. The more often students plan their experiments and practicums, the higher the achievement of students' scientific inquiry skills [18].

The development of assessment instruments used to measure the stages of inquiry skills can refer to practicum planning activities. Inquiry skills measurement instruments are prepared to meet the stages of inquiry skills based on Pedaste et al. (2012), namely: identifying problems, formulating research questions, formulating hypotheses, planning experiments, conducting experiments, analyzing and interpreting results, and drawing conclusions. The instruments developed to assess inquiry skills are shown in Table 2.

Table 2: Assessment to Measure Inquiry Skills

Stage	Aspect to measure	Level	Answer Criteria
Identifying the problem	Identify practical problems to illustrate the above research!	1	Identifying problems in general and mentioning only one problem phenomenon.
		2	Identify the problem by mentioning one root cause.
		3	Identifying problems by looking at the connectedness of the two influential factors.
		4	Identifying the problem by paying attention to all possible factors of influence.
Formulating research questions	A suitable problem formulation to describing the above research!	1	Not using the word question to formulate the problem. The formulation of the problem does not show the relationship between free and bound variables.
		2	Not using the question word just uses statements and already shows the relationship of free variables and bound variables but not details.
		3	Use the correct question word to construct a problem formulation that correctly connects a free variable and a bound variable. The formulation of the problem is incomplete and not detailed.
		4	Use the correct question word to construct a problem formulation that correctly connects a free variable and a bound variable. The formulation of the problem is clear, logical, and investigatable. Formulation of focus and detail problems.
Formulating hypotheses	Make a hypothesis that matches the research above with your opinion!	1	Does not fit the formulation of the problem.
		2	Does not fit the formulation of the problem. Not detailed and incorrect in stating the relationship between a free variable and a bound variable.
		3	Drawing up a hypothesis that corresponds to the formulation of the problem. Develop hypotheses that can be tested through experiments. Creating a detailed and correct hypothesis expressing the relationship between a free variable and a bound variable.

Stage	Aspect to measure	Level	Answer Criteria
		4	Drawing up hypotheses that correspond to the formulation of the problem. Drawing up hypotheses that can be tested through experiments. Make a detailed and correct hypothesis stating the relationship between a free variable and a bound variable. Drawing up hypotheses in the form of statistical symbols.
Plan an experiment	Design the experiment according to the research above!	1	Only specifying materials and tools but less according to size
		2	Determine the material and tools according to size. Develop experiment procedures/steps.
		3	Determining materials and tools according to size Determines the operational definition of bound variables. Develop experiment procedures/steps.
		4	Determines the number of tests. Determining materials and tools according to size. Define the operational definition of a bound variable. Build experiment procedures/steps.
Conducting experiments	Make a procedure following the research above with your opinion!	1	Choosing the suitable materials and tools.
		2	Choosing the suitable materials and tools. Following the correct procedure.
		3	Choosing the suitable materials and tools. Following the correct procedure. Collecting data and recording it.
		4	Choosing the suitable materials and tools. Following the correct procedure. Collecting data and recording it. Controlling disruptive variables.
Analyzing and Interpreting Results	Create a table related to the experimental data! Make an analysis and interpretation of the results in the above data!	1	Unable to determine the correct way the data is presented. Unable to decide on the exact reason.
		2	Unable to determine the correct way the data is presented. The possibility of being right in determining the reasons.
		3	Determine the correct way of presenting the data. No detail in determining the exact reason.
		4	Determine the correct way of presenting the data. Determine the exact reason.
Drawing Conclusions	Conclude the above data research!	1	Unable to answer the formulation of the problem
		2	Answering the problem formulation.

Stage	Aspect to measure	Level	Answer Criteria
		3	Answering the formulation of the problem Proving a hypothesis that indicates the acceptance and rejection of the hypothesis.
		4	Answering the formulation of the problem Proving a hypothesis that indicates the acceptance and rejection of hypotheses Expresses significance. Mentions recombination.

4 Conclusion

The conclusions of the literature review results are:

1) Inquiry skills are skills needed to carry out the process of scientific inquiry and develop best in the context of rich practices in activities.
2) The inquiry skills stage consists of identifying problems, formulating research questions, formulating hypotheses, planning experiments, conducting experiments, analyzing and interpreting results, and drawing conclusions.
3) The achievement of the inquiry skills stage must be carried out in order, so it requires developing an assessment that refers to these stages to measure the accomplishment of inquiry skills.
4) The development of assessment instruments used to measure the stages of inquiry skills can refer to practicum planning activities, the form of essay questions that ask students to write answers about the design and conclusions of the practicum or experiment.

Based on these findings, further research can be carried out to develop an assessment to assess valid inquiry skills and can be used to measure student inquiry skills.

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