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Pre-service Science Teachers' Competence and Confidence in Scientific Inquiry

Rohandi [1,*]

[1]*Department of Physics Education, Sanata Dharma University, Yogyakarta, Indonesia*

[*]*Corresponding Author: rohandi@usd.ac.id*

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Abstract

The quality of science learning has a very important role in science education. The quality of science learning is largely determined by the quality of science teachers. Inquiry-based science learning is becoming a model that must be developed today. In order for inquiry-based learning to be carried out properly, science teachers must have adequate inquiry competencies. Teachers must also have adequate confidence in conducting inquiry-based learning with students in the classroom. The objective of this study was to examine students' competence and confidence in scientific inquiry. 42 pre-service science teachers were involved in this study. Data collected were analyzed using Rasch modeling. The results of data analysis show that mean of the Rasch score for students' competence (1.76 Logits; SD = 1.20) is higher than the mean of the Rasch score for students' confidence (1. 41 Logits; SD = 1.01). These results show that although students feel competent to do inquiry, they do not yet fully have the confidence to carry out inquiry learning with students in classroom activities. Implications for a science teacher and pre-service science education based on these results are discussed.

Keywords: pre-service science teacher, scientific inquiry, learning science

1 Introduction

Science Education plays an important role in providing a good climate for students who have an interest in exploring science. The more students who are interested in science the more chances a scientist or researcher in science is born. The development of science cannot be separated from the development of scientific investigations by scientists. At the heart of the process of inquiry in the field of science is the process of hypothesis testing through a series of experiments.

The learning science outcomes besides students can have an understanding of science, they need to have experiences and skills in terms of testing their ideas in solving a problem through the process of inquiry. In the inquiry-based learning process, students are trained to think and reason properly and correctly. Engaging students in applying thinking and reasoning skills and promoting inquiry-based instruction has become the focus for many science educators. The process of inquiry promotes the exploration of questions raised by both students and the teacher. When the inquiry process skills are connected with science content, students discover meaningful concepts and understandings [1].

In this way, students will use these experiences to contribute to their identity in science in and outside the classroom and eventually a future career. In terms of students' science identity, they are able to demonstrate performance in relevant scientific practices with deep meaningful knowledge and understanding of science, and recognize themselves and get recognized as science persons by others. Students develop identities by engaging in science activities and in broader tasks in their community of practice in accordance with the science classroom.

Researchers have advocated for teachers to lead students to collaboratively solve problems in the context of real-world situations and students' culture [2] instead of conducting validation experiments based solely on textbooks. The fundamental of science learning activities is the interaction between students and objects or phenomena in the form of material objects and objects of events/phenomena. Students' interaction with nature objects is not just to describe the situation, but further than that, it is hoped that at least it will be continued with generalization activities, which can develop students' cognitive and affective potential. Understanding science begins with a specific problem space, where scientists must formulate a problem-solving plan, form a hypothesis, perform an experiment, and gather evidence to explain the problem [3]. Similarly, students must learn to ask questions about specific issues and answer those questions based on evidence. They learn to explore, gather evidence from different sources, construct arguments, construct explanations based on available information, and communicate and defend their conclusions.

In inquiry-based learning, teachers act as facilitators and students take greater responsibility for their learning. Constructivism advocates that teachers help students think through and solve problems that require higher-order thinking and reconstruct their knowledge by interacting with the environment. Inquiry-based learning is an effective method to achieve this objective. It will lead students actively seek knowledge and generate new ideas are key features of inquiry-based science learning [4]. The essential characteristics of inquiry are connecting personal knowledge and scientific concepts, designing experiments, discovering, and building meaning from data and observations [5]. This characteristic describes that implementing inquiry teaching lead students to enhance their science learning by processing personal experience and connecting new and old knowledge. In summary, inquiry-based learning engages students to question, design, and implement discovery, analyze, and communicate their findings to expand their knowledge.

To ensure the achievement of the objectives of learning in science education, well prepared instructional design of learning science is needed so that it is guaranteed that students gain hands-on experience, and opportunities for conceptualization, and are trained to use science process skills in the inquiry process. Such a learning objective in science education will be possible to achieve if the (prospective) science teachers have adequate inquiry competence in teaching science to students which will have a good impact on student learning as well as training students in conducting science investigations (doing science). The skills and knowledge of scientific inquiry enable science teachers to be successful in their teaching of science.

In teaching science and accompanying students to learn science, science teachers need to do it with confidence. Besides competence in inquiry, science teachers'

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confidence in conducting and guiding students to learn through the inquiry process is an important factor in the successful teaching of science. Confidence is a feeling of self-assurance arising from one's appreciation of one's own abilities or qualities. Science teacher confidence in the inquiry will promote students' learning even when facing difficulties. Teacher confidence in inquiry helps students feel ready for their inquiry activities and life experiences. When science teachers are confident in teaching through inquiry, they are more likely to move forward with students and opportunities to gain the students' potential in learning science.

In this study, pre-service teachers' competence and confidence were investigated and the Rasch model was used to analyze collected data. Pre-service teachers' competence and confidence will be mapped and discussed. Some implications are formulated from the results of the study.

2 Research Methodology

2.1 Sample

This study aimed to investigate pre-service science students' competence and confidence in inquiry at the School of Teacher Education. 42 students from the primary teacher education department who participated in the Teaching and Learning Science course were involved in this study.

2.2 Data Collection

An instrument used in this study was the questionnaire to measure students' competence and confidence in inquiry in learning science developed by Chang [6]. This questionnaire was designed to evaluate pre-service science teachers' competence and confidence in the inquiry. The questionnaire consisted of 14 items for both competence and confidence in the inquiry. As this instrument had not been used in Indonesia before, the questionnaire was first translated into Bahasa. The students' responses were categorized using a Likert scale. The extreme categories in the Likert scale are labeled ''strongly disagree'' (coded 1) and ''strongly agree'' (coded 4). These instruments were administered in the presence of a researcher who would provide assistance if the students encountered any difficulty. These instruments were distributed at the beginning

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of the Teaching and Learning Science course. Overall, the administration of the questionnaires proceeded smoothly, all students had sufficient time to complete the questionnaire.

2.3 Data Analysis

The responses of pre-service teachers' competence and confidence in scientific inquiry were analyzed using *Winsteps* (Rasch-Model Computer program). In order for the items can be used in the Rasch model, the items *infit mean square* and *outfit mean square* should be distributed between 0.7 and 1.4, and the *item point measure correlation* should be greater than 0.3 [7].

The Rasch model has been implemented in analyzing data in this research. The Rasch model provides valuable data for the development, modification, and monitoring of valid measurement instruments. In this paper, the Rasch model was used to examine students' competence and confidence in inquiry in the primary teacher education department. The equal interval measures transformed by the Rasch model are used to map persons and items into a linear (interval) scale. Such mapping (called person–item maps) produces useful tools for evaluating students' competence and confidence of students in the inquiry. The person–item maps of students' competence and confidence of students in the inquiry provided ways for evaluating and interpreting the data. Items ordered in person–item maps illustrate the level of item difficulties. This means that items which more difficult to agree with or items which easier to agree with can be identified.

The Rasch model explains how the pre-service teachers' competence and confidence in scientific inquiry can predict a student's response to a particular test item involving competence and confidence in scientific inquiry. Students at the same logits value as an item have a 50% chance of correctly answering that item. Items above their ability level can still be answered correctly, but students have less than a 50% chance of correctly answering the item. Items listed below a student are those that the student has less than a 50% chance of correctly answering. Consequently, the higher position of the item on the single line means that the item is more difficult to agree with. Conversely, the lower position of the item on the single line means that the item is easier to agree with.

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3 Results and Discussions

Before the output of *Winsteps* can be used for interpretation of the results of data analysis, all items used in the questionnaire are first evaluated (diagnosed) whether they meet the Rasch model criteria. The evaluation (diagnosis) results showed that for competence items, the *infit mean square* was distributed between 0.49 and 1.40; the *outfit mean square* was distributed between 0.46 and 1.4 and the *item point measure correlation* is greater than 0.3. In the evaluation results for confidence items, the *infit mean square* was distributed between 0.64 and 1.36; the *outfit mean square* was distributed between 0.64 and 1.36 and the *item point measure correlation* is greater than 0.3. The results of this diagnosis indicate that all items can be used in the Rasch model analysis. Furthermore, all data (42 students and 14 items) were transformed using Rasch analysis to order students along the continuum of the measure of competence and confidence in the inquiry.

The distributions of students (n = 42) according to competence and of items (n = 14) according to the difficulty are shown in Figure 1. On the left-hand side of Figure 1, the distribution of students is represented. Items located below a participant are items that the students were likely to agree to. Items located above are items that the students were unlikely to agree to.

The mean Rasch score for students' competence was 1.76 Logits (SD = 1.20). By looking at which items are located above and below this point, we can understand the student's average level of competence. Whereas, the mean Rasch score for items was 0.0 Logits (SD=1.36). Looking at the mean of Rasch score on persons and items and their respective standard errors, students' competence is compatible with the items difficulty score. It means that for this sample of students, their competence in inquiry could not be justified whether or not they tend to have more competence. However, the distribution of the items on the map has valuable information of students existing competence. Figure 1 displays an item–person map of inquiry competence in which students are placed relative to the hierarchy of items. On the right side, items are listed in order of difficulty, with the hardest item to agree to at the top (item12) and the easiest item to agree to at the bottom (item13).

```
TABLE 12.2 Students'Competence in inquiry        ZOU999ws.txt Sep 22 22:21 2021
INPUT: 42 PERSONS, 14 ITEMS  MEASURED: 42 PERSONS, 14 ITEMS, 4 CATS        3.49
--------------------------------------------------------------------------------

                                  PERSONS MAP OF ITEMS
                                    <more>|<rare>
                             5            +
                                          |
                                          |
                                       XX T|
                             4        XXX  +
                                          |
                                          |
                                       XX  |
                             3          X S+
                                          |T
                                      XXX  |
                                     XXXX  |
                             2         XX  +  item12  item7
                                        X M|
                                          |  item3   item6
                                XXXXXXX  |S
                             1 XXXXXXX  +
                                      XXX  |  item10
                                   XXXXXX S|
                                          |  item9
                             0            +M item11
                                          |  item1   item2
                                          |  item4   item5
                                        X T|
                            -1            +
                                          |S
                                          |
                                          |  item8
                            -2            +  item14
                                          |  item13
                                          |
                                          |T
                            -3            +
                                    <less>|<frequ>
```

Figure 1. Item Map of Pre-service Teachers' Competence

The mean Rasch score for students' confidence was 1.41 Logits (SD = 1.01). The mean Rasch score for items was 0.0 Logits (SD=0.95). Looking at the mean of Rasch score on persons and items and their respective standard errors, students' confidence is compatible with the items difficulty score. It means that for this sample of students, their confidence in inquiry could not be justified whether or not they tend to have more confidence. However, the distribution of the items on the map has valuable information on students existing confidence. Figure 2 displays an item–person map of inquiry confidence in which students are placed relative to the hierarchy of items. On the right side, items are listed in order of difficulty, with the hardest item to agree to at the top (item12) and the easiest item to agree to at the bottom (item10).

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TABLE 12.2 Students'Confidence in inquiry          ZOU999ws.txt Sep 22 22:29 2021
INPUT: 42 PERSONS, 14 ITEMS  MEASURED: 42 PERSONS, 14 ITEMS, 4 CATS         3.49
--------------------------------------------------------------------------------

                           PERSONS MAP OF ITEMS
                             <more>|<rare>
                        4       X  +
                                   |
                                X  |
                                X T|
                                   |
                        3          +
                                X  |
                               XX  |
                               XX S|  item12
                                   |
                        2    XXXX  +T
                              XXX  |
                            XXXXX  |
                              XXX M|  item5
                                   |
                        1   XXXXX  +S item6
                               XX  |
                           XXXXXX  |
                                  S|
                              XXX  |  item11  item7
                        0       X  +M item13
                                X  |  item1
                                   |  item14  item4
                                X T|  item2   item8   item9
                                   |  item3
                       -1          +S
                                   |
                                   |  item10
                                   |
                                   |
                       -2          +T
                             <less>|<frequ>
```

Figure 2. Item Map of Pre-service Teachers' Confidence

The results of data analysis show that mean of the Rasch score for students' competence (1 76 Logits; SD = 1. 20) is higher than the mean of the Rasch score for students' confidence (1. 41 Logits; SD = 1.01). These results show that although students feel competent to do inquiry, they do not yet fully have the confidence to carry out inquiry learning with students in classroom activities.

In terms of inquiry competence shown in Figure 1, students have difficulty in describing and interpreting data through scientific terminology (item12), controlling extraneous variables that may interfere with results (item7), and posing verifiable hypotheses according to data (item4). The three competencies require a high level of thinking skills. The results of this data analysis, show that students' thinking skills still need to be improved so that these three competencies can be done better. This difficulty is consistent with students' confidence in conducting inquiry learning. As shown in

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Figure 2, students are least confident in using scientific terms learned to explain the meaning of experimental data (item12) in science class. In carrying out inquiry learning, it is also indicated that students are still not confident in choosing suitable study methods based on the question (item5), and considering possible factors that may influence the experiment (item6) in science class.

The results of data analysis (see Figure 1) also show that students are able to build conclusions according to collected data (item 13), infer according to collected data (item14), and conduct experiments according to a predefined plan (item8). These results are consistent with the analysis of students' confidence in conducting inquiry learning. Students are very confident (see Figure 1) in carrying out the experiment in accordance with the experiment's procedures (item 10). These results show and likely caused because students are very familiar with doing a practicum with a recipe model where all the things that must be done have been described in the practicum instructions. Students just need to follow the procedures that have been compiled with the order of their activities.

From the results of data analysis as outlined above, some implications in science learning in schools or in pre-service science education can be formulated as follows:

- Science learning activities in schools need to be directed to inquiry rather than prescription models. This is because, in this prescription model, students are given little or no opportunities to propose problems for investigation, ask questions, formulate hypotheses, design procedures, process answers, and explanations, predict and communicate results as well as identify assumptions, use logical and critical thinking and engage in argumentation.

  It is also to respond to the demands of learning for the 21st century that most of the learning goals of 21st century skills can be taught within the context of scientific inquiry or project-based learning which requires teachers to be able to engage students in self-directed strategies, to organize activities that delegate learning decisions to students and monitor their progress, to facilitate learning activities such as collective problem solving, and to guide students in thinking about complex problems by giving them feedback following assessment [8]. Furthermore, Chu et al. [8] suggest that delivering inquiry-based tasks is

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important in learning science. Inquiry-based tasks will facilitate students to become active agents in building knowledge through constructing their own understanding and through meaning-making, which requires them to have an inquiry mindset. Similarly, Kuhlthau et al. [9] argue that inquiry is a way of learning new skills and broadening our knowledge for understanding and creating in the midst of rapid technological change. Inquiry is the foundation of the information age school [9]. In the teacher preparation context, inquiry-based instruction can also improve the critical thinking and inquiry skills of students in pre-service teacher education [10, 11]

- The importance of conducting experiments in the laboratory or in the outside classroom by focusing not only on the results but also the process of inquiry. The model that needs to be developed is reflective inquiry There is an element of reflection in each step of the experiment to; 1) recognize the extent to which students have confidence in carrying out the experiment correctly, 2) recognize the extent to which students need to learn/practice in performing steps in the inquiry, and 3) formulate an improvement action plan. This is in line with the research result that the use of the reflective worksheets showed that inquiry-based learning activities promoted students' scientific process skills such as defining the problem, formulating a hypothesis, and observing and interpreting results during the inquiry-based learning process. Students also improved in terms of ability such as using scientific terms, drawing scientific and comprehensible figures, and making scientific explanations. In addition to these, it was found that students had more positive opinions about the learning process [12].

To ensure the achievement of the objectives of science education, a planned instructional organization is needed, so that it is guaranteed that students gain hands-on experience, and opportunities for conceptualization, and are trained to use science process skills. Facilitating students' learning is a crucial factor. Inquiry-based approaches encourage science teachers to become a facilitative role. Proper teacher guidance will allow students to internalize inquiry skills in every step of the investigation. This is in line with the findings of the study Kuhlthau et.al. [9] that

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students need considerable guidance and intervention throughout the process to enable a depth of learning and personal understanding. Without guidance, students often approach the process as a simple collecting and presenting assignment that leads to copying and pasting with little real learning. With the teacher's guidance, students are able to concentrate on constructing new knowledge and learning useful strategies in each stage of the inquiry process.

One of the strategies that focus on the process of acquiring inquiry skills is guided inquiry. With this model of inquiry, the teacher provides essential intervention at critical points in the inquiry process that fosters deep personal learning and transferable skills [9]. In inquiry learning, teachers need to restructure their learning environment so that students' beliefs about science, scientists, and themselves will lead to positive attitudes.

4 Conclusion

As the objective of this study was to examine students' competence and confidence in scientific inquiry, the results of data analysis show that mean of the Rasch score for students' competence (1.76 Logits; SD = 1.20) is higher than the mean of the Rasch score for students' confidence (1. 41 Logits; SD = 1.01). This indicates that although students in pre-service science education feel competent to do inquiry, they do not yet fully have enough confidence to carry out inquiry learning with students in classroom activities. For the development of competence and confidence of pre-service science teachers in scientific inquiry, science activities in the classroom need to be directed towards the inquiry model with an emphasis not only on the results of the investigation but also on proper guidance during the inquiry process.

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Appendix:

A. Students' competencies in scientific inquiry:

1. Be able to pose questions according to data observed
2. Be able to pose an explorable question
3. Be able to describe a concept with an operational definition
4. Be able to pose a verifiable hypothesis according to data
5. Be able to pose a feasible explorative plan according to the question
6. Be able to manipulate variables related to plan
7. Be able to control extraneous variables that may interfere with results
8. Be able to experiment according to a predefined plan
9. Be able to collect data through different methods
10. Be able to record data through different instruments
11. Be able to compare and classify data collected from an experiment
12. Be able to describe and interpret data through scientific terminology
13. Be able to build a conclusion according to collected data
14. Be able to infer according to collected data

B. Students' confidence in inquiry teaching:

1. In science class, I could ask questions about what I don't understand through observation.
2. When learning science, I could collect information related to questions to obtain a deeper understanding.
3. When learning science, I could deduce possible answers to the questions.
4. In science class, I could describe what data should be collected in the experiment.
5. In science class, I could choose suitable study methods based on the question.
6. In science class, I could consider possible factors that may influence the experiment.
7. In science class, I could design the experimental steps based on the question.
8. In science class, I could observe and record the results of the experiment carefully.
9. In science class, I could operate the experimental apparatus to measure data.
10. In science class, I could carry out the experiment in accordance with the experiment's procedures.
11. In science class, I could compare or classify data collected in the experiment.
12. In science class, I could use scientific terms learned to explain the meaning of experimental data.
13. In science class, I could draw conclusions based on the mathematical relationship among experimental data.
14. In science class, I could explain experimental results or phenomena based on the experiment's conclusion.