Characteristics of Abductive Inquiry in Earth and Space Science: An Undergraduate Teacher Prospective Case Study

T R Ramalis\textsuperscript{1,4}, Liliasari\textsuperscript{2} and D Herdiwidjaya\textsuperscript{3}

\textsuperscript{1}Physics Education Department, UPI
\textsuperscript{2}Postgraduate School, UPI
\textsuperscript{3}Astronomy Department, ITB
\textsuperscript{4}taufik_lab.ipba@upi.edu

Abstract. The purpose this case study was to describe characteristic features learning activities in the domain of earth and space science. Context of this study is earth and space learning activities on three groups of student teachers prospective, respectively on the subject of the shape and size of Earth, land and sea breeze, and moon's orbit. The analysis is conducted qualitatively from activity data and analyze students doing project work, student worksheets, group project report documents, note and audio recordings of discussion. Research findings identified the type of abduction: theoretical models abduction, factual abduction, and law abduction during the learning process. Implications for science inquiry learning as well as relevant research were suggested

1. Introduction
Abduction is a mode of reasoning which aims to find patterns of a phenomenon by proposing a hypothesis. In the context of learning, abduction is a form of creative and evaluative reasoning that enable learners to produce a plausible hypothesis based on previous knowledge. This is a logical operation which introduces a new idea. In view of the construction theory, abduction is a kind of theory the formation of hypotheses. In exploratory data analysis, does not start with a pre hypothesis of generated and then collect data to test the hypothesis. Instead, after observing some surprising patterns, use it in as many ways as possible until the "tale of data" appears reasonable.

Characteristics abduction inquiry is essential in earth and space science, because this inquiry relates to a problem retrodictive, where is a reasoning process in which historical effects are observed and the past causes or conditions are inferred. Retroduction can be expressed as simply a conjecture which arises in the mind. Abduction has a logical empiricists called justification context and used in the literature for the various processes of reasoning. Abduction involves computation and reasoning, depending on the background knowledge, relevant theoretical background, as well as methodological working habits a person. Based on the kind of abducted hypothesis, the kind of evidence that abduction and cognitive mechanisms, abduction classified into four types, namely: the factual abduction, law abduction, theoretical model abduction, and second order existential abduction.

2. Background
One of the important goals in science education is to provide an explanation of natural phenomena. An abductive inquiry is also implemented in a similar way that leads learners towards new explanations on the basis of background theories and observations. Abductive inquiry was also conducted in the...
same way that directs students toward a new explanation based on background theory and observation\(^5,6\). However, in this type of inquiry, learners are not immediately sure about his conclusions but they get some further explanation, which allows guiding learners to formulate hypotheses. This is the essence of the abductive, which begin with the explanation that is not comprehensive and ended with the creation of new knowledge that is satisfactory, by linking the phenomena and concepts are expressed as hypotheses.

Abductive inquiry model (AIM) consists of four elements: exploration, examination, selection, and explanation\(^7\). The four phases can be described in a flowchart as shown in Figure 1.

**Figure 1. Phase of abductive inquiry model**

In the exploration phase, students investigate scientific phenomena given by observing the data and find a way to explain it scientifically. Examination phase was followed so that learners know the scientific facts or theories to formulate a scientific hypothesis. In other words, the main focus of this phase is to examine all the rules that may be able to provide an explanation to investigate the phenomenon. During the selection phase, learners evaluate all previously formulated hypotheses and chose which provides the most plausible explanation. If learners find flaws or problems in this phase then they can go back to the previous step more; exploration and examination for the development of a better explanation of the observed phenomena. Therefore, this phase is not defined in the AIM linear, but rather is cyclical in nature, and iterative hypothesis modified and explained through sustainable development. At the final phase of explanation, learners recommend a full explanation of the phenomenon is given by using the rules and hypotheses selected in the previous stage. Referring to the type of abduction, selection phase and stage of this explanation can kind of factual abduction, law abduction, theoretical model abduction, or existential abduction.

These study was conducted because a lack of studies that analyze the characteristics of abductive inquiry students to formulate scientific hypotheses. Specifically, this study examined the learning episode of earth and space science (ESS) for student teachers candidates. It is assumed that understanding the characteristics of abductive inquiry will assist students in generating scientific hypotheses, and will provide implications useful for improving the quality of education and science teaching in schools.

3. Methods

The context this study was ESS learning activities of student teachers candidates on odd semester 2013/2014 of the physics education department an educational institution and educators in Bandung Indonesia, and the author as teacher this course. Total 24 students, who were divided into five groups. Four groups of each their members is five students, and the fifth group its members is four students. Each group was given the task of different projects. The task of this project is done inside the classroom, some are done the classroom outside. Learning activities which studied consisted of three groups, represented by groups A, B, and C respectively on the subject of our study is the shape and size of Earth, land and sea breeze, and the moon's orbit.

In the A group, student explores determination of diameter of the earth has ever done Eratosthenes. Then they are assigned to determine the coordinates and the distance between the two cities, through browsing on the site https://maps.google.com. Then they are invited to formulate hypotheses to
determine the diameter of the Earth from the coordinate data and the distance of the two cities, as it had been done by Eratosthenes. Students in B group observe movement of the wind on the coast simulation. They were asked to describe explanation sea breeze and land breeze. Then they are invited to formulate the hypothesis of the cause of the sea breeze and the land breeze. Previously they had to understand that the air moves from higher pressure to lower pressure. Their hypothesis associated with the heat capacity of water and soil heat capacity. In the C group they explore the observational moon data in the tracking device, which they made themselves. During the previous month they were working on the project tasks take distance data pinhole. From the 27 planned data, they managed to obtain 24 data, as three nights a thick cloudy sky conditions, preventing the appearance of the month. They are invited to draw up hypothesis to describe the orbit of the Moon.

Data were collected from the activities of the students in doing the project each group, student worksheets, group project report documents, and audio recordings of group discussions. Rewritten audio recordings, narrated in the form of a dialogue between authors and students and among students themselves. In the initial analysis, diverse data sources examined to determine how activities and group dialogue that occurs during learning. The next stage is to identify the pedagogical strategies used by researchers to help students generate hypotheses, then identify the type of inquiry each group dialogue.

4. Results and Discussions
The findings of this study are presented in the following three sections. The title of each section accordance with the findings and features of AIM phase. Thus, the discussion describe how the performance of students carry out abductive inquiry ESS

4.1. Theoretical Model Abduction
In the A group is found that they know the shape of the earth is round, but was not sure about the evidence that supports it. Even some of those who show evidence based model of the shape of the earth. This is reflected in the quoted dialogue (R stated the researcher, and S stated the student).

From exploration data and a calculated undertaken to Eratosthenes, student groups can understand that if the difference in angle of the shadow of two places (cities) and the distance between the two places (cities) are known, the radius of the Earth can be determined. At first they claimed that what Eratosthenes cannot be done, because the difference in the angle of shadows on the two cities is not known, its reflected in the dialogue:
S4 : The distance between the two places today can easily be ascertainable, but the divergence angle of the shadow of the data is not known in both places.
R : What lead to the occurrence the angular difference in the shadow of the two cities?
S1 : Position difference. S2 : Coordinates.
R : What expressed magnitude coordinates on the earth's surface?
S2 : Latitude and longitude.
Finally they can be reveal that determine the radius of the earth from the coordinate data and the distance of two places, a problem that they must solve.

In the examination phase, they discussed to formulate a data link both cities with a diameter of Earth. After about 6 minutes they have not been able to formulate a relationship. Then the researchers used a globe and the two cities marked. The following quote the dialogue:
R : Well the distance that you have received it actually curved huh?
S : Yes ... (almost their answered unison)
R : Curve that is part of the circumference of the Earth passing through the two cities ... Yeah, right?
Well now try to find a mathematical relationship between the distance of the two cities with the circumference of the Earth passing through the two cities.
It took quite a long time, but finally they could formulate mathematically the relationship between the two second-place position and the distance to the radius of the Earth (equation (1) in Figure 2).
In the selection phase, they chose both places as a city, Jakarta and Merauke. By using the map they obtain coordinate data and the distance between the two cities. Jakarta coordinates of 6°S 106°E, and Merauke 8°S 140°E. The distance between the two cities is 3,785.3 km. They use the analogy of the Earth as a sphere with a diameter that remains. Therefore they use spherical trigonometry formula for cosines. They already understand the notion of θ (equation (2) in figure 2) proficiency level. It is shown when the author posed the question:

R: Well, how to calculate the radius of the Earth at the equator?
S2: We must choose two places at the equator.

In the activity of the A group, they found the formula by abducting that a full circle 360° with path πd (d: diameter). Their activities extend the theory to the case of new applications, instead of changing theories or create new ones. Type abduction happened was theoretical model abduction, as stated as selective or creative abductive, with syllogistic both as follows:

Background theory: Angle of circular cross section of Earth 360°, with a circumference of πd.
Fact explained: The diameter of the circle of the earth (d).
Abduced conjecture: When the distance and coordinates of the two cities are known, then the diameter of the Earth can be calculated.

4.2. Factual Abduction
In the exploration phase, B group observes land and sea breezes simulation. Dialogue that occurs quotation as follows:
R: At daylight, where are the wind direction at the beach?  S1: To the land
R: Yes, from sea to land. It was called the sea breeze. How at night?  S2: From land to sea.
R: Why is that so? Why the sea breeze blowing at daylight, and the land breeze blowing at night? After discussions between them, finally they declared that the cause of the sea breeze and land breeze, is a problem that they must solve.

In examination phase, they use knowledge background to formulate hypotheses. They have understood that the wind moves from high pressure to the low pressure area. The next dialog excerpt:
S3: At noon, sea air pressure is higher than mainland air pressure.
R: Well, why at daytime air pressure of the sea is higher than the air pressure of the mainland?

![Figure 2. Results of formulation and calculation of the radius of the Earth of A group.](image)
Because there is no participants answer as expected, the author gave the guiding question

R : Try connecting to the existence of sun during the day and night. Connect with solar radiation. How they affect marine and terrestrial.

S3 : At daylight, mainland hotter than the sea, at the night otherwise...

R : Try connecting to the existence of sun at noon and night, how it affects marine and terrestrial.

S4 : At daytime, mainland hotter than at sea. Otherwise at nighttime...

S2 : Well it means a heat faster inland and cool faster than the oceans... that’s right Sir?

Dialogue continues, until the student can formulate the hypothesis that the occurrence of sea breeze and land breeze due to the difference between the heat capacity of water and soil heat capacity. As the evaluation phase they could identify that the heat capacity of the oceans is higher than the heat capacity on the mainland. That sea water is difficult to accept the heat but when it receives heat also difficult to remove.

From dialogue in this group seemed student helped with the questions guiding which given by authors. With these questions, finally they can formulate the best hypothesis. Type abduction that occurred is theoretical model abduction. Abduction such as inference to the best explanation, which is also as hypothetical evaluation. Syllogistic formed:

Background theory : Heat capacity is the energy required for the object raise the temperature 1 °C.

Described facts : Water slower to heat and cool more slowly.

Abduced conjecture : Ocean heat capacity is greater than land.

4.3. Law Abduction

Activities C group exploring the observation moon data with tracking device, they made themselves (figure 3). A month before they have been working the project tasks to take pinhole distance data. From the 27 planned data, they managed to obtain 24 data, because two nights the sky is overcast conditions, thereby blocking the appearance of the month. Their reports the distance pinhole shown in figure 4.a.

![Figure 3. Moon probe diagram](image)

Although they have taken the data and find out that the moon's orbit ellipse shaped, they could not formulate a way of describing moon orbit. Their hypothesize are not associated with the observed data, it appears from dialogue:

R : How does the size of the moon sighting during observation? S1: Change...

R : Why it’s change? S1: It may depend of cloud anyway.

S2 : Because Moon’s phases. S3: The distance is varying

S1: Yes, distance was changed... the elliptic orbit.

After discussion they be able to find the problem to be solved is how to describe that the moon's orbit ellipse based on observation data. But they have not been able to formulate a hypothesis. Even the hypothesis they are not associated with the observed data. And after being reminded and guided with the question:

R : You take the data for the one month, it means the moon circulated one round, that’s right?

S : Yeah ... (they replied unison)

R : Try to associate with the fact that the 360° round.(They discuss with analysing the observed data)

S1 : Describe the distance pinhole, we connect the dots... and the result is this distance elliptic shape.
After they discussed about 7 minutes, they could describe the moon's orbit as shown in figure 4.b. Among pinhole lines distance they describe with an angle of 12°, this figure they get from the approach of the 360° round of observations divided by the number of 30 days. They find representations of the moon's orbit by describing discs pinhole distances, as the stage of examination and selection phase. It appears that the evidence will be explained and abducted hypothesis is legal implications, and abduction is controlled by the implications of rules known. The abduction of the type accordance with the rules abduction, or as creative abduction, with syllogistic:

**Background law** : Elliptic trajectory radius varying
**Empirical law explained** : Pinhole distances varying

Abduced Conjecture : There is a relationship between the pinhole with the moon distance.

5. Conclusions
Abductive inquiry covers the process of generating, evaluating, selecting, and propose hypotheses to explain the phenomenon. There were identified three abductive hypotheses types of students, namely: theoretical model abduction, factual abduction, and law abduction. During the exploration phase, students investigate scientific phenomena with the data provided and transform data into new forms to find a problem that must be explained in abductive. At this phase of the examination, the students tried to activate and expand their background knowledge to find the proper rules for abductive inference. Furthermore, using cognitive strategies such as analogies, existential, and modeling strategies, they are creating a new rule that contains a hypothesis to explain the problem. Selection phase provides an opportunity to students to evaluate their hypothesis with empirical and theoretical criteria and selecting the most plausible. Finally, in the phase of explanation, the students give a mathematical description and narration to evaluate the hypothesis that selected in the previous stage.

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