An analysis of thinking patterns of natural sciences teacher candidate students in understanding physics phenomena using P-Prims perspective

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Abstrak. This research aimed to identify thinking patterns of natural sciences teacher candidate students in understanding physics phenomena. Results of thinking patterns could be used to determine appropriate learning models and materials for students’ thinking capacity. In this research, thinking patterns were analyzed using Phenomenological Primitive (P-Prims) perspective. A random sampling technique with purposive sampling was used. The sample consisted of undergraduate students majoring in natural sciences education of Tidar University. The research method used in this research was qualitative, accompanied with The Investigation of Lived Experience with Cognitive Psychology type. Data were collected using tests and interviews. The research results show that in explaining unfamiliar physics phenomena which had never been taught before, students used 1) inductive thinking pattern, by calling back their existing, relevant knowledge and 2) deductive thinking pattern, by using synthesized general premises.

1. Introduction

Several studies suggest that thinking/reasoning capability influences learning outcomes [1,2], especially in physics subject. Young et. al. states that to understand physics phenomena, a good reasoning capability is required [3]. Natural sciences teachers are expected to understand physics phenomena thoroughly. Therefore, natural sciences teacher candidate students must possess good reasoning capability.

Designing learning process requires analysis of needs, including research based learning. One instance of analysis of needs is student’s cognitive condition. Therefore, any learning model should be designed according to it. Student’s cognitive capability which needs to be analyzed is thinking pattern. Research based learning allows students to be more active in thinking. Information procession requires good learning capability.

Each student who comes to class has different initial understanding from the well-established knowledge [4]. If students are presented with a familiar phenomenon, they will understand it through their initial understanding. If, during a learning process, students fail to perform assimilation process towards the initial understanding, their initial understanding will become misconception. When presented with an unfamiliar phenomenon, students will try understanding it by involving their personal experiences [5]. In other words, in understanding unfamiliar phenomena, students would employ their intuitions related to personal experiences. This creation of knowledge in diSessa is called Phenomenological Primitive (P-prims) [6].
P-prims is an individual’s phenomenology in explaining new phenomenon without adequate supporting knowledge, therefore involving other knowledge which is deemed relevant, although in fact it might be not [7]. P-prims involves thinking pattern and analogy [8]. P-prims is almost identical with misconception in terms of individual’s inability to abstractly explain a natural phenomenon. Misconception perspective views students’ incorrect explanation towards new phenomenon as one’s stable knowledge structure, whereas P-prims views one’s incorrect explanation towards new phenomenon as a newly constructed knowledge as a result of questioning. Therefore, lecturers do not have to eliminate students’ existing P-prims [9] like when they eliminate students’ misconception.

In research based learning, students’ P-prims could be developed by lecturers as an alternative hypothesis to be proven via data testing. The hypothesis testing would be conducted by taking into account types of students’ thinking. The hypothesis testing could be performed both inductively or deductively.

This research aimed to analyze thinking pattern of natural sciences teacher candidate students in understanding unfamiliar physics phenomena using P-prims perspective. P-prims was selected because students would construct unfamiliar phenomena using original thinking patterns, not learned thinking pattern like when they would understand familiar phenomena. P-prims would result in original thinking patterns which later could be used to develop research base learning model in natural sciences education program.

2. Research Methods

2.1. The approaches used

Qualitative research approaches used in this research were The Investigation of Lived Experience with Cognitive Psychology type [10]. The Investigation of Lived Experience is a qualitative method for digging inner experience, whereas Cognitive Psychology is a qualitative method for digging structures and processes involving mental activities, how they are learned and how to develop maturity. A research in Cognitive Psychology would take into account perceptions, memories, attentions, thinking and problems solving capabilities.

This research was designed based on qualitative research paradigm attempting to reveal inner experience. It attempted to explore P-prims creation process and analyze emerging thinking patterns. It was started with theoretical studies aiming to establish direction and framework of research by developing research instruments. The research instruments would then reveal inner experience in form of new phenomena unfamiliar to respondents, of which respondents would be asked to explain.

The research tradition used in this research was Cognitive Psychology. The assumption used was that human’s thinking process in responding a stimulus could not be revealed wholly, but what could be only identified was brain’s response towards the stimulus. Response is a result of thinking process, therefore thinking process could be identified by analyzing emerging responses. The stimulus given were written tests and oral questions, whereas responses were in form of answers, how answers were produced and answers for oral questions. Here, responses were used as research data. The data collection process can be seen in Figure 1.

![Figure 1. Data Collection Process](image-url)

Responses in form of answers were divided into two categories, newly learned phenomena and previously learned phenomena. Only thinking patterns in the newly learned phenomena were analyzed. A complete research design could be viewed in Figure 2.
2.2. Research subject
The subject in this research consisted of 79 university students of natural sciences education undergraduate program, of Tidar University, of Class A and B. They were administered with written test instruments. As for interviews, respondents were selected using the Snowball technique. Once the amount of research data was deemed enough, the interviews were ended.

2.3. Data and their sources
All data used in this research were primary data. Data were collected directly from respondents. Primary data were used because Cognitive Psychology approach is impossible to receive valid data from secondary data. The research data were in written and verbal (oral) forms. The collected data were students’ written answers in explaining physics phenomena. Their answers were further deepened via interviews. During data collection, a triangulation method was used by employing written tests and interviews. Therefore, data were in form of written answers and interview transcriptions.

2.4. Data collection method
The method for collecting data used in this research was written tests and interviews. Written tests allowed respondents to construct cognition in explaining questioned phenomena, resulting more structured answers. The respondents’ answers were documented in answer sheets. Their written answers were further deepened via interviews. According to Moleong, interview could be used to triangulate data. Triangulation aimed to validate data by confirming and verifying respondents’ written answers [11].

Interviews used in this research was structured, open formal interview. During the interview process, the researchers asked respondents’ permission to record their conversation. The record would then be transcribed into written documents for easier analysis.

2.5. Research instruments
Based on the data collection methods above, research instruments used in this research were open essay tasks and interview guide. The open essay question items allow multiple answers according to approaches used. For example, a question “Why could a fruit fall down from fruit stem?” could be answered using physics, biology or chemistry perspectives.

Although interview method used in this research was structured, the interview guide used was informal; the researchers were free to explore respondents’ answers. The guide consisted of several ways to conduct interview in order to achieve research credibility and lead primary questions to the working hypotheses. Questions could be developed further by researchers during the process based on situation [11].

2.6. Data reliability
The requirements of credibility, transferability, dependability and confirmability must be met by qualitative research data [12]. Validity, external validity, reliability and objectivity used in quantitative research are replaced with credibility, transferability, dependability and confirmability in qualitative research [13]. In this research, data credibility could be achieved by data triangulation technique. Data transferability could be achieved by describing data in details. Data dependability could be achieved by the snowball technique in collecting data. Data confirmability could be achieved by avoiding researcher’s subjectivity in collecting data by developing an interview guide, test assessment guide and presenting data as they are.

2.7. Data analysis technique
The data analysis process used in this research was adapted from the fixed comparison method by Moleong which consists of Organizing Data, Reducting Data, Categorization, Synthesization and Developing “Working Hypotheses” [11]. Organizing Data was performed by transcribing interview results and combining them with written test results. Reducting data was started with coding data based on respondents and then followed by selecting data categories which could be analyzed using P-prims. Synthesization was started with grouping same or almost same thinking patterns and describing their differences from other patterns. The next step was to name each thinking pattern group based on each own characteristics. The last step of the fixed comparison method was developing working hypotheses. Working hypotheses were developed by adopting and/or adapting existing thinking theories.

3. Results And Discussion
The research results show that in explaining physics phenomena which had never been taught before, the students used inductive thinking pattern by calling back relevant knowledge they already possessed. This can be analyzed from the following excerpt of transcription of the interview with Respondent B1:

I: What influences the magnetic nature of metal?
R: I don’t know. According to my knowledge, since metals have different categories (in the periodic table), so will their magnetic nature be.

From the excerpt above it can be seen that the thinking pattern used by respondent is inductive in nature. They make conclusions by attracting specific cases. Zalaghi and Khazaei states that inductive reasoning is inferring a general principle from observing specific cases [14]. The respondent used his/her existing knowledge to explain unfamiliar phenomenon. The similar case was also found in the transcription excerpt of interview with Respondent A5 as follows:

I: How can metal be pulled by magnet?
R: Metal possesses particles which can create electricity when collided among other.
I: How does electricity relate to magnet?
R: To create magnet, electricity is required. Magnet can be made by the act of rubbing, resulting in static electricity.
I: If a ruler is rubbed, will it produce magnet or magnetic pull or simply react to magnet?
R: Yes, it can produce magnet. It can pull papers.

From above transcription excerpt it can be seen that the thinking pattern used was inductive. It involved respondents’ previous, existing knowledge and/or experience.

From the data above it can be seen that respondents called back their existing knowledge. This finding is in line with Julianto’s findings which suggest that to answer unknown problems, elementary students used inductive thinking pattern involving analogy [15]. The analogy thinking requires individual’s existing knowledge. Analogical thinking plays a central role in creative idea generation [16]. Step of analogical reasoning is paying attention to relevant information, extracting relationships within and across items, and making the appropriate mappings across domains to either generate inferences and/or derive their common principles [17]. Analogical reasoning will be appears when someone meets with new situations [18]. Students more easily understand sophisticated and complex scientific concepts by using analogies [19]. diSessa posits that in answering newly discovered phenomenon without adequate supporting knowledge, other deemed relevant knowledge will be involved [7].

The research results also show that in explaining physics phenomena never taught before, students used deductive thinking by using synthesized, general premises. This can be found in the following transcription excerpt of interview with Respondent B2:
I: Why can metal bar be expanded when heated?
R: Once heated, the force among its particles weakens, lengthening the distance among them, thus extending the metal bar.

From the excerpt above it can be seen that to answer ‘why a heated metal bar can be extended?’, respondent used a general premise “Once heated, the force among its particles weakens” to develop deductive thinking pattern. Inferences of younger children, while impressive and important, are consistently simpler than those of older children [20]. The essence of the deductive inference is formal logic [21]. The similar case was also found in an excerpt of the transcription of interview with Respondent A1 below:
I: Could all metals be pulled by magnet?
R: In daily life, aluminum, a type of metal, cannot be pulled by magnet.
I: How about iron?
R: It can.
I: How come magnet can pull iron but not aluminum?
R: In iron, there are certain particles which can be pulled by magnet.
I: So, aluminum has none of them?
R: Nope.
I: Suppose an iron only has pure particles, without mixed ones which can be pulled by magnet. Can the iron still be pulled by magnet?
R: Maybe it can.
I: Why?
R: All irons have the magnetic particles, Sir.

From the above excerpt it can be seen that the respondent used general premises which were characteristics of deductive thinking. The respondent argued that materials which could be pulled by magnet contained certain particles reactive to magnet. His/her opinion was synthesized into a conclusion.

4. Conclusion
Based on the discussion above, it can be concluded that in explaining physics phenomena which have never been taught before, some students used inductive thinking pattern by calling back their existing,
relevant knowledge while others used deductive thinking pattern by using general premises which were synthesized.

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