Promoting the Development of Student's Epistemic Cognition

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Abstract. In this disruptive era students need to master skills of acquiring new knowledge. Like scientist new knowledge is acquired by coordinating theories with evidence or usually called as scientific thinking. The capability of scientific thinking is determined by the epistemic development. Students must have metacognitive knowledge that theoretical claims are not always true. A theoretical claim could be wrong if we find evidence that is not consistent with this theory. Epistemic cognition is defined as cognition about knowledge and knowing. Epistemic cognition has been studied as a cognitive developmental processes or a system of beliefs. Developmental model proposed four level of epistemic development. In order to be able to coordinate theories and evidence, students need to achieve evaluativist thinking or need to change the beliefs or theories about knowledge and knowing. The purpose of this paper is to review previous research that focus on how to promote the development or the change of beliefs about knowledge and knowing. Some research will be described and evaluated in terms of the kind of change the intervention is intended to bring about and higher-order thinking involved in epistemic change intervention. The implication related to the suitable intervention for undergraduate students in Indonesia are discussed.

Keywords: epistemic cognition · scientific thinking · intervention · training

1 Introduction

This paper was initiated by a question about the individual differences with regard to acquiring new knowledge. There are some people that keep searching for knowledge throughout their life and trying to find the truth about him or herself and about the universe, while some other people are never concerned about the beliefs they hold about their life. The difference of people motivation to search for knowledge has long been studied under the label of some constructs such as need for cognition, typical intellectual engagement, and intellectual values. Need for cognition is a motivational construct predicting the extent to which an individual try to search for knowledge and make use of it [1]. Typical intellectual engagement is defined as aversion or interest toward activities that require intellectual capabilities [2]. Kuhn [3] proposed intellectual values that is defined as one's belief that intellectual activities is worthwhile.

The motivation or the belief that acquiring knowledge is important could be explained by one of the most popular theory of cognitive development from Jean Piaget. Piaget

R. Harold Elby Sendouw et al. (Eds.): UNICSSH 2022, ASSEHR 698, pp. 785–794, 2023.
https://doi.org/10.2991/978-2-494069-35-0_96

viewed children as constructivist who actively build new understanding of the world based on their own experiences. The new understanding of the world is processed through two complementary activities, assimilation and accommodation. Assimilation refer to the process by which children make sense of new experiences by incorporating them into their existing schemes. Accommodation refer to the process by which children adjust their existing schemes in order to incorporate or adapt to new experiences. The adjustment of existing schemes is motivated by a cognitive condition called disequilibrium. Disequilibrium occurs if there is discrepancy or contradictions between one's thought processes and environmental events [4]. Even though this theory was intended to explain children's cognitive development, it can be used to explain the differences of motivation to search for knowledge among adults. Among people who are aware that they experience the cognitive disequilibrium they will keep learning and searching for knowledge and make accommodation until achieving the congruence between their beliefs and experiences.

In the context of higher education, one of the important competencies undergraduate students should achieve is being able to learn and to acquire new knowledge. This competency should be achieved by completing final task called skripsi. Most of study program in universities demand students doing research. Many courses were provided to support students to be capable of committing research, such as research method, statistic, the development of research instrument, and others.

Many problems arises in the course of doing research from finding a research problem until how to understand and to interpret the result of the research. Most students do not understand what a research really is and why it is important to be done. Because of the lack of the understanding about research, most students do the steps of the research just like what the previous students do. So if previous students made a mistake, this mistake will be repeated again and again by the next students. Another problem is students do not know how to find and choose good and valid references. There are thousands of sources about a particular topic in the internet, but most students have not yet skills to differentiate between good and bad sources.

Students also do not have yet the understanding how to justify theoretical claims. What is hypothesis, how to establish a hypothesis, why data need to be collected, how to coordinate data with hypothesis are some of the essential understanding about research that students have not understood yet. The most difficult part of research for students is discussion where they must explain the result of their research and how to integrate their result with previous findings.

In about the last three decades the reasoning underlying steps of the research are studied as scientific reasoning or scientific thinking. Scientific thinking is defined as the consciously controlled coordination of theory and evidence [5]. The capability of coordinating theory and evidence is determined by the extent to which level of epistemological understanding students achieve. Epistemological understanding is a kind of metacognitive knowledge or knowledge about knowledge. Kuhn and Pearsall [6] propose that epistemological understanding is a developmental origins of scientific thinking. There are three requirement so that students achieve scientific thinking skill. First, students must have metacognitive knowledge that theoretical claims are not always true. A theoretical claim could be wrong if we find evidence that is not consistent with this theory.

Second, evidence should be understood as a means to falsify a theoretical claim. The last requirement is theoretical claim and evidence are understood as different epistemological categories.

In order to students to be able to conduct a good quality research and can contribute to development of knowledge, we have to promote the development of their epistemological understanding. The purpose of this article is to review previous research that focus on training or intervention for promoting the development or change of epistemic cognition.

The development of epistemological understanding also have a significant role to the students' critical thinking [7] [8]. If students have beliefs that knowledge is certain and stable there will be no use for them to be critical towards all the theories they learn. Students with these beliefs consider knowledge is acquired from an authority. This is why we find many students are not motivated to learn and seek knowledge independently. So this underlying beliefs are so important if we want our students change their academic behavior. It is not enough to give a reward or different learning method to change students' attitude. We need to intervene the root of the problem, in this case is students' underlying beliefs about knowledge and knowing.

The next part of this paper present brief explanation about two approaches to epistemic cognition, epistemological development and epistemological theories, followed by the descriptions of four intervention studies. Two studies develop intervention that are based on epistemological development and the other two studies try to change participant's epistemological theories. This review aims to understand the mechanism of cognition change the author try to make. The second purpose is to find the best model of intervention that could be applied to promote the development of student's epistemic cognition in Indonesia.

There are some different terms from different researchers that refer to the one's beliefs about knowledge and knowing that is "personal epistemology," "epistemic metacognition," "epistemological understanding," and "epistemic cognition." The term personal epistemology refers to personal theory of knowledge and knowing [9]. If we read or hear information or knowledge about a topic, how do we know that it is true or that it can be believed. In this kind of situation personal theory of knowing play an important role to determine whether it is true or not. The term epistemic metacognition is used to study personal epistemology as a metacognitive process [10]. Epistemological understanding is a term that refer to the levels of the understanding of how knowledge is constructed [7]. Epistemic cognition is defined as cognition about knowledge and knowing [8].

Basically those different terms explain the same thing that is the beliefs people hold about the nature of knowledge and the process of acquiring knowledge. The difference is that some researcher view the process occurring in cognition and other researcher in metacognition level. This paper will use those terms alternately in accordance with whose study that is described.

1.1 Epistemological Understanding Development

We find the term epistemological understanding in studies conducted by Kuhn et al. [7, 11]. This term refer to a developmental progression that move through some levels that reflect an ability to coordinate subjective and objective aspect of knowing. Knowing is the way we know something that may comes from an external source (objective aspect) or

is generated by human minds (subjective aspect). A child may see for example a pencil box, so he/she thinks that there are pencils inside the box. In this case his/her mind generates knowledge that a pencil box contain pencils (subjective aspect of knowing). But when he/she opens that box and finds some chocolate inside, he/she gets knowledge from an external source (objective aspect of knowing).

Epistemological understanding move through four levels, from realist to absolutist, then multiplist and finally evaluativist. Preschool age children are in realist level. They think that what one knows are copies of an external reality. Therefore there is no possibility that there will be different knowledge or beliefs between different individuals because everyone is perceiving the same external reality. For realist children, critical thinking do not needed because they think that everyone have the same knowledge or thought [12].

Children in the absolutist level begin to be aware that knowledge or beliefs are not only taken from external reality but are constructed also by human mind. So children in this level think that people might have an accurate or inaccurate knowledge. Accurate knowledge is the one that consistent with reality and inaccurate knowledge is not consistent with reality. For absolutist children, critical thinking is necessary for comparing knowledge to reality and determining that it is true or not. So in this level children begin to recognize the subjective aspect of knowing but still for them the objective aspect is dominant [12].

Most adolescent move to multiplist level of epistemological understanding. In this level there is a shift from objective to subjective aspect of knowing. Adolescent in this level think that knowledge is generated by human minds and consider that everyone freely choose what they want to believe. So critical thinking is irrelevant for anyone in this level because they think everyone has a right to have their own opinions [12].

Evaluativist level of epistemological understanding is characterized by the ability to coordinate the subjective and the objective aspect of knowing. In this level the objective aspect is reintegrated to the understanding of how we come to know something. Someone who achieve this level understands that even if everyone has a right to have their own opinion, some opinions are supported by stronger argument and evidence than the other opinions. Then we can decide to believe in which opinion based on argument and evidence that support it. The achievement of this understanding will motivate us to engage in intellectual activities and to develop critical thinking. We consider that intellectual activities is worthwhile because it is a process we need to justify the different opinions [12].

So far, it is quite clear that epistemological understanding is considered as the developmental origins of scientific thinking. Kuhn [5] defined scientific thinking as coordination of theory and evidence. This capability is achieved if we understand that opinions or beliefs or theoretical claims is constructed by human mind. Theoretical claims could be right or wrong so it must be justified by examining the argument and evidence that support it.

Promoting student's epistemological understanding from the developmental perspective means finding the way to foster students progression from absolutist or multiplist level to evaluativist level of understanding. How previous researchers conducted the intervention will be described in the result section.

1.2 Epistemological Theories

Individual thoughts about knowledge and knowing could also be organized into theories called epistemological theories. Epistemological theories consist of two main components, *the nature of knowledge* and *the nature of knowing*. Theories about the nature of knowledge is what people believes knowledge is. Knowledge can be considered as fixed and certain or tentative and evolving (the dimensions *certainty of knowledge*). Knowledge can also be regarded as the collection of separate facts or as interrelated concepts (the dimensions *simplicity of knowledge*) [10].

Theories about the nature of knowing is what people believes about how one comes to know. This component comprises of *source of knowledg*e and *justification for knowing*. People could have beliefs that knowledge is passed on from external authorities or view oneself as an active builder of knowledge. Justification for knowing is how people consider that some information or claims can be regarded as valid knowledge. Some people justify knowledge claims based on observation or authority or on the basis of what feels right. Some other people justify claims based on evidence and the evaluation of expertise [10].

It can be explained now based on epistemological theories that some theories or beliefs support people to keep learning and searching for knowledge. Anyone with beliefs that knowledge is uncertain, tentative, and evolving and view knowledge as a complex and interrelated concepts will be more motivated to learn and acquire new knowledge. Promoting the development of student's epistemological theories means how to make students change their theories about the nature of knowledge and the nature of knowing.

2 Research Method

The aim of this paper is to learn from experts in previous studies how to foster the development of epistemic cognition. Articles were obtained from google scholar website by using keywords intervention, training, epistemological understanding, and epistemic cognition. In previous studies, epistemic cognition was developed or changed by using 3R-EC (Reflection, Reflexivity, and Resolved Action for Epistemic Cognition) [13–15], promisingness judgments [16], and metacognitive training to prevent belief-bias [17], and argument-based intervention [18, 19].

As mentioned before, epistemic cognition has been conceptualized as developmental progression and as theories or beliefs. For detail description, two articles with epistemological development and two articles with epistemological theories approaches were chosen. The description will be focused on first, what kind of epistemic change the intervention is intended to bring about, and second on method and procedure used to gain the expected epistemic change.

3 Result and Discussion

3.1 Intervention to Foster Evaluativist Level of Epistemological Understanding

This part describes two studies by Hefter et al. [18] and Iordanou [19]. These two studies have similar purpose to foster students to achieve evaluativist level of epistemological

understanding, but they used different participant, Hefter et al. used high school students, whereas Iourdanou used sixth grade students.

In Hefter et al. study, to achieve evaluativist level participants have to make cognitive progression from absolutist level to the multiplist level and then from multiplist level to the evaluativist level of epistemological understanding. The absolutist individuals are dominated by the objective aspect of knowing. To make this individuals move to the multiplist level they must recognize that there could be disagreement between experts and it means that the every individual construct their own belief or knowledge. This way make participants begin to aware of the subjective aspect of knowing. The next cognitive step from the multiplist to evaluativist epistemological understanding, participants have to understand that even though everyone construct their own beliefs or opinion, there must be some way to evaluate which opinions are better than the other.

Hefter et al. developed the computer based training intervention that consists of four major components. First, participants were given information about the goals of the training. Second, participants were asked to learn about the three levels of epistemological understanding (absolutist, multiplist, and evaluativist) and about intellectual values. In the third step participants watch two video presenting a model composing their opinion about two conflicting scientific positions, the first video is about biodiversity and the second is about global warming. In biodiversity topic, model make up argument supporting the position "resettling the lynx in local forest have negative ecological consequences" vs. "resettling the lynx in local forest does not have negative ecological consequences." In global warming topic, model build argument that support the position "global warming leads to forest dieback" vs. "global warming does not lead to forest dieback." In the final step, participants watch video presenting conflicting scientific positions and were asked to compose their own argument with topic genetic engineering. Hefter et al. found that their training intervention had positive effects on epistemic orientation, intellectual values, and conceptual knowledge. This effect were remain after a week.

In the second study by Iordanou [19] participants was randomly assigned to social condition or science condition. In social condition participants were asked to debate about homeschooling and in science condition about dinosaur extinction. For the homeschooling topic, participants were presented with a story about a Japanese child who immigrate to Cyprus for a year. Participants were asked to determine if the child should learn in the school or he could learn at home. For the dinosaur extinction topic, students were presented two differ scientist opinion about how the dinosaur extinct, one scientist consider that dinosaurs were quickly destroyed by the collision of asteroid with earth, whereas the other scientist think that dinosaurs disappear gradually in consequence of giant volcanic eruptions.

The intervention was conducted through six steps, first participants were assessed where their position are in the homeschooling or in the dinosaur extinction conflicting views. Do they will support the child to learn in the school or to learn at home in the homeschooling topic. In the dinosaur extinction topic, do they will support the opinion that dinosaurs were destroyed by the collision of asteroid with earth or the opinion that dinosaurs disappear in consequence of volcanic eruptions. The result of this assessment was used to form two groups with the different position in social domain (homeschooling topic) and two groups in scientific domain (dinosaur extinction topic). In the second step

participants in each condition (social or scientific domain) worked with other participants with the same position to prepare for supporting reasons of why they take a position with evidence. In the next step, participants were arranged into pairs and practiced to convince that their position was better and followed by engagement in reflective activities. Finally, participants performed real debate with the opposing side.

Iordanou [19] found that participating in argumentative activities contributed to the development of evaluativist domain-specific epistemological understanding. Moreover, it was found that there were differences between domain in how participants valued evidence in the process of knowing. This finding support the view that there are different challenges in the development of epistemological understanding across domain.

3.2 Intervention to Change Epistemological Beliefs

This part describe two studies by Kienhues et al. [20] that reported the result of a short-term intervention to the changing of epistemological beliefs, and by Ferguson et al. [21] that conducted a think-aloud study to examine the mechanism of epistemic cognition change. Think-aloud study is a method to assess the cognitive process of participants during completing a cognitive task. Participants are asked to say or report what they think while performing the task. This method is usually called online to emphasize that assessment is conducted directly while participant's cognitive is performing a cognitive task, to differentiate with offline method such as using a scale to assess participant's cognitive not during the cognitive is processing but after cognitive completing a cognitive task.

Kienhues et al. developed an intervention to change domain-specific epistemological beliefs, from simple and naïve beliefs that knowledge is certain and stable to sophisticated beliefs that knowledge is complex and tentative. The sample of this study were 58 students at a German university. Participants were randomly assigned to one of two groups, one group receive the informational instruction and the other group receive the refutational epistemological instruction. The researcher selected a topic about DNA fingerprinting to be the subject of epistemological instruction. The informal instruction focused on facts about DNA fingerprinting and did not highlight any conflicting views. On the contrary, the refutational epistemological instruction contain two different views about DNA fingerprinting, a widely accepted theory was first introduced to participants and an alternative, more satisfactory theory was then presented. The refutational epistemological instruction was meant to change the formerly participant's belief that knowledge or theory is certain and stable to belief that theory is tentative and potentially false.

Kienhues et al. found that the group receiving the refutational epistemological instruction changed their beliefs about the nature of knowledge towards a more complex, sophisticated view. This study provided evidence that there is possibility to change epistemological beliefs of university students through a short-term intervention.

A study by Ferguson et al. [21] investigate topic-specific epistemic cognition of Norwegian university students. The material of this study are six documents containing conflicting views on the topic of cell phones and potential health risks. The epistemic change occurs through three cognitive condition, first epistemic doubt, then volition or the strong intention to overcome epistemic doubt, and finally resolution strategies [22].

This study provide evidence that epistemic doubt and resolution strategies occur over the course of reading multiple conflicting documents except volition.

There are similarity and a slightly differences between intervention studies that foster evaluativist epistemological understanding with studies to change epistemological beliefs. This two kind of studies use argument-based intervention that teach participants the argumentation skills. Argumentation skills are competencies in identifying and evaluating positive and negative attributes of conflicting views or scientific position on a topic, considering the reasons and evidence for the different views [22]. Intervention materials that are intended to trigger the development or the change of epistemic cognition are conflicting views or scientific position.

The difference between these two kind of intervention studies lies on the mechanism of change. Studies to foster the development of epistemological understanding try to encourage the awareness of subjective aspect of knowing (from absolutist to multiplist) and finally to encourage the capability to integrate the objective and subjective aspect of knowing (from multiplist to evaluativist). Whereas studies to change the epistemological beliefs try to encourage the student's awareness that knowledge or theories are not certain, theories could be wrong or need to be revised.

4 Conclusion

The purpose of this paper is to find out the epistemic cognition intervention which is suitable for university students. Among the four studies described, the short-term intervention developed by Kienhues et al. [20] seems to be the best method to apply to university students in Indonesia, even though it only comprises of the beliefs about the nature of knowledge that change the beliefs that knowledge is simple and certain to the beliefs that knowledge is complex and uncertain. Related to domain-general or domain-specific epistemological understanding, it would be easier and more suitable for university students to be provided with domain-specific conflicting scientific positions in different fields.

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