

DOES CONSTRUCTIVIST TEACHING HELP STUDENTS MOVE THEIR EPISTEMOLOGICAL BELIEFS IN PHYSICS THROUGH UPPER LEVELS?

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Abstract: The examination of the development of students' epistemological beliefs is important. There is little empirical evidence for precisely how epistemological beliefs are altered. Therefore, the purpose of this study was to investigate the effects of constructivist teaching on students' epistemological beliefs in physics. One-group pretest-posttest research design was utilized for the study. The participants were 15 nine-grade students. The participants were interviewed before and after the instruction where constructivist teaching was employed. Results indicated that teaching methods and strategies based on constructivist approach helped the students move their epistemological beliefs in physics through upper levels.

Keywords: Epistemological beliefs, constructivist teaching, physics

Introduction

Epistemology is the theory of the nature and justification of human knowledge and interested in how individuals come to know the world and how they justify, interpret, and construct knowledge and knowing (Burr & Hofer, 2002). Epistemological beliefs may act as resources facilitating conceptual change and guide students to intentionally pursue the goal of knowledge revision (Mason, 2002). The examination of the development of students' and teachers' epistemological beliefs is important because this information would help us better understand the teaching and learning processes in classrooms (Hofer & Pintrich, 1997).

Purpose of the Study

There is little empirical evidence for precisely what fosters epistemological development or how epistemological beliefs are altered (Hofer & Pintrich, 1997). Therefore, in this study, it was intended to investigate the effects of constructivist teaching on students' epistemological beliefs in physics.

Methodology

One-group pretest-posttest research design was utilized for the study (Cohen & Manion, 1994). An inventory was applied before and after the treatment as pre-test and post-test.

Participants and Setting

The participants were 15 nine-grade students. They were volunteers from one classroom whose population was 22. Physics course starts at the ninth-grade according to the curriculum. Accordingly, nine-grade students were preferred to study by considering that possible benefits in terms of epistemological beliefs in physics would be useful for them in their future instruction. Because the school was a boy's military school, all the participants were male and boarding students.

Treatment

The treatment was the instruction based on the constructivist approach. The instruction continued through the geometrical optic unit and lasted one semester. Gagnon and Collay (2001)'s six-element Constructivist Learning Design was used as a reference. The elements were situation, groupings, bridge, questions, exhibit, and reflections. This design enabled group working, brainstorming, discussion, and development and presentation of a product. Teaching methods and strategies, activities, materials, assignments, and assessment methods were planned before the beginning of the instruction. The teacher had a Ph.D. degree in science education and was familiar with Gagnon and Collay (2001)'s Constructivist Learning Design. This was the first time that the students were introduced constructivist teaching practice. Physics was the only course where the instruction was based on constructivist approach. This situation brought out some students' complains about too much work.

Inventory

After a comprehensive literature review, Hofer and Pintrich (1997) proposed two general areas representing the core structure of epistemological beliefs. The general areas are nature of knowledge and nature of knowing. Then, they suggested two dimensions for each area. Under the nature of knowledge area, they proposed certainty of knowledge and simplicity of knowledge. Within the area of nature of knowing, on the other hand, they suggested source of knowledge and justification of knowing. According to Hofer and Pintrich (1997), certainty of knowledge is the degree to which one sees knowledge as fixed or more fluid appears throughout the research. Simplicity of knowledge is the degree to which knowledge is viewed as an accumulation of facts or as highly interrelated concepts. While, at lower levels of source of knowledge, knowledge originates outside the self and resides in external authority, from whom it may be transmitted; at higher levels of

source of knowledge, knowledge is constructed by interaction between individuals within society. The dimension of justification for knowing includes how individuals evaluate knowledge claims, including the use of evidence, the use they make of authority and expertise, and their evaluation of experts (Hofer & Pintrich, 1997).

In order to examine students' epistemological beliefs in physics, an inventory was developed. The Epistemological Beliefs in Physics Inventory (EBPI) consisted of 12 open-ended questions distributed across four dimensions, i.e. certainty, simplicity, source, and justification. The questions were prepared by the researcher and then, she and two professionals having a doctorate degree were reviewed the questions to ensure content and face validity. Final revisions and changes were made after the inventory was pilot tested twice with nine- and ten-grade students. The following two questions are examples from the inventory:

- Around the time of Aristotle, people believed that the Sun and planets rotated around the Earth. Now, people think that the Earth and other planets rotate around the Sun. What do you think about this change? (certainty of knowledge).
- Do you discuss the concepts and laws of physics with your peers and/or review your experiences while you are studying physics? Why? (justification of knowing).

Data Collection

The EBPI was used in the semi-structured interview protocol. Each participant was interviewed before and after the instruction where constructivist teaching was employed. The interviews were done by the teacher not the researcher due to the school policy. The purpose of the interviews was told to the students. In addition, they were explained that their answers did not have any effect on their grades. The interviews lasted between 20 and 35 minutes and were tape recorded.

Data Analysis

Because beliefs are held in clusters, students' epistemological beliefs in physics were categorized as realist, absolutist, multiplist, and evaluativist for each dimension. These levels were determined by Kuhn, Cheney and Weinstock (2000). According to realists, assertions are copies of an external reality, reality is directly knowable, knowledge comes from an external source and is certain, and critical thinking is unnecessary. Absolutists think that assertions are facts that are correct or incorrect, reality is directly knowable, knowledge comes from an external source and is certain, and critical thinking is a vehicle

for comparing assertions to reality and determining their truth or falsehood. From multiplists' point of view, assertions are opinions freely chosen by and accountable only to their owners, reality is not directly knowable, knowledge is generated by human minds and is uncertain, and critical thinking is irrelevant. As said by evaluativists, on the other hand, assertions are judgments that can be evaluated and compared according to criteria of argument and evidence, reality is not directly knowable, knowledge is generated by human minds and is uncertain, and critical thinking is valued as a vehicle that promotes sound assertions and enhances understanding (Kuhn, Cheney & Weinstock, 2000). Therefore, data analysis was done qualitatively based on the pre-assigned coding scheme developed along with the levels mentioned above (Bogdan & Biklen, 1998). For instance, before the instruction, S15's response to the question "How are the laws of physics formed" was as follows:

"The laws of physics are formed by the scientists according to the results of their experiments.....We also see the reality of these laws when we are in the lab" (S15, pre-test).

The question was under the source of knowledge dimension. As he assumed that knowledge came from an external source and his understanding was related to seeing the reality, his epistemological belief for this dimension was coded as realist .

Results and Discussion

Table 1 presents the participants' epistemological beliefs in physics before and after the constructivist instruction. Before the instruction, all students held either realist beliefs or absolutist beliefs. This finding is consistent with the results that emerged from the research by Perry (1970). Perry's work culminated in a developmental scheme of the abstract structural aspects of knowing and valuing in college students. None of his participants held higher level epistemological beliefs. The finding also aligns with the results drawn from the research conducted by Hofer (2000) who worked with first-year college students to investigate disciplinary differences in personal epistemology. She found that students saw knowledge in science as more certain and unchanging than in psychology, were more likely to regard personal knowledge and firsthand experience as a basis for justification of knowing in psychology than in science, viewed authority and expertise as the source of knowledge more in science than in psychology, and perceived that in science, more than in psychology, truth was attainable by experts.

Table 1. *The students' epistemological beliefs in physics before and after the constructivist instruction.*

S	Certainty		Simplicity		Source		Justification	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
1	A	A	A	A	A	A	A	A
2	A	M	A	M	A	A	A	M
3	A	M	A	M	A	M	A	M
4	R	A	R	M	R	A	R	A
5	R	A	R	A	R	A	A	A
6	A	A	R	A	A	A	R	A
7	R	M	R	A	R	M	A	A
8	R	A	R	M	R	A	A	A
9	A	A	R	R	R	A	A	A
10	R	M	R	A	R	A	R	M
11	R	A	R	A	A	A	A	A
12	R	A	R	A	A	A	A	M
13	R	A	R	A	R	A	R	A
14	R	A	A	A	A	A	A	M
15	A	A	R	R	R	M	R	A

S: Students, R: Realist, A: Absolutist, M: Multiplist, E: Evaluativist

Table 2. *Percentage values of the students' epistemological beliefs in physics before and after the constructivist instruction.*

Dimensions	Before the Instruction		After the Instruction		
	Percentage Values		Percentage Values		
	Realist	Absolutist	Realist	Absolutist	Multiplist
Certainty	60	40	0	73	27
Simplicity	73	27	13	60	27
Source	53	47	0	80	20
Justification	33	67	0	77	33

Detailed analysis of the results showed that nine students (60%) held realist beliefs while six students (40%) held absolutist beliefs in the certainty of knowledge dimension before the instruction (see Table 2). Regarding simplicity of knowledge, 11 students (73%) had realist beliefs while four students (27%) had absolutist beliefs. Moreover, eight students (53%) were realists and seven students (47%) were absolutists when the source of knowledge was taken into account. Finally, five students (33%) held realist beliefs whereas 10 students (67%) held absolutist beliefs in terms of justification of knowing. Apart from S1's beliefs, all of the students' epistemological beliefs in physics were moved

through upper levels in most of the dimensions after the instruction. According to the teacher's observations, S1 did not show interest in class discussions about the physics concepts and saw the discussions as a waste of time. The only factor that had an impact on his motivation was grades. Results revealed that 11 students (73%) had absolutist beliefs whereas four students (27%) had multiplist beliefs when certainty of knowledge was allowed for after the instruction. Similarly, two students (13%) were realists, nine students (60%) were absolutists, and four students (27%) were multiplists in the simplicity of knowledge dimension. While 12 students (80%) held absolutist beliefs, three students (20%) held multiplist beliefs with regard to source of knowledge. When justification of knowing was taken into consideration, 10 students (77) were in absolutist level and five students (33%) were in multiplist level.

S2 is a good case to illustrate how the participants' beliefs were changed after the constructivist teaching. Before the instruction, his answer for the question related to Aristotle was:

“Science is changing and developing. People are trying to prove their knowledge by doing experiments and using technology. Sometimes, they make mistakes. But they find reality in the end. There was no technology around the time of Aristotle. Now, there is technology so that the reality can be explored” (S2, pre-test).

At the first glance, it seemed that he believed tentativeness of scientific knowledge and was against to certainty of knowledge. However, his perception about change was related to the correction of past mistakes. He thought that the reality could be reached with the help of technology. Thus, he was considered as absolutist by means of the dimension of certainty of knowledge.

After the instruction his response to the same question was quite different:

“Change is possible as long as scientists' perspectives change. For example, we perform a mathematical operation for 2 and 2, and find 4. Someone says the operation is addition while other one says the operation is multiplication. There are different points of views. Both views can be true” (S2, post-test).

There appeared to be some changes in his beliefs in terms of certainty of knowledge. He argued that scientific knowledge could change regarding different aspects and assumptions. Because he believed that there could be various explanations, he was considered as multiplist in the certainty of knowledge dimension.

However, none of the students could move their beliefs through evaluativist level. The reasons behind this result might be students' difficulties in reaching different resources other than their textbooks, the study's limitation in terms of one subject area of physics discipline, and thirteen-week duration of the study. This result is agreement with the result of Magolda's (1992) longitudinal study. Magolda focused on epistemological development of college students. Contextual knowing was not common in his study sample and found only in 2% of senior interviews and 12% of fifth-year interviews.

Results indicated that teaching methods and strategies based on constructivist approach helped the students move their epistemological beliefs in physics through upper levels. The students had a chance to reflect their beliefs and experiences, aware their peers' views, and promote argumentation on different ideas with the assist of group working, brainstorming, and discussion. Furthermore, the students were required to use different resources in their assignments. All these activities might facilitate improvement in the students' epistemological beliefs in physics.

Nevertheless, some students could not change their absolutist beliefs in the dimensions of source of knowledge and justification of knowing. Advancement in these dimensions demand qualification in content knowledge in terms of theories, concepts and alternative views. Having such a qualification in physics might be difficult for nine-grade students. This is probably one of the reasons for the conclusion of most research that there is some developmental progression of epistemological beliefs in the movement to college education (Hofer & Pintrich, 1997).

Although the students struggled to reach different resources and the study was limited in the subject of optics, there was growth in the students' epistemological beliefs in physics. Thus, results of this study are promising about positive effects of constructivist teaching on individuals' epistemological development.

Suggestion

Ideas about knowledge and knowing may be part of cognitive development and determinative in academic achievement. Consequently, teaching process should be designed so that it enhances students' epistemological beliefs.

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