Epistemic Artifacts for Supporting Students' Constructing Arguments on Socio-Scientific Issues

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Abstract

In this research, I propose 'epistemic artifacts', a new instructional strategy for supporting students' constructing arguments. Epistemic artifacts embody the epistemic criteria for distinguishing good arguments from poor arguments. The theoretical background of epistemic artifacts is the theory of artifacts based on socio-cultural approach. The purpose of this research is to examine the efficacy of instructional strategy using epistemic artifacts for constructing arguments on SSIs. I set up an experimental condition (with epistemic artifacts), and a control condition (without epistemic artifacts). Then, I compared the arguments on SSIs that the students constructed before and after instruction between conditions. In both conditions, the students read materials and received a lecture from the teacher on the differences between good and poor arguments. After this lecture, the students constructed arguments. Afterward, the students received feedback from the teacher on the quality of their arguments, and improved their arguments. Only in the experimental condition, the teacher provided the students with epistemic artifacts. These artifacts were provided during the teacher's lecture and the phases of constructing and improving arguments. Looking at the pre- assessment task results, there was no significant difference in the distribution of scores in the control and experimental conditions with respect to some elements of arguments, and the scores tended to be lower among the control condition compared to the experimental one with respect to the other elements. However, for the post- assessment task, the scores for all elements except element exhibited a ceiling effect were significantly higher in the experimental condition. Based on the above findings, I concluded that an instructional strategy with epistemic artifacts is effective for improving the quality of students' arguments on SSIs. This research contributed to the existing body of knowledge on instructional strategies for supporting students' arguments.

Keywords: argumentation; epistemic cognition; socio-scientific issues

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Theoretical Background

Argumentation and epistemic cognition

Argumentation is a core activity in science, and has been incorporated into science education around the world as part of scientific literacy, inquiry, and practices (Erduran & Jiménez-Aleixandre, 2008). Research on argumentation has become a major theme in science education research (Erduran, Ozdem, & Park, 2015; Lin, Lin, & Tsai, 2014). Much of the previous research on instructional strategies for supporting students' constructing arguments has focused on the knowledge and skills required to construct arguments (e.g., McNeill et al., 2006); for example, teaching the use of diagrams to support the connections between components of argument. However, the results of this type of instructional strategies have been mixed.

More recent studies have focused on epistemic cognition (Chinn, Buckland, & Samarapungavan, 2011; Greene, Sandoval & Bråten, 2016). It has been empirically shown that an instructional strategy reflected on epistemic cognition will improve the quality of students' arguments (Duschl, 2008; Kuhn et al., 2013; Ryu & Sandoval, 2012). However, there are few research focused on epistemic cognition. So, much work needs to be done to accumulate instructional strategies.

Epistemic artefacts for supporting student's constructing arguments

In this research, I propose epistemic artefacts, a new instructional strategy for supporting students' constructing arguments. Epistemic artefacts embody the epistemic criteria for distinguishing good arguments from poor arguments. The theoretical background of epistemic artefacts is the theory of artefacts (Greeno, 2006; Reiser & Tabak, 2014) based on socio-cultural approach (Vygotsky, 1978; Wertsch, 1998). According to the theory of artefacts, cultural artefacts are embedded with cultural customs and values. As artefacts mediate people's practices, those practices become culturally authenticated. If students are taught to use epistemic artefacts when constructing arguments, I expect that their arguments will be authenticated as scientific practices.

Socio-scientific issues and argumentation

Socio-scientific issues (SSIs) refer to topics in modern science that have the potential to greatly influence people's lives and society. SSIs are complex matters without a single solution. They are thus considered to provide a learning context suitable for teaching not only science content knowledge, but also argumentation (Sadler & Dawson, 2012). In fact, there are many studies on argumentation in which SSIs have been used as learning context (e.g., Christenson, Chang Rundgren & Zeidler, 2014). In view of the above, I use the genetic engineering in agriculture as one of SSIs for learning context of argument.

Purpose of This Research

The purpose of this research is to examine the efficacy of instructional strategy using epistemic artefacts for constructing arguments on SSIs. I set up an experimental condition (instructional strategy with epistemic artefacts), and a control condition (instructional strategy without epistemic artefacts). Then, I compared the arguments on SSIs that the students constructed before and after instruction between conditions.

This research was guided by the following research question: How will the quality of the arguments on SSIs constructed by students who received instruction with epistemic artefacts improve in comparison to the quality of the arguments on SSIs constructed by students who received instruction without epistemic artefacts?

Methodology

Participants

The participants were university students in Japan. There were 14 participants in the experimental condition and 35 in the control condition. None had received prior instruction on argumentation. Before the instruction, I carried out a test to evaluate their knowledge of genetic engineering. There were no significant differences in the test scores when comparing the two conditions.

The instructional strategy

The learning topic was genetic engineering in agriculture. First, the students read materials explaining the respective advantages and disadvantages of three agricultural methods: intensive farming, organic farming, and genetic engineering farming. The students then had to choose which method should be promoted in society, and build an argumentative discourse as a group. Next, the students received a lecture from the teacher on the differences between good arguments and poor arguments. After this lecture, the students constructed arguments using the material to justify their chosen agricultural method. Afterward, the students received feedback from the teacher on the quality of their arguments, and improved their arguments. Only in the experimental condition, the teacher provided the students with artefacts that embodied the epistemic criteria for distinguishing between good and poor arguments. These artefacts were provided during the teacher's lecture and the phases of constructing and improving arguments. The epistemic criteria corresponded to the analytical framework outlined in 3.3.

The assessment task

Before and after instruction, the participants were asked to construct an argument on global warming as transfer task. Despite global warming was different topic from genetic engineering in agriculture, the arguments on global warming had similar structures to the arguments on genetic engineering in agriculture. Students read three pairs of materials, each presenting opinions for and against reducing CO_2 as a means to stop global warming; then, the students used the materials to form a rationale on whether Japan should reduce CO_2 levels. The students were allotted 20 minutes to complete the assessment task.

For the analytical framework, I used the Knowledge Integration scoring scheme developed by Seethaler and Linn (2004); this scoring scheme was created in accordance with Toulmin's argument structure (Toulmin, 1958). The framework comprises five elements: a) Evidence in favour of a chosen position, b) Evidence against a chosen position, c) Normativity, d) Counter-evidence to argue against their position, and e) Conclusions to the overall argument. The five elements were awarded scores ranging from 0 to 3 points, the highest total score being 10 points.

Findings

Table 1. The findings of analysis of the arguments on global warming.

Elements of argument	Scores	Control condition		Experimental condition	
		Pre (*N*=35)	Post (*N* =35)	Pre (*N* =14)	Post (*N* =14)
Evidence in favor of chosen position	0	21	0	9	0
	1	12	5	4	0
	2	2	30	1	14
Evidence against chosen position	0	7	1	9	0
	1	27	20	5	0
	2	1	14	0	14
Normativity	0	0	0	0	0
	1	35	35	14	14
Counter-evidence to evidence against their position	0	22	6	14	0
	1	11	23	0	3
	2	2	6	0	11
Conclusions to overall argument	0	1	0	0	0
	1	30	14	14	1
	2	0	0	0	0
	3	4	21	0	13

Table 1 shows the findings of analysis of the arguments on global warming. Looking at the pre-assessment task results, according to the outcomes of the Mann-Whitney U test, there was no significant difference in the distribution of scores in control and experimental conditions with respect to the elements Evidence in favour of a chosen position ($z = 0.25$, *n.s.*), Normativity ($z = 0.00$, *n.s.*), and Conclusions to the overall argument ($z = 0.86$, *n.s.*) The scores for Evidence against a chosen position ($z = 2.66$, $p < .01$) and Counter-evidence to argue against their position ($z = 2.66$, $p < .01$) tended to be lower among the control condition compared to the experimental one. As for the post- assessment task, the scores for Evidence in favour of a chosen position ($z = 1.74$; $.05 < p < .10$), Evidence against a chosen position ($z = 3.91$; $p < .01$), Counter-evidence to argue against their position ($z = 4.03$; $p < .01$), and Conclusions to the overall argument ($z = 2.27$; $p < .05$) were significantly higher in the experimental condition.

Conclusions and Implications

Based on above findings, I concluded that an instructional strategy with epistemic artefacts is effective for improving the quality of students' arguments on SSIs. I conjecture that because the students were able to reflect on the epistemic criteria of their arguments through the mediation of epistemic artefacts, as a result, the quality of their arguments was improved. In this research, I proposed a new instructional strategy focused on epistemic cognition for supporting students' arguments on SSIs, and I demonstrated the efficacy of this strategy. In doing so, this research contributed to the existing body of knowledge on instructional strategies for supporting students' arguments. While I used SSIs as the argument topic in this study, I believe that the idea of epistemic artefacts can be effectively applied to other topic as well.

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