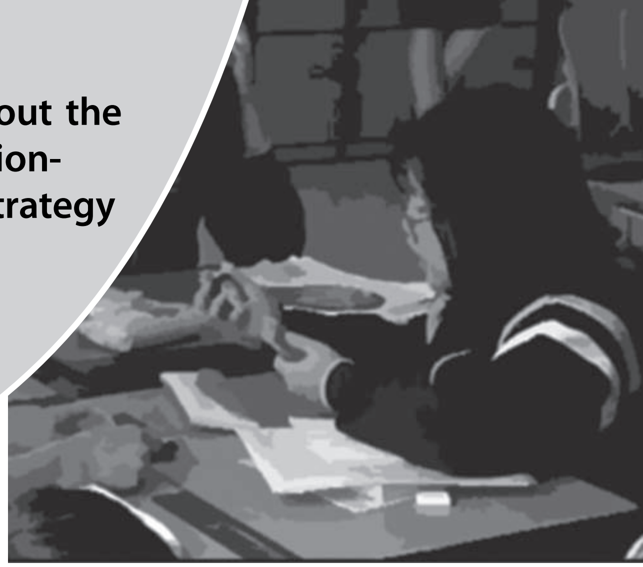
RESEARCH ON LEARNING

Argumentation Activity about the Sense of Vibration: Prediction-Observation-Explanation Strategy Based on the Resources Perspective



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Abstract

As an attempt to contribute to implementing scientific argumentation in classrooms, this study aimed to design an argumentation activity in which students were supported in engaging in the epistemic practices of scientific community. We reinterpreted prediction-observation-explanation strategy based on a resources perspective to acknowledge the role of students' prior knowledge in their construction of arguments and to consider students as active participants with epistemic authority. This argumentation activity was intended to encourage students to construct scientific concepts with valid justifications based on their conceptual resources. Specifically, the activity consisted of three stages: (a) prediction with justification: predicting the result of the task and justifying the prediction; (b) observation: conducting the task to gather first-hand data: and (c) explanation with justification: reconstructing a valid argument with justification. We implemented this activity in classrooms to investigate its practical outcomes with students. The students were able to construct a rigorous argument on their own, evaluating and revising their arguments based on the resources they already possessed and the data they gathered in the observation stage. The results of this research shed light on how to develop scientific argumentation activities that support students as epistemic agents having the ability to construct scientifically rigorous arguments.

Key Words: *scientific argumentation; resources perspective; prediction-observation-explanation (POE) strategy.*

In an attempt to reflect the epistemic aspect of the scientific community (Duschl, 2008), it has been emphasized that we need to implement scientific argumentation—the process of justifying and critically evaluating knowledge claims—in science classrooms (Driver et al., 2000; NGSS Lead States, 2013). Despite the arguments emphasizing the importance of scientific argumentation, many science teachers continue to struggle to adopt this epistemic practice in their classes. To provide support for teachers of biology in this situation, there have been efforts to design argumentation activities for biology classes (Chen & Steenhoek, 2014; Sampson & Schleigh, 2013).

Nevertheless, in the process of adopting these activities in classrooms, various problems have been encountered. In particular, the expectation of many students to be passive recipients of scientific knowledge, a role they were accustomed to in traditional instructional environments, often resulted in them trying to satisfy teachers with superficial work (Berland & Hammer, 2012). Recognizing such epistemic aspects of students, literature to date has emphasized students' potential to engage in authentic argumentation activities, an ability that could be activated in appropriate contexts (Berland & Hammer, 2012). Thus, as a contribution to the design of argumentation activities for science classrooms, we aimed to illustrate our design and implementation of an argumentation activity with the context for students to engage in authentic scientific argumentation.

○ Reinterpreting the Prediction-Observation-Explanation Strategy from a Resources Perspective on Designing an Argumentation Activity

The prediction-observation-explanation (POE) strategy was developed based on Posner's cognitive theory (Posner et al., 1982), as a way to support students in replacing alternative conceptions with scientific ones (White & Gunstone, 1992). This approach supports students' conceptual change by unveiling their alternative conceptions and offering opportunities to substitute scientific conceptions, derived from external sources, for those already held. The POE strategy has implications for the design of argumentation activities in that it provides contexts that reveal students' former knowledge claims, accompanied by their justifications, and prompts a realization of the necessity of evaluating and revising former ideas based on the new data students gather in the observation stage. However, the cognitive basis of the POE strategy interprets students' preconceptions as objects to be replaced, not as potential resources to be developed into new knowledge. Classes based on this perspective typically place students in the role of depending on another source of knowledge to construct scientific justifications and thereby limit the scope of their epistemic practices.

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To address this issue, recent literature has shifted toward a perspective that interprets students' prior knowledge as consisting in fine-grained conceptual resources, namely, the resources perspective (Hammer et al., 2005). Conceptual resources are explained as already existing in students' cognitions and are activated based on students' intuitive perceptions in the specific context within which they are situated (diSessa, 1993; Elby, 2000; Hammer, 2004).

In light of this resources perspective, different implications emerge for the POE strategy, potentially supporting students' epistemic practices during an argumentation activity so that they are empowered to use their own prior knowledge to construct new scientific knowledge. The conceptions students articulate at the prediction stage can be described as an incoherent constitution of activated conceptual resources based on their perception of their situation. In the observation stage, students encounter anomalous phenomena and gather new data that rebuts their predictions, a situation encouraging them to attend to other aspects of their context and to activate other resources. This experience encourages students to evaluate the arguments they made at the prediction stage and to adjust their activation and reconstruct coherent arguments at the explanation stage, so that they can make sense of their observations. From this resources perspective, the POE strategy is reinterpreted as an approach that recognizes students as capable of actively adjusting the activation of their conceptual resources to construct new scientific knowledge. Thus, we employed the POE strategy in designing our argumentation activity, while modifying its epistemic features in light of the resources perspective.

○ Principles for Designing Learning Environments that Support Authentic Scientific Argumentation

In authentic scientific argumentation, students engage in an activity as members of a community within which scientific knowledge claims are constructed and justified (Duschl & Osborne, 2002). Several studies have contributed to the design of argumentation activities that support this shift away from traditional learning environments (e.g., Engle & Conant, 2002; Jiménez-Aleixandre, 2007).

Engle and Conant (2002), for example, have suggested four main aspects to consider in designing learning environments to model authentic scientific inquiry: (a) problematize an intellectual problem that encourages students' engagement; (b) provide students with sufficient authority to address the scientific problem; (c) hold students accountable to others and to disciplinary norms; and (d) provide students with relevant resources to use. Engle and Conant asserted that these aspects would help create an environment in which students are empowered to engage in disciplinary practices as agents who construct shared knowledge in a collaborative process.

Concerning the design of scientific argumentation activities specifically, Jiménez-Aleixandre (2007) proposed principles to support the engagement of students in the practice of argumentation. She indicated that each element of the classroom environment needed to reflect epistemic aspects of the scientific community, supporting students to develop arguments that offer valid strategies of justification. Based on this body of research, one key aspect of a learning environment conductive to an authentic argumentation activity is offering enough space for students to activate and share their resources, developing their reasoning to address intellectual problems.

○ Purpose

This article presents an argumentation activity about the nervous system, for biology classes, that provides the necessary context for students to engage actively in the construction of arguments by activating their conceptual resources. To support this form of engagement, we applied the POE strategy in our design, facilitating data gathering by students and subsequent construction of scientific arguments. We implemented this activity in classrooms to investigate the practical outcomes in the classroom and explore the validity of our design. In addition, we investigated other contextual aspects that served to bolster the students' authentic engagement in the argumentation activity.

○ Method

Participants

A biology teacher in a middle school participated in this research with two classes of students. Each class was composed of 28 students who, for this activity, formed small groups of four to five students.

Data Collection and Analysis

We introduced the argumentation activity, including its purpose and design, to the teacher and provided worksheets (see Supplemental Material) so that the teacher could adopt the activity in classes as a way of supporting students' engagement in the epistemic practices of the scientific community. The activity was about nervous system and neural pathways, asking students to discuss the order in which they would feel vibrations (on the head, on the spine, or on the back of the hand). We video-recorded the classroom discussions both in the class as a whole and in the small groups, and then transcribed the records. We also collected the students' worksheets after the activity, for further analysis.

We investigated the students' answers to each claim, in both the "prediction with justification" and the "explanation with justification" stages, to explore the effect of the new data they gathered in the "observation" stage. In addition, we inductively identified the potential conceptual resources that had been activated by analyzing the arguments using a two-stage analysis of what students wrote on their worksheets. First, to sort out the arguments constructed using scientific conceptual resources, we analyzed how the claims were justified, based on the framework proposed by Sandoval and Millwood (2008). There was one case of illegible handwriting, and other cases where no justification was provided on the worksheet (8 cases at the prediction stage and 6 cases at the explanation stage). The potential conceptual resources that the students activated were then categorized inductively based on the totality of the cases using an inductive approach (Miles & Huberman, 1994). We categorized them based on what kind of difference among body locations the students used to justify why vibrations were perceived more or less rapidly in each location of the body (Table 1).

Second, we analyzed the cases that were justified in relation to the structure of the nervous system to investigate how students constructed justifications based on two criteria: (a) coherence: whether the argument was justified with all data the students collected, without ignoring part of the data; and (b) rigor: whether the students reviewed their ideas critically to construct a rigorous argument. The arguments made at the prediction and explanation

Table 1. The grounds for students' justifications and the potential conceptual resources revealed in their justifications.

0. No justification provided
1. Based on the description of each body part in everyday terms *Example: "Because the brain is super-sensitive."*
2. Based on experiments or previous experience *Example: "Because I usually feel the touch with my hand."*
3. Based on potential conceptual resources
a. Based on the concept of adaptation *Example: "I think hands are more adapted to feel touch more precisely because we usually use the phone with our hands."*
b. Based on the structure of the nervous system
i. Distribution of sensory receptors *Example: "Because I think there are more sensory spots distributed on the back of the hand."*
ii. Distance from the central part of the nervous system (spinal cord or brain) *Example: "Because the spine is in the center of our body, I think it would be the most sensitive part."*
iii. The presence or thickness of something covering the organs or nervous system *Example: "Because the spinal cord is covered by the spine, it perceives less stimulus."*
iv. The speed of transfer of the vibrations through the matter of the part *Example: "Because the spine is composed of bone, it would vibrate faster than other parts."*
v. The different composition of each part *Example: "Because the hand is a sensory organ and the spinal cord is the nervous system."*

stages were analyzed separately to observe any changes between the two stages.

Furthermore, to investigate how the students' epistemic practices changed and to identify the additional contextual features that supported such a change, we analyzed how the students constructed and evaluated their arguments and how the teacher provided support for this practice, using qualitative data. We selected one focus group that showed active engagement in the argumentation activity to construct a shared argument. We established the validity of our findings based on triangulation, comparing the recordings of the classroom discussions, the students' worksheets, and the field notes taken during the activity to document the necessary contextual information (Merriam, 2009).

○ The Argumentation Activity and its Design Principles

The argumentation activity we designed was intended to facilitate students' construction of scientific concepts about sensory receptors in the skin and sensory pathways, producing valid justifications based on the conceptual resources available to them. Specifically, the students were asked to construct an argument to justify the difference in how vibrations were perceived (more or less rapidly) in different parts of the body: top of the head, back of the hand, and on the spine. The activity consisted of three stages: (a) prediction with justification: predicting the result of the task and justifying the prediction; (b) observation: conducting the task and gathering first-hand data; and (c) explanation with justification: reconstructing a valid argument with justification based on the results of the task.

We designed this activity using the principles established in the literature (e.g., Engle & Conant, 2002; Jiménez-Aleixandre, 2007), as discussed above, to promote students' authentic engagement in the biology classroom. Next, we will outline how we applied these principles according to the four aspects of learning environments identified by Engle and Conant (2002).

First, we designed the intellectual problem so as to provide data that would rebut initial predictions, to encourage students to reflect on their original argument and to facilitate their reconstruction of more rigorous justifications. The vibration-sensing task was designed so that students could easily gather data using their phones. Also, because the task did not take much time, students could gather data repeatedly, reducing the chance that they would dismiss anomalous data as an error. The conflict between the prediction and the results of the task would be seen by students as a problem, which would encourage them to reconstruct their arguments.

Second, we intended to position students as active participants with epistemic authority by encouraging them to engage in the construction and evaluation of their own arguments. Specifically, because there would be no immediate assessment of the activity, the prediction stage was designed to encourage students to activate their various conceptual resources without depending on other epistemic authority. The observation stage task allowed students to gather first-hand data; therefore, students could discover on their own the need to evaluate the validity of their own initial justifications. Furthermore, this process would encourage students to reconstruct their arguments using more rigorous conceptual resources to justify their claims using the new data.

Third, we required students to be accountable to others by asking them to gather first-hand data together and then to reconstruct an argument that all members of each small group agreed upon. This request was intended to encourage students to propose ideas and to evaluate them as they constructed a shared argument. Through reaching a shared interpretation that would make sense of their data, students would be enculturated into epistemic aspects of the scientific community by engaging in the activity as contributors to the construction of valid arguments.

Finally, we offered materials and contexts that would elicit resources to be used in the development of justifications. Specifically, the observation stage was designed for the students to gather first-hand data. As the students conducted their data-gathering task, we expected them to be stimulated by this context to activate the diverse resources at their disposal. Also, because it is challenging for students to construct an argument and gather data simultaneously, and also because it is helpful to use both first-hand and second-hand data in balance (Magnusson et al., 2004), we provided additional second-hand data in the form of "evidence cards" (see Supplemental Material) at the explanation stage. The contents of the evidence cards were about the structure of the neural system and neural pathways, offering material that was relevant to the argumentation activity.

○ Students' Learning Process in the Argumentation Activity

During this argumentation activity, students exhibited changes in the way they constructed their arguments, specifically in the epistemic aspects of their discussion.

Prediction with Justification

Students were introduced to the vibration-sensing task and were asked to predict the results and justify their predictions. They wrote down the body parts in order, from the part they thought would sense the vibrations most rapidly to the part that would sense it most slowly, while constructing justifications for these predictions. Because students focused on different features of the phenomenon and therefore activated different conceptual resources to justify their predictions (Table 1), they made diverse claims, as shown in Table 2. Even when they activated the same resources, the students' justifications varied as some of them activated multiple resources or attended to varying features of the phenomenon.

Table 2. The number of students using each claim to construct an argument.

Claim[1]	Number of students	
	Prediction stage	Explanation stage
h-b-s	4	0
h-s-b	4	0
b-h-s	4	0
b-s-h*	28	46
s-h-b	4	4
s-b-h	11	5

[1]h = head, b = back of the hand, s = spine, * = scientifically canonical claim.

Furthermore, although 28 students offered a scientifically rigorous prediction, some of them did not construct a rigorous justification, instead saying, for instance, "because the spine is covered with bone" or "because hands are really sensitive." The logical coherence and rigor of the students' arguments thus varied widely at this stage of the activity (Table 3).

Instead of the teacher evaluating the arguments, the students were encouraged to share their ideas with each other. At the prediction stage, students focused on simply sharing arguments, revealing the diversity of their conceptual resources (Table 4). At this point, they did not attempt to negotiate the differences between their ideas. When Student B provided refuting data (the presence of the skin on the head) at the end of this discussion, no one responded. The discourse showed the students' limitations, at this stage, in constructing a valid argument through evaluation and revision.

Observation

At the observation stage, the students gathered data through a vibration-sensing task. Fifty-one students recorded that they felt the vibrations on the back of their hands first, then on the spine, and then on their heads. However, some students obtained different results (Table 2).

Since the task was designed to provide an opportunity for students to gather first-hand data that would refute their predictions, the students had to deal with this anomalous data while maintaining the coherence and rigor of their arguments. Data could be gathered by students repeatedly, reducing the chance of results being considered as representing measurement error, a form of anomalous data that students usually ignore (Magnusson et al., 2004). Therefore the students were led to reflect on the validity of their justifications and acknowledge the necessity of revising them.

Explanation with Justification

Unlike the students' discourse at the observation stage, which was mostly about the procedures for the task, in the explanation stage, they focused on reconstructing a valid argument. Students would propose various arguments, evaluating them based on whether

Table 3. The number of arguments constructed in the prediction and explanation stages based on the potential conceptual resources about the structure of nervous system, with or without coherence or rigor.

Coherence or rigor	Number of arguments	
	Prediction with justification	Explanation with justification
Coherent and rigorous	6 (10.9 %)	39 (70.9 %)
Coherent but not rigorous	9 (16.4 %)	4 (7.3 %)
Incoherent but rigorous	2 (3.6 %)	0 (0%)
Incoherent and not rigorous	20 (36.4 %)	6 (10.9 %)

Table 4. Focus group students' discourse at the prediction stage.

Student	Discourse	Epistemic practice	Grounds of the justification
E	Spine, hand, and head. . . . Because there are more sensory neurons on the spine and hand than on the head.	claim, justification	distribution of sensory neurons
D	I thought it would be felt on the hand, on the spine, and then on the head because we sense the vibrations with our hands, and I can't figure out the rest. I tried on the head but couldn't feel anything.	claim, justification	experiments or previous experience
A	The skin tissue on the hand is sensitive, isn't it? The skin. Well, though, there's also skin here (touching her own head). . . . I don't know much about the spinal cord, but I could feel the vibrations here slightly . . .	justification, rebuttal, data	description of each part in everyday terms
E	There's bone in the head, right?	data	the presence of the covering
A	Right. Other parts are just skin, but there's bone in the head.	data	
B	But it's quite soft before getting to the bone there.	rebuttal	

Table 5. Focus group students' discourse at the explanation stage.

Student	Discourse	Epistemic practice	Grounds of the justification
E	(pointing at the figure of the spine on the worksheet) It's because of the bone.	justification	the presence of the covering
D	Huh? There's a bone in the hand, too.	rebuttal	
E	But the bone is thinner in the hand.	justification	
B	Hey, that could vary among people.	rebuttal	
. . .			
D	Peripheral nerves take up the stimulus and transfer it to the central nervous system. It's the central nervous system here (touching her own head), but it's peripheral nerves here (raising her hands), so that's why the vibrations were felt faster on the hand. . . . but I can't explain the spine data.	justification, rebuttal	the distance from the peripheral nerves
. . .			
E	Sensory receptors. . . . It's because there are fewer sensory receptors on the spine.	justification	the distribution of sensory receptors in skin
. . .			
D	If we justified with the distribution of sensory receptors . . . then what about the brain part?	rebuttal	
E	What's wrong with the brain? There are sensory receptors in the brain (referring to the distribution of sensory receptors in skin shown in the evidence card).	justification	
. . .			
D	Is there a sensory receptor in the brain?	rebuttal	
E	No, it's in the head.		
D	Oh, it's not the brain. It's the head. . . .	reaching a shared justification	

they could be justified based on the data the students had observed during the activity, and whether it was coherent with their existing scientific knowledge, such as the distribution of sensory receptors in the human body (Table 5). By evaluating and revising these justifications, the students could jointly reach a valid argument that would justify their results.

As a result of this discussion, the resources activated were narrowed down to those relevant to the adaptation or structure of the nervous system; more students constructed coherent and rigorous arguments at this stage (Tables 2 and 3). Certain students gathered different results at the observation stage and constructed alternative arguments to make sense of their observations. To support them in constructing a rigorous argument together, students were encouraged to share their arguments during a whole-class discussion and evaluations of their arguments based on whether the argument could coherently justify their observations. This process encouraged students to reflect on their practices at the observation stage, leading them to reach the level of scientifically rigorous argument. As a result, the students were able to co-construct these rigorous arguments to make sense of their results through evaluation and revision of their earlier arguments.

○ Conclusion

The argumentation activity was designed from a resources perspective to support students as they acted as epistemic agents to construct scientific arguments and in gathering data that would refute their predictions. Using the outcomes of the students' practical activity, we illustrated that they were able to activate a variety of conceptual resources, and that the design of the activity was helpful in encouraging students to evaluate and reconstruct their arguments. Most of the students developed rigorous arguments through argumentation, reflecting the epistemic aspects of the scientific community. By demonstrating an activity that adapted the POE strategy according to a resources perspective, we hope to shed light on how to develop science classes that support students as epistemic agents with the ability to construct their own scientifically rigorous arguments.

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