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The Relationship between Argumentation and the Conceptual Change Model in a Science Teacher's Explanations

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ABSTRACT

This study explored the relationship between argumentation and the conceptual change model in a science teacher's explanations. Ten audiotape recordings (about 9 hours) collected in a high school physics classroom were all transcribed. The transcripts were analyzed using the components of Toulmin's argument framework and two constructs of the conceptual change model: the status of a conception, and the conceptual ecology. This analysis reveals that there are dynamic relationships among Toulmin's argument components, the status of a conception, and the conceptual ecology. The episode extracted from the transcripts shows the science teacher's explanations in the flow of classroom discourse, as directed and guided by her, presenting the intelligibility or plausibility of a conception by using warrants or backings such as examples or anomalies, two components of conceptual ecology.

Key words: conceptual change, argumentation, explanation, justification

I. Introduction

A model of learning as conceptual change, presented by Posner, Strike, Hewson, and Gertzog (1982), and expanded by Hewson (1981, 1982), has provided important insights on learning and teaching in science education. In the conceptual change model, learning is explained as lowering the status of an existing conception, and raising the status of a new one in the context of the learner's conceptual ecology. The status of a conception means the extent to which the conditions of a conception, i.e. intelligibility, plausibility, fruitfulness, are met.

The conceptual ecology, which is drawn from Toulmin's (1972) ecological analogy, is considered the learner's intellectual environment. The conceptual ecology provides the context of learning, and functions as a facilitator of, or a restraint on, conceptual change (Posner, Strike, Hewson & Gertzog, 1982; Strike & Posner, 1985). Hesse and Anderson (1992) emphasized that teachers should use students' conceptual ecologies related to certain subjects as the starting points for learning those subjects. The discourse of the classroom provides students with opportunities to think reflectively about their and others' conceptions, and to justify a particular conception that is compatible with their conceptual ecologies.

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The role of teachers in teaching for conceptual change is to create a situation where students can justify scientific concepts using various criteria within their conceptual ecologies. This study focuses on the ways in which a teacher's explanations have the potential to influence conceptual change in students. To a significant extent, the science teacher in a given classroom will be responsible for whether or not the justification of a conception is operative for students. The adequacy of teacher arguments requires close attention to both the subject matter being taught, and the mechanisms through which teachers assert.

Research related to argumentative discourses in science classrooms has pointed to the importance of argumentation as a scientific activity, as well as a constructivist learning approach for developing conceptual understanding (Alexopoulou & Driver, 1996; Chinn & Anderson, 1998; Driver & Newton, Osborne, 2000; Geddis, 1991; Kelly, Druker & Chen, 1998; Kuhn, 1993; Meyer & Woodruff, 1997; Russell, 1983; Zeidler, 1997). According to the researchers, argumentative discursive practices play a central role in justifying knowledge claims. To investigate the teacher's explanations in the classroom discourse, we used Toulmin's (1958) argument framework and the constructs of the conceptual change model: the conditions of a conception and the conceptual ecology. Toulmin's argument framework has been getting attention in the area of explanations or reasoning research (Alexopoulou & Driver, 1996; Chinn & Anderson, 1998; Driver Newon & Osborne, 2000; Kelly, Druker, & Chen, 1998; Russell, 1983).

From a conceptual change learning perspective, the purpose of this study is to explore whether there are relations between argument components, and the conditions of a conception and the conceptual ecology in the science teacher's explanations. If so, how are they related?

II. Theoretical Foundations

Argumentation is a process of making claims, and providing justification for the claims, using evidence (Toulmin, 1958). Argumentation is an essential kind of informal reasoning that is central to the intellectual ability involved in solving problems, making judgements and decisions, and formulating ideas and beliefs (Kuhn, 1993). Toulmin, in his book, The Uses of Argument, analyzed arguments in a range of contexts, including legal settings and arguments in science. He presents a model that describes the constitutive elements of argumentation and represents the functional relationships between them. This model has been used to analyze argument in the science educational literature, to provide a template for the description of students' arguments (Alexopoulou & Driver, 1996; Kelly, Druker, & Chen, 1998), and to provide a basis for inferring what attitude toward authority is being suggested by teaching (Russell, 1983).

1. Toulmin's Argument Frame

Toulmin's model, used in this study, specifies the components in reasoning from data to a conclusion or knowledge claim. He suggests that a substantive argument is a move from data to a claim. A visual representation of this argument frame is shown in Figure 1.

As shown in Figure 1, the main components identified by Toulmin are (Toulmin, 1958; Toulmin, Rieke, & Janki, 1984):

■ Data: Each of the claims is supported by data, that is, statements specifying particular facts

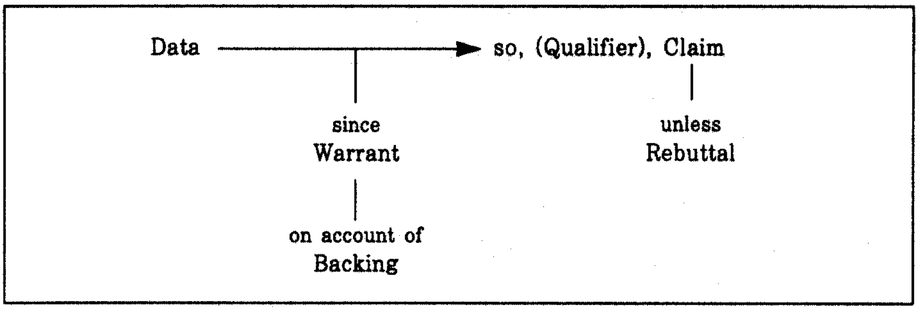

Fig. 1. Toulmin's layout of arguments

about a situation. These facts are already accepted as true, and can therefore be relied on to clarify and make good the previous claim, or - in the best case - to establish its truth, correctness, or soundness, in turn.

- ■Claim: As the conclusion of the argument, a claim is supported by data or factual premise.
- ■Warrant: The statement has the effect of authorizing the step from Data to Claim. Such a general, step-authorizing statement is called a warrant.
- ■Backing: If warrants are not self-validating, they draw their strength and solidity from further, substantial supporting considerations. An argument will carry real weight and give its claims solid support only if the warrants relied on in the course of it are both sound (i.e., reliable or trustworthy) and also to the point (i.e., relevant to the particular case under examination).
- ■Qualifier: Qualifiers specify conditions under which the claim can be taken as true. They represent limitations on the claim.
- ■Rebuttal: Rebuttals specify the conditions when the claim will not be true.

According to Toulmin, all arguments fundamentally consist of (a) a claim, (b) data that support the claim, and (c) warrants that explain how the data are related to the claim. An argument is reasonable if a warrant is provided that leads from data to conclusion. If challenged, the warrant can be (d) backed. Arguments can have the other components (qualifier or rebuttal) mentioned above, but those four are the ones relevant here.

2. The Conceptual Change Model

The Conceptual Change Model consists of two constructs to interpret and facilitate conceptual change: the status of a conception and the conceptual ecology.

1) The status of a conception

A conception's status can be determined according to how well it fulfills four conditions: intelligibility, plausibility, fruitfulness, and dissatisfaction. The conceptual change means the status of a conception rises to a higher level. That is, the higher status of a new conception and the lower existing conception create a new conception. Posner, Strike, Hewson, and Gertzog (1982) identified four conditions for conceptual change to occur:

- ■There must be dissatisfaction with the existing conception. A learner will not go to the trouble of learning the new conception, if the existing one is satisfactory.

- The new conception must be intelligible. That is, the learner must know what it means, be able to find or construct a representation of the new conception.
- The new conception must be initially plausible. That is, in addition to knowing what it means, the learner must believe that new conception to be true, that the conception can fit into the learner's view of the real world.
- The learner must find the new conception fruitful. That is, it should not only solve the problem generated by the previous conception; it should also have the potential to be extended, to open up new theoretical or technological possibilities. Unless the new conception appears fruitful, the learner is unlikely to make the effort required to understand it.

1) The conceptual ecology

The conceptual ecology provides a context for the conceptual change, and affects the change (Hewson, Thorley, & Beeth, 1998). The conceptual ecology is composed of numerous components, and includes their interactions in individual epistemological and psychological context of the conceptual change. Research on conceptual ecology has revealed that the conceptual ecology influencing the conceptual change consists of numerous components, including anomalies, analogies and metaphors, exemplars and images, epistemological commitments (e.g., consistency or generalizability), metaphysical beliefs, past experience, and other knowledge (Hewson, 1985, 1988; Ponser, Strike, Hewson, & Gertzog, 1982; Strike & Posner, 1985, 1992).

The components in the conceptual ecology are listed by Strike and Posner (1985) as:

- <u>Anomalies</u> which arise from an existing conception can act to select for its successor.
- <u>Analogies and metaphors</u> can suggest new ideas or make them intelligible or plausible.
- <u>Prototypical exemplars and images</u> including thought experiments can serve to determine what a learner can understand or find reasonable.
- <u>Past experience</u>, with which conceptions should be consistent.
- <u>Epistemological commitments</u>, including both subject-matter specific and more general beliefs about the character of knowledge, especially scientific knowledge.
- <u>Metaphysical beliefs</u> about science and the universe, and basic ontological categories assumed about the world.
- <u>Other knowledge</u>, with which conceptions should be consistent.

Within conceptual ecology, which involves various components, conceptions exist as a part of ecology, rather than as quite independent of each other. That is, the status of a conception could be affected by the conceptual ecology. Beeth (1993) made the relationship of features of a conceptual ecology to the conditions of a conceptual change into a table (see Table 1). As shown in Table 1, it could be interpreted that anomaly, as a component of the conceptual ecology, plays a role of satisfying the conditions of a conception: dissatisfaction, plausibility, and fruitfulness. Analogy, metaphor, example, or image contribute to fulfill the condition of a conception: intelligibility. And all the components of conceptual ecology contribute to fulfill the condition of a conception: plausibility. Table 1 will be used as the referent of our analysis in this study.

Table 1. The relationship of components of a conceptual ecology to the conditions of a conceptual change

Components of conceptual ecology	Conditions for an accommodation			
	Dissatisfaction	Intelligibility	Plausibility	Fruitfulness
Anomaly	o		o	o
Analogy, Metaphor		o	o	
Example, Image		o	o	
Epistemological commitment	o		o	
Metaphysical beliefs and conceptions	o		o	
Past experience	o		o	o
Other knowledge	o		o	o

Ⅲ. Methodology

This research is a naturalistic study. Ten audiotape recordings were collected in a general physics classroom in a Wisconsin city high school. Sound and waves were the topics being studied by the 11th grade students during June and July, 2002. The physics class met, 45 minutes a day, 5 days a week, completing the unit 'Sound and Waves' in 3 weeks. In this study, there were 26 students in the classroom. The teacher has 12 years of experience in teaching physics at the high school level and has a reputation for encouraging active classroom discussion. Throughout the period of this study, the first author observed the physics class. The teacher and her students do not know what this study is about at that time of this study.

The recordings (about 9 hours) were all transcribed for analysis. For preliminary analysis, the classroom discourse was separated into segments, an episode containing the concept the teacher aims at teaching (for example, waves) in the classroom. The episode that we will present in this paper includes the concept 'waves' and is consisted of three segments; light is a wave which can pass through another, waves transfer energy without net transfer of matter, and waves pass through each other. We applied Toulmin's argument frame to identify what the components of the argument are, and how they are connected. In each segment we identified the components - data, warrant, claim, and backing - of each argument.

And then we identified which components of conceptual ecology are used in each segment. Here, we assumed that the teacher used the components of conceptual ecology (for example, anomaly or analogy) for students' understanding in her explanations. Referring to Table 1, we came to an agreement of the conditions (intelligibility, plausibility, or fruitfulness) of the concept that the teacher explained. And finally, the relationship between arguments and the components of the conceptual change model—the conditions of a concept and the conceptual ecology—, based on the above analysis, were explored. Table 2 gives an example of our analysis.

Table 2 includes the discourse between students and the teacher in science classroom (column 2). Focusing on the teacher's explanations, we identified the components of argument (column 3) and of the conceptual ecology and the status (column 4). In column 5, we added some comments on the relationship of argumentation and the CCM in the stream of her explanations.

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Table 2. Shown are our analysis by the components of argument and CCM (Conceptual Change Model) in classroom discourse. This example includes the discourses in segment A.

	Classroom Discourses	The components of argument	The components of CCM	Comments
F	Sound waves		Example / I	
T	Sound waves. What else?		Example / I	Soliciting examples
F	Light		Example / I	
T	Now, do you guys realize that according to me, how come <u>I can see all of you?</u>	<u>D1</u>		Soliciting a claim from D1
M	Your eyes			
T	What's happening?			
F	Waves go to your eyes	C1		Student's claim
T	Waves are going to my.. Now, are waves from sun, they're coming to my eyes here, and then *there's some waves back there from, say a computer and are bouncing off.* And <u>waves here</u>, and I know you guys can't see it, but, you know, *when you talk on your cell phones, or radio waves, are those coming, are those around? I mean, we live in a sea of radiation. We can't see it all. We can see the narrow band that we call 'visible light' and that gives us colors.* But it's all there And how come, how come <u>when you talk on the phone, on the cell phone, your wave can get to whoever the receiver is, but there's other ones, too</u>. Do they interfere with each other?	C1 *W1* <u>D2</u>, C2 *W2* <u>D3</u>	*Example / I* *Example / I*	Elaborating the student's claim Providing an example as W1 Giving D2 related to W1 Providing C2 and examples as W2 Giving D3 citing examples used in W2 Soliciting a claim
F	Sometimes			
I	A little bit. But right now. The waves that are coming from you, and you, and you, and you, they're all getting to my eye, but they're not interfering with each other. *It's amazing that waves have this ability to pass through each other.* **Whereas, objects don't, that would be nice on the highway if cars could just pass through each other. But, unfortunately, that's not the case, which is why we have insurance industry, and car repair, and body shop, and blah, blah, blah.** But waves are unique, and we studied them early in the year, but we didn't really study the nature of the light wave itself	C3 *W3* **B3**	*Conception* **Anomaly**	Giving C3 in connection with C1 Using general concept as W3 Providing anomaly to establish W3

T: teacher, F: female, M: male, D: data, C: claim, W: warrant, B: backing, I: intelligibility

Ⅳ. Results and Discussions

Episode: What is a wave?

This episode is the opening portion of a 'sound and waves' lesson, which focuses on illustrating the nature of waves. This episode includes three segments.

1. Segment A: Light is a wave which can pass through another.

This segment is an introduction of the target conception 'waves' in classroom discourse. In this segment, the conceptions the teacher is explaining are about 'light is a wave' and 'waves can pass through one another'. This segment involves three arguments to explain the conceptions (see Figure 2).

In argument 1, she starts to ask a question *"how does light get from me to your eyes?"* to solicit a claim with a warrant. After a sequence of discourse with her students, she presents the claim *"waves are going to my, now, are waves from sun. They're coming to my eyes here"* with the warrant *"there's some waves back there from, say, a computer that are bouncing off"*. At that point, she presents the intelligibility of the conception 'wave', using an example of a computer which is familiar to students.

In argument 2, she assumes the datum *"waves here"* based on argument 1 and claims *"waves go to your eyes"*. For warranting the claim, she explains:

> *When you talk on your cell phones or radio waves, are those coming, are those around? I mean we live in a sea of radiation. We can't see it all. We can see the narrow band that we call visible light and that gives up colors. But it's all there.*

In the explanation above, she is trying to juxtapose the data *"you talk on your cell phone or radio waves"* as examples based on experiences, next to the warrant to be continued. It can be inferred that the examples she gives students have a role of expanding the conception's intelligibility.

Argument 3 includes the backing, as well as the data and the warrant. The teacher presents the datum *"your wave can get to whoever the receiver is but there's other ones, too"* on the basis of the warrant extracted in argument 2 and claims *"they're not interfering with each other"*. To elicit the relation of the data to the claim, she uses the general wave conception *"it's amazing that waves have this ability to pass through each other"* as the warrant. And then, the backing she presents as an anomaly, 'the case of objects', draws the strength of the warrant and supports it. The backing she provides is:

> *Whereas objects don't, that would be nice on the highway, if cars could just pass through each other, but unfortunately that's not the case, which is why we have insurance industry, and car repair and body shops.*

Argument 3 shows that the plausibility of the conception 'waves can pass through each other' can be provided through the warrant as the general conception and the backing as the anomaly. In other words, the claim in argument 3 can be made more believable.

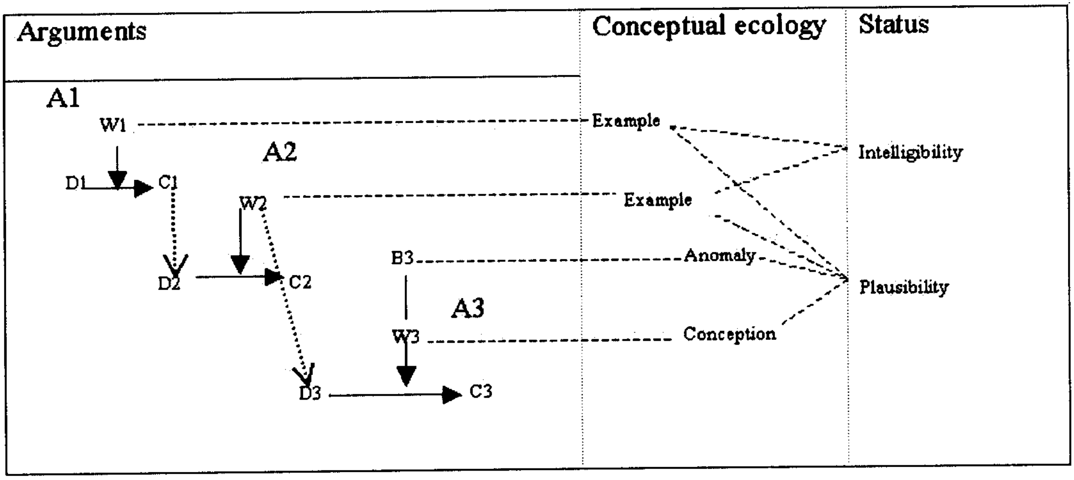

Fig. 2. Shown are the relationships of the components of the arguments and CCM involved in segment A. (D: Data C: Claim, W: Warrant, B: Backing)

Figure 2 shows the relationships of the components of the arguments and CCM involved in segment A. In the segment A, the target conception is 'Light consists of waves which can pass through one another'. In this segment, the teacher uses argumentation including data, claim, warrant, and backing as a rational approach for teaching about waves. As the components of the conceptual ecology, she provides examples (argument 1 and 2), the conception built in argument 2 (argument 3) as a warrant in her arguments. And the anomaly is used as the backing in argument 3. Through warrants or backings, the conception can fulfill its conditions–intelligibility and plausibility.

2. Segment B: Waves transfer energy without net transfer of matter.

As the teacher comments *"how energy is transferred without actually transferring matter"*, she asks students to stand up and line up voluntarily. She shows a demonstration of transferring energy, without any net transfer of matter using students. After five students line up shoulder to shoulder, the teacher causes a disturbance by pushing the first student's shoulder.

In argument 1, the teacher describes the demonstration as the data using scientific conceptions of energy and force, *"now, a disturbance is going to come from my putting some energy into that system by means of an interaction we call force, okay?"* And she presents the demonstration three times to confirm that the students in line still stay in the same place. She emphasizes the data *"what I have done is I have transferred energy at the end... Did they all stay where they were?"* And then she draws the claim that *"so what I did is, I transferred energy without any net transfer of matter"*. To connect the data and the claim, she presents an anomaly, the conception of energy transferring without transferring matter, as a warrant: *"Now if I want to transfer matter, I can take something and throw it. And that's kinetic energy, but waves are a way to transfer energy without transferring matter overall"*. And then she gives an anomaly as a backing to support the warrant, so that her argument 1 builds the argument frame. The dialogue between the teacher and students as backing is:

T: Think about what would happen to all the water in the oceans if the water waves ended up not going back to where they started from
S: It would be kind of weird
T: Yeah, how come they don't just stay there on the beach? We'd have no beaches, we'd have no oceans, we'd have just..
S: Just move around
T: Yeah, that'd be, that would be odd.

And the teacher emphasizes the claim of argument 1 once again summarizing that "*we studied energy transfer, and we talked about different kinds of mechanical energy. But realize that waves are just another way to do that. It's not involving any net transfer of matter, but it is now the temporary transfer of matter*".

Argument 2 involves the concept that waves are another way to transfer energy without transferring matter. The explanation the teacher provides includes the data and the claim together: "*(Data) in all of those visuals here, there was a temporary displacement of matter, but then it went back to where it was in equilibrium.(Claim) So waves transfer energy without net, without net transfer of matter*". From Toulmin's argument frame, argument 2 does not include a warrant or a backing to support the relationship between the data and the claim. However, it can be inferred that the claim of argument 1 as a kind of general conception plays a role of a warrant for explaining of transferring energy of waves, so that the teacher draws the claim from data without a warrant or a backing in argument 2.

Argument 1 consists of the demonstration as the data, anomalies as the warrant or the backing, and gives a warrant of the claim in argument 2. The conception of 'Waves transfer energy without net transfer of matter' has its conditions: intelligibility and plausibility (see Figure 3).

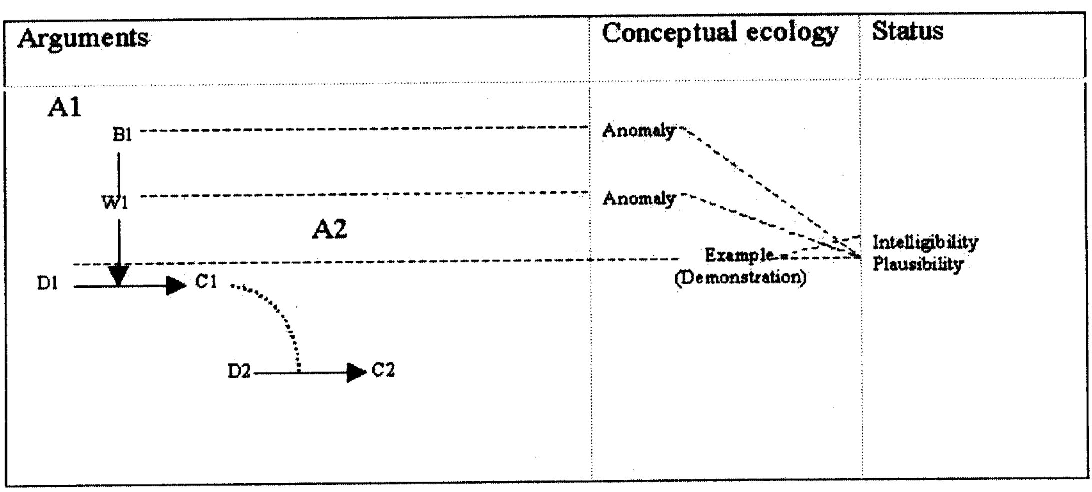

Fig. 3. Shown are the relationships of the components of the arguments and CCM involved in segment B. (D: Data C: Claim, W: Warrant, B: Backing)

Figure 3 shows the relationships of the components of the arguments and CCM involved in segment B. In the segment B, the target conception is 'Waves transfer energy without net transfer of matter'. In this segment, the teacher gives a demonstration as the data, draws the claim from the data, and presents anomalies as the warrant and the backing. And argument 1 plays a role of a warrant to support argument 2. Like the segment A, the target conception of this segment poses the conditions of: intelligibility and plausibility.

3. Segment C: Waves pass through each other (using demonstration as data)

This segment includes only one argument (see Figure 4). The teacher uses a demonstration as the data to elicit the conception 'waves pass through each other'. One student holds the one end of the rope and the teacher holds the other end. They try to send three types of pulse: first, both the student and the teacher make the same size wave; secondly, the student makes a bigger wave than the teacher; lastly, the student makes a smaller wave then the teacher. After demonstration, the teacher asks students to see what happened, and her students express a surprise, "*whoa*". This demonstration serves as the data in an argument to explain what they see. The teacher describes the phenomenon of demonstration "*do you think this pulse bounded off mine and came back to him, or do you think my pulse went straight through to him and his came*". And then she induces her students to consider the claim by asking her students "*they came back through each other?*" and elicits the response "*yes*" from students. She suggests the claim by describing the event:

> *He could go the other way, and he.. I'm going to send mine this way, and he's going to send his the other way. So whatever one gets back to me, we'll see which is right. So one, two, we'll practice, actually. Quicker, yes, good, okay. Ready, set, go. Whoa, what happened. Through each other. We'll try it again. Okay, ready, set, go. See mine got his, and he got mine. So waves do pass through each other. Sure, you go the other way, now, yeah, that way. You do a big one and I'll do a little one.*

This argument involves the data and the claim, and does not contain a warrant or a backing as the components of an argument. Although this argument does not fulfill the components, it shows the students do not have any difficulty following from the demonstration as the data to the claim the teacher presents.

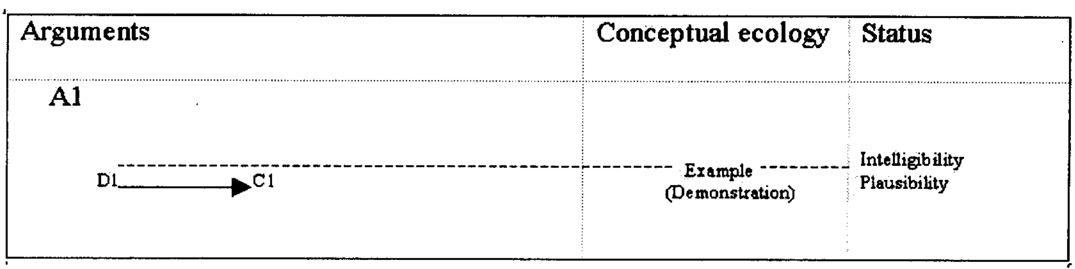

Fig. 4. Shown are the relationships of the components of the arguments and CCM involved in segment B. (D: Data C: Claim, W: Warrant, B: Backing)

Figure 4 shows the relationships of the components of the arguments and CCM involved in segment C. In the segment C, the target conception is 'Waves pass through each other'. In this segment, the target conception is presented here more strongly than in segment A. The teacher uses a demonstration as the data in argument. Although only one argument with the data and the claim is in this segment, the conception can fulfill the condition: intelligibility and plausibility. Because demonstrations are sufficient to bring learners to accept a new view as plausible (Thorley, 1990). Therefore, the target conception achieves intelligibility and plausibility.

V. Conclusion and Implications

This study addresses how argumentation and the conceptual change model are related in the science teacher's explanations in classroom discourses. The episode reveals that there are dynamic relationships among the components of argument and the conditions of a conception and the conceptual ecology. This episode is the opening portion of a 'sound and waves' lesson which focuses on illustrating the nature of waves. This episode includes three segments. The target conceptions are: 'waves' in the segment A; 'waves transfer energy without net transfer of matter' in the segment B; 'Waves pass through each other' in the segment C.

In the segment A, the teacher's argumentation includes data, claim, warrant, and backing. She provides examples in argument 1 and 2, and the conception (built in argument 2) as a warrant in argument 3. And the anomaly is used as the backing in argument 3. Through warrants or backings, the target conception can fulfill its conditions—intelligibility and plausibility. In the segment B, the teacher gives a demonstration as the data, draws the claim from the data, and presents anomalies as the warrant and the backing. And argument 1 plays a role of a warrant to support argument 2. Like the segment A, the target conception of this segment poses the conditions of: intelligibility and plausibility. In the segment C, the target conception is presented more strongly than in the segment A. The teacher uses a demonstration as the data in argument. Although only one argument with the data and the claim is in this segment, the conception can fulfill its condition: intelligibility and plausibility. In this study, we couldn't find dissatisfaction or fruitfulness of the conceptions in the teacher's explanations because of the limitation of our study. This research contained just the teacher's explanations of 'waves'. There is thus a clear need to extend the inquiry to the status of students' conceptions and their conceptual ecologies, and also to their argumentations in justifying their conceptions.

When teachers are explaining something, they are always explaining something to someone. In classrooms, explaining a thing to students is to promote new discovery and new understanding in them. It can be said that explanation is closely linked to conceptual change. In teaching as conceptual change, the explanations have the goal of being change in students' knowledge, interest, and beliefs, with regard to the topic under study. The challenge for most classroom teachers is to not only initiate, but to guide that change process. Teachers want students not only to change toward scientific knowledge, but also to hold it as significant and meaningful. By presenting examples, anomalies, past experience, and so forth, appropriate to students' conceptual ecologies, teachers can begin to help student achieve richer understandings and more meaningful conceptualizations of scientific concepts.

Conceptual change for teaching involves taking the argumentation structure for students to justify scientific concepts and adapting it to the explanations and the discourses the teacher orchestrated. Conceptual change has typically been thought of as a rational process whereby students reason from their initial conceptions with available evidence, given a particular conceptual ecology, to a new set of conception (Ponser, Strike, Hewson, & Gertzog, 1982; Kelly, Druker, & Chen, 1998). The warrant in argumentation structure is the reason that students should accept the claim given the particular evidence that has been offered. The results show that the teacher uses examples or anomalies as warrants to justify the claims (see segment A and B). It appears important to consider warrants as the component, related to students' conceptual ecologies, when teachers present unfamiliar or abstract concepts. Or warrants are implied within the explanations in the case that students can infer them in an argument (see segment C). In this case, we interpret that the warrant is so obvious that its presence in the teacher's explanations seems needlessly redundant. Therefore, the well-designed explanations, explicitly drawing connections between students' conceptual ecologies and scientific understanding, may be particularly effective at persuading students to adopt the new understanding.

This trace of the teacher's explanations provides important insights on their structure and content for promoting students' understandings. Our analytic approach combined the components of conceptual change model and argumentation components that until now have been separate. Diagramming the teacher's explanations using argumentation framework and the conceptual change model is a relatively new approach to analyzing the quality of them. It could be powerful to examine whether the teacher's explanations are rationally structured and whether the content of them are appropriate to students' conceptual ecologies for understanding. That is, argumentation framework and the conceptual change model are complimentary to each other in a sense of showing both the structure and the content of explanations.

We believe that this research suggests that further studies using this combined analytical approach can provide additional information to science education research. Beyond the teacher's explanations provided in this study, this diagramming may well be effective in building new understanding of instructional conversations aiming at conceptual change. That is, this diagramming could be valuable for generating new insights into the give-and-take of ideas by teachers and students. By mapping out instructional conversations, one can illuminate the developmental argumentation process among teachers and students, as well as the semantic relationships among ideas.

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