

Figure 1. Depictions of the 11 Problems in the “Air and Water” HEI Unit.

Table 1: Wording of the 11 problems in the “Air and Water” HEI unit.

Problem 1. When an empty glass is pushed into water upside down, will the water come into the glass?
Problem 2. If you place a crumpled piece of paper in the glass and do the same as in Problem 1, will the paper get wet?
Problem 3. An upside-down glass with water inside is in the water. When you lift it up through the surface of the water, what will happen to the water in the glass?
Problem 4. What will happen when you suck air through a straw from an upside-down glass in the water?
Problem 5. Which dropper sucks more water, one whose tip is deep in the water or one whose tip is shallow?
Problem 6. Can water be sucked through a 1m straw?
Problem 7. A can of juice has just one hole on top. When the can is turned upside down, will some juice come out of it?
Problem 8. Will some juice come out of a can that has two holes on its top and is turned upside down?
Problem 9. Suppose you put the can used in problem 8 deep into the water, keeping your finger tight on one of the holes. Will some water go into the can?
Problem 10: What will happen to the can in problem 9 if you let your finger go?
Problem 11: Will some soy sauce come out of its container if you put your finger onto the hole on its top?

Table 2: Four-stage model of conceptual change.

Level 4	Scientific concept, created and shared in the scientific community
Level 3	Confirming explanation by integrating many ideas, including “textbook” scientific concepts
Level 2	Rules of thumb created by accumulating one’s own (yet many) perspectives from different situations
Level 1 ^t	Explanation or “theory” like folk concept based on one incidence

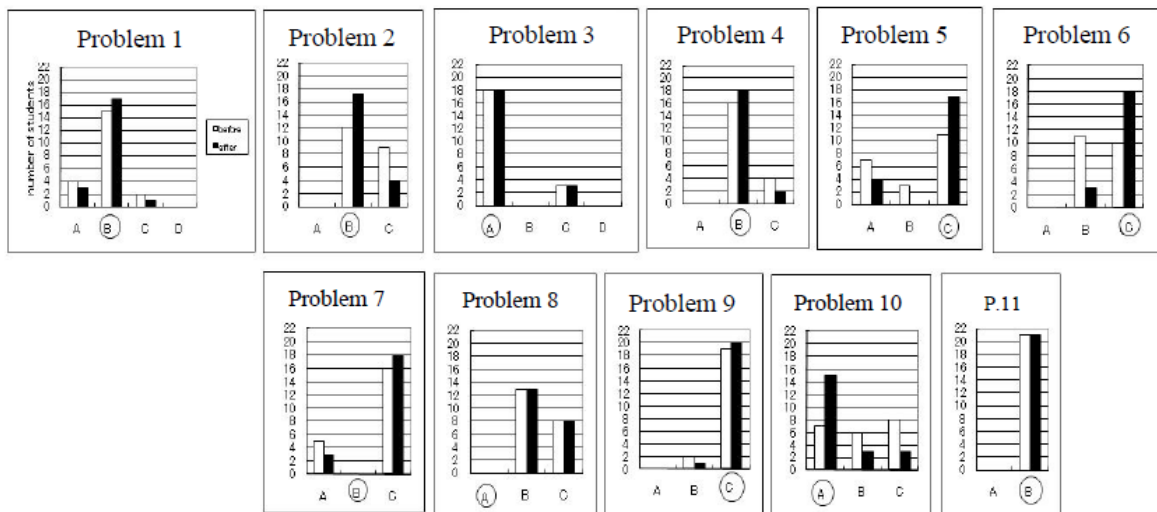


Fig. 2. Student's Choices of Alternative Answers for Each Problem in the "Air and Water" HEI Unit.

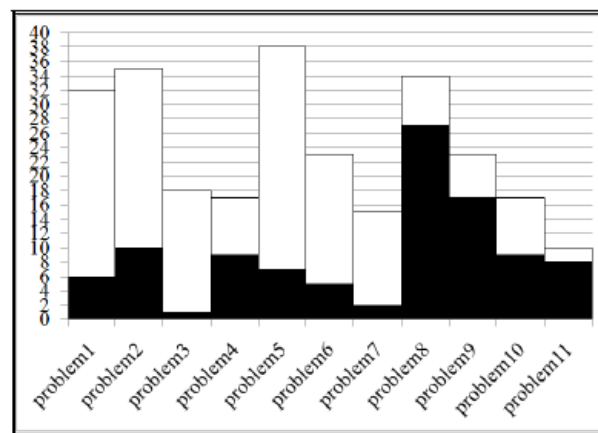


Figure. 3. Number of Students' Utterances during Discussion in the "Air and Water" HEI Unit.

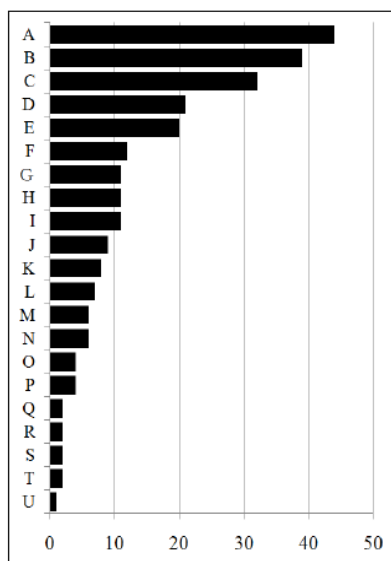


Figure 4. Number of Utterances for Each Student.

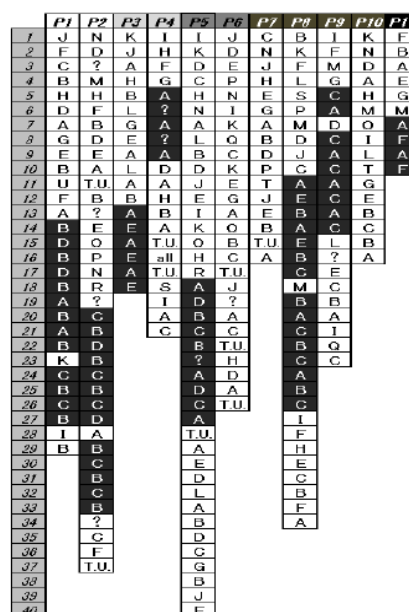


Figure 5. Role-exchange Patterns for Each Problem.

Table 3: Excerpts of typical utterances during the discussion session of P7.

3	J	I want the juice to come out fast.
...
7	A	The can has only one hole so the air can't escape.
8	B	When I punched a small hole in a milk carton, the milk dripped out continuously.
...

(N.B. Numbers in the left-most column are orders of the utterances in this session. The letters in the second-to-th column denote students, as in Fig. 4.)

Table 4: Excerpts of group-based dialogues during the discussion session of P8.

1st Group-based dialogue	
11	A The juice in the can would block the air from coming in.
12	E I think the air would enter from both holes and block the juice.
13	B The air would enter from both holes and pass through the juice in the can.
14	A Oh yes! The air will turn into bubbles and pass through the juice!
15	E If the air blocks both holes, where can the juice come out from?
16	B When the air enters into the can, the juice would come out. But I don't know how.
2nd Group-based dialogue	
17	C The air won't enter the can because it is filled with juice.
18	M Oh! I got it!
19	B C didn't listen to me. I said, "The air passes through the juice in the can."
20	A The can has no space. It is filled with juice.
21	C The can is filled with juice. So the air can't break into the can. Why do you think the air can enter the can?
22	B The can has some space on top.
23	C I don't think cans of juice have any space.
24	A Yes, I think so, too.
25	B Even a little space is enough for the air to enter.
26	C The can is filled with juice. So the air will never break into the can!

Table 5: Excerpts of a group-based dialogue during the discussion session of P9.

5	C	Half of the air would escape from the can when it lies sideways.
6	A	I think that air tends to rise. So air won't escape from the hole punched on the lower side of the can.
7	D	What do you mean?
8	C	The can will be put deeply into the water. So I think we don't have to worry about the position of the hole.
9	A	The base of the can would push back the water.
10	C	When we tipped the glass in <Problem 2>, I remember, the glass was filled halfway with water.
11	A	The can with a hole doesn't have a wide mouth like the glass.
12	C	Small bubbles can pass through even a small hole of the can.
13	A	Anyway, I think the position of the can has nothing to do with the amount of water.
14	C	I think that all the air would escape from the can when it stands up. So half of the air would escape from the can when it lies sideways.

Table 6: Excerpts of typical utterances during the discussion session of P10.

1	K	The can has two holes. So the water will replace the air that filled the can.
4	A	The air will escape from one hole, and the water will come in from the other hole.
14	J	The air will powerfully block the movement of the water.
17	B	The air will escape from the two holes. After the movement of the air, the water will come in from the two holes.