

An Analysis of the Features of 'Typically-Perceived-Situation(TPS)' for in-depth Understanding of Students' Ideas: The Case of Four Elementary School Students' TPSs related to the Action of Force

Yong-Jae Jung* · Jinwoong Song

(Seoul Top-Dong Elementary School)* · (Seoul National University)

ABSTRACT

A Typically-Perceived-Situation(TPS) is a situation which might be useful for conceptual learning of science, rising spontaneously in an individual's mind when someone is thinking about, or in relation to, any object such as physical object, concept, situation, etc. But, for a discussion about the TPS' usefulness in depth, we need to analyze the specific features of the TPS in relation to conceptual learning of science. This study investigated four elementary school students' TPSs related to the topic of the action of force, especially (a) 'the situation where force is being acted on an object', and (b) 'the situation where force is not being acted on an object', with an interview as well as with a drawing-and-explanation type questionnaire. Their TPSs were then compared with their concepts, checked by a misconception questionnaire of choice-and-explanation type. The results showed that the students' TPSs illustrated not only their conceptions about the action of force, but also gave more fruitful details of their ideas, including (a) clues of their conceptions, (b) concrete situations, and (c) their past experiences with emotional components. On the whole, the TPS's appeared to be rather stable, affected by their past experiences, and needed to be analyzed into their sub-units for more subtle details. Finally, some practical ways of how to apply the ideas of the TPS to the conceptual learning of science are suggested.

Key words: Typically-Perceived-Situation, TPS, ideas about the actions of force, elementary school students, conceptual learning of science

I. Introduction

Conceptual learning has been one of the most important issues in science education. Nowadays, we have about 6000 reported research papers related to conceptual learning of science(Duit, 2004). Many researchers have shown that pupils' preconceptions are very strong and so are not easily changed by the traditional ways of instruction(Driver *et al.*, 1985; Hashweh, 1986; Kuhn *et al.*, 1988; Duit, 1991; Wandersee *et al.*, 1994). If so, what can we do to overcome these barriers? We suggest a good first step would be to investigate the features of pupils' preconceptions(or misconceptions), and explore the component which is largely

responsible for those features.

One of the features of pupils' preconceptions is that they are intuitive and experience-based. Many researchers agree that most preconceptions arise as a result of experience in interacting with the world(Hashweh, 1986). Through a continuous use of them, these preconceptions become readily available for interpreting events and shaping expectations. And these preconceptions are intuitive(Stepans, 1991), and their usage is automatic at an unconscious level(Hashweh, 1986) like 'procedural knowledge' (Newell & Simon, 1972). In Newell & Simon' system(1972), a production, such as a student's preconception, is composed of knowledge of the if-then form, and when the conditions of a first part are met, then the second part is automatically executed.

Andersson(1986) also claimed that pupils' preconceptions are formed through many-folded experience and are used automatically. He demonstrated there was a common core element in students' explanations and interpretations, i.e. 'experiential gestalt of causation'. An infant pulls his parents' hair, takes a stick and push away a toy, and he tests and investigates continuously, so his experiential gestalt is enlarged. Therefore the pupil discovers, for example, that 'the greater the effort he makes, the bigger the effect on the object(p.137)'. Experiential gestalt of causation, a common core, is one of pupils' oldest and most deeply rooted thinking habits. diSessa(1993)'s claims were also similar. He showed that students had different kinds of *phenomenological primitives(p-prims)* such as *Ohm's p-prims*(it means that an agent that is the locus of an impetus acts against a resistance to produce some sort of results), *force as a mover*(it means that pushing an object from rest causes it to move in the direction of the push), etc. These p-prims are formed through the interaction with a large number of experiences. For example, *Ohm's p-prims* can be abstracted from any number of physical experiences, such as pushing objects. And p-prims, intuitive and pieced knowledge, served important roles in explaining physical phenomena. These claims have also something in common with the claim that, when people have an 'abstractive information(prototype)' or 'representative example(exemplar)' then they categorize the world through considering similarity with this prototype or exemplar(Rosch *et al.*, 1976; Howard, 1987; Shin, 2000).

Another of the features of pupils' preconceptions is that they are network-like things composed of various interactive elements(Strike & Posner, 1982 & 1985; Pines, 1985), and are especially affected by contexts or situations(Mori *et al.*, 1974; Dreyfus & Jungwirth, 1980; Driver *et al.*, 1985). The features of network-like were shown well by Strike & Posner(1982 & 1985). They adopted a term, 'conceptual ecology', from Toulmin(1972)'s evolutionary theory. An individual's conceptual ecology which includes various resources, for example anomalies, analogies and metaphors, exemplars and images, past experience, etc., will influence the selection of a new conception.

Pines(1985) pointed out two aspects of concepts: "Firstly, concepts are not independent entities but, rather, are complex collections of relations embedded in a larger framework (or multiple frameworks), and secondly, these bundles of meaningful relations we call concepts are, on the one hand, capable of change, and on the other hand, can never be acquired in any finalistic fashion(p.110)". In his view, concepts have various meanings within different contexts. And misconception does not exist independently, but is contingent upon a certain existing conceptual framework, i.e. complex collections of relations.

The context effect on preconceptions was also shown by Dreyfus & Jungwirth(1980). They examined the assumption that the logical structures of a contextually different situation are

perceived as equivalent by pupils. They concluded everyday contextual factors exert a 'deflecting effect' (away from the logical task), causing pupils to pay more attention to the topical content of the offered conclusion rather than to the logical structure of the situation. Similarly, Driver *et al.*(1985) pointed out that pupils' ideas were dependent on the situation of problems. Mori *et al.*(1974) showed also that pupils' concepts were affected by cultural context. And White(1985) divided context into 'real context' and 'perceived context'. He pointed out that the perceived context, which was accepted by an individual's mind, had practical influence on students' ideas and learning, and so the perceived context was more important(Song, 1997).

Considering the features of pupils' preconception -that is intuitive, experienced dependent, network-like, and context dependent, -we suggest that 'Typically-Perceived-Situation(TPS)' should be one of the important components of conceptual learning of science. The TPS, named by the authors, is 'a kind of mental representation rising spontaneously and immediately in an individual's mind when someone is thinking about, or in relation to, any object such as physical object, feeling, concept, situation, etc'.

'Typically' represents especially the feature of intuitive and experienced dependent, and 'Perceived-Situation' represents especially the feature of network-like and context dependent. Thus, the TPS could have an important role in students to understand a given problem situation at first hand. And the TPS could be useful for instruction aiming at conceptual learning of science because it would be able to provide a suitable anomalous situation(Strike & Posner, 1985) which raises students' cognitive conflict, and also provide reinforcing examples(Gagné, 1970) which challenges students' original ideas. The TPS also could be useful for understanding students' ideas including practical situations, especially the ideas of young children whose linguistic ability are not high because the scene of the TPS is to be described by children's drawing, while other methods of understanding students' ideas require somewhat high linguistic ability(e.g., Novak, 1998), and also because TPS represents the practical situations related to students' ideas, while other methods focus on concept itself, even though some of them have an element of drawing(e.g., Feher & Rice, 1988; Kim, 2004).

Before discussing these practical uses of the TPS further, however, we need to investigate the concrete features of the TPS, i.e. what characters the TPS has, and whether the TPS gives practical information about students' ideas, and if so, what kind of information the TPS gives, etc. This is because the meaning and strength of usefulness of the TPS would be changable, according to what features the TPS has. Thus, to illustrate more clearly the features of TPS in relation to conceptual learning of science, we undertook a case study with four 6th grade students.

II. Research Design

This case study was conducted with four 6th grade upper-achievement students(two boys: Myung-Ho¹⁾ & Hong-Min, two girls: Jae-Hee & Ok-Sun) attending the same elementary school in Seoul. They were purposefully selected from three classes by the researcher who is their science teacher. They all express themselves well, and have not learned about science outside school. It can be said that they have not acquired physics concepts of force, and of force and

1) These names are assumed name.

motion, because there is no clear and detailed content related to those concepts in Korean 7th science curriculum.

In this study, we investigated, firstly, the whole scene of the TPS, which students were recognizing, secondly, the sub-units of students' TPSs, and thirdly, the answers of the students to the misconception-testing questionnaire, in order to compare them with the examined TPSs.

Firstly, the investigation of the whole scene of the TPS were executed by using the investigation tool a total of three times, with an interval of 4 days. The tool, developed by the researchers, contained two questions. Students were asked to draw the scene of the TPS regarding the situation given to them by the questions, and to add an explanation about their TPSs. The questions given to them were as follows.

- (a) When you hear that "force is being acted on an object", what kind of situation first enters your mind?
- (b) When you hear that "force is not being acted on an object", what kind of situation first enters your mind?

Considering that our definition of a TPS is a situation rising spontaneously and immediately in the mind, it was necessary for students to respond as quickly as possible. Students were also reminded that the result of this test had nothing to do with school records, thus there was no need to make any effort to provide 'the right answer'. And we told them that we were measuring response time, and thus encouraged them to provide their answers as soon as possible.

Secondly, the investigation of the sub-units of the TPS were executed by using the investigation tool including, asking to write down the content and the importance degree of the sub-units, and by individual interviews conducted with the use of videotapes, audiotapes, and field notebooks.

The sub-units, as we call them, are more basic components of the TPS. We set up the sub-units based on '5W1H principle' -i.e. when, where, who, what, why, how, - and on the elements which are concerned with the causation of the action of force. In the case of 'force is being acted on an object', we set up 'the background', 'the agency', 'the object', 'the action', 'the result', and 'the criterion for becoming the situation where force is being acted' as the sub-units. For example, if the TPS is "the situation where a person pushes a cart to move in a laboratory", the sub-units of this TPS would be 'laboratory(as the background)', 'human body(as the agency)', 'cart(as the object)', 'pushing(as the action)', and 'being rolled and moved(as the result)'. And if a student thinks that the reason for this situation being the case of 'force is being acted' is because 'a person gives force, then the position is changed'; his criterion would be 'whether or not a human body gives force, and the position is changed'. In the case of 'force is not being acted on an object', we substituted 'the cause provider' for 'the agency', and 'the cause' for 'the action'.

We also asked students to mark an importance degree(0 to 10) of each sub-unit, representing how much the sub-unit is responsible for characterizing the whole situation. This importance degree was used to check comparative importance of each sub-unit that a student was thinking about. Since letting the student describe the sub-units can itself affect the TPS, the investigation of the sub-units was executed about 2 weeks later after the third investigation of

the whole scene of the TPS.

Thirdly, the investigations of students' misconception were carried out by using the tool, which was developed by Kim(2004), but modified by the authors to make it suitable for the 6th graders. This tool is composed of five choice-and-explanation type items about the topics of the motion of a vertically thrown-up ball, a stone hung by a rope, and a book on the desk(see Appendix).

With an intent of coming to a better understanding the features of the TPS, we collected and synthesized the students' responses to the questionnaires for the whole scene of the TPS with drawings, for sub-units of TPS, and for the misconception test, and the documents from individual interviews. We firstly interpreted students' drawings and explanations with a focus on their ideas about the action of force, and compared them with their answers which were provided by other sources. Our interpretations were often examined and compared with the interpretations by one physics teacher and one graduate student whose major was physics education, and then our interpretations were modified.

III. Results

1. The Case of Myung-Ho

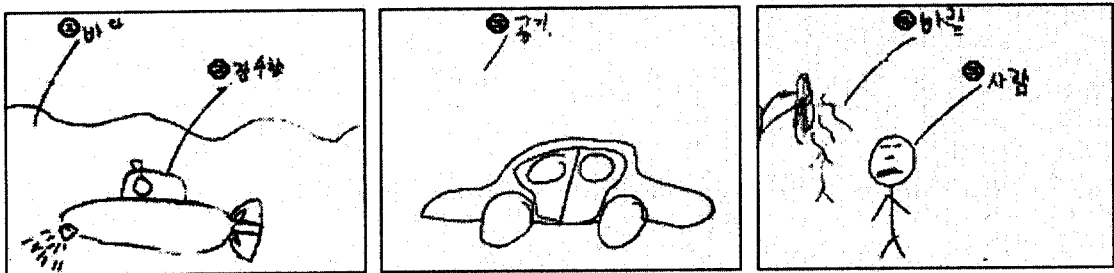


Fig. 1. The scene of Myung-Ho's TPS which was responded in the 1th, 2th, and 3th investigation in relation to the situation where force is being acted on an object. The numbers in the figure were added by the authors in order to illustrate the meanings of Korean words: ① seawater, ② submarine, ③ air, ④ wind, ⑤ person

Fig. 1 shows answers of Myung-Ho to the situation where force is being acted on an object. In the first answer, Myung-Ho drew a scene of seawater and a submarine, and gave an explanation as follows: "I think that this is the situation where force is being acted. Because the submarine is being pressed down by water". Such an idea was also revealed clearly in the second answer. Seawater has just been substituted by air, and a submarine by a car, but the reason given by him was the same as the first. Though he drew a bit different scene in the third answer, this scene also included factor common with the former ones, in respect of the situation of being surrounded and pressed down by something.

Fig. 2 shows answers of Myung-Ho to the situation where force is not being acted on an object. In the first answer, Myung-Ho drew a scene of a floating space shuttle in outer space, and gave an explanation as follows: "[Even though] I haven't been to space, I think the force of

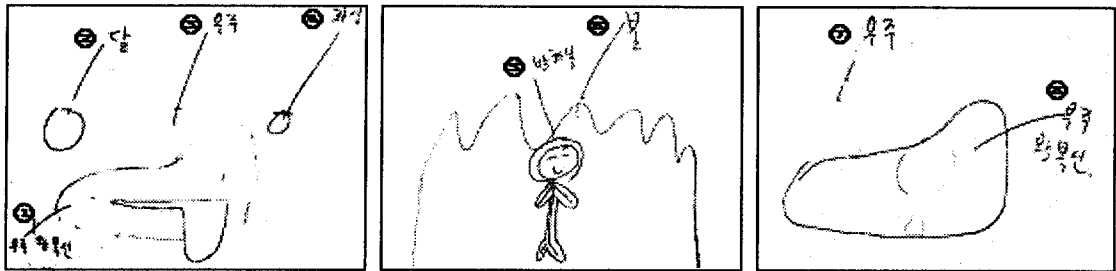


Fig. 2. The scene of Myung-Ho's TPS which was responded in the 1th, 2th, and 3th investigation in relation to the situation where force is not being acted on an object. The numbers in the figure were added by the authors on the original figures in order to illustrate the meanings of Korean words: ① space shuttle, ② moon, ③ outer space, ④ Mars, ⑤ anti-fire clothes, ⑥ fire, ⑦ outer space, ⑧ space shuttle

the object will not affect because there is no gravitation". This shows that he knew already about gravitation, and that he considered the situation with no action of gravitation as the case of 'force is not being acted'. He drew a scene of a person with anti-fire clothes standing in fire in the second answer, and gave a reason as follows: "Because I think even though fire is hot, it will have no weight". This shows that he concentrated on weightlessness due to zero gravity. The drawing and reason of the third answer was the same as that of the first.

On the whole, the above findings show that Myung-Ho's TPS's were stable²⁾ as (a) 'the situation of being surrounded and pressed down by something', and (b) 'the situation of floating around due to the lack of gravity'.

Table 1. The answers of Myung-Ho to the questionnaire for misconception inspection

Item	Choice	Reason
1	④	The earth has gravitation. The ball rose due to a person's force, but due to gravitation there is force acting downward.
2	①	After rising with the force of a person's strength, gravitation comes to act as a break and stops it in that position.
3	①	It is coming down due to gravitation.
4	②	Gravitation is pulling at a rock. But because the attached string is not allowing it to fall the rock is not moving.
5	①	It is not moving from the desk because gravitation is pushing down.

On the one hand, from Myung-Ho's answers to the questionnaire for misconception inspection, it was found that he thought that the moving thing, once it was moved by a person, was being affected continuously by the force(see Table 1). Although he also thought that force is acting in case of object which is still, he figured out and understood the force of being acted by a desk or by an attached string, not as 'an explicit force' but as something to prevent object's moving or falling. On the other hand, he figured out gravitation as an explicit force. His idea as this was reflected in his TPSs which contained the situations of being pressed down by gravitation. Further more his TPSs provided clues to cause him to think that way in respect that he focused

2) In this study, 'be stable' means that there is little change of the students' answers from the first test through the third test. In order to examine exactly the stabileness of the TPSs, it would be required to study its change further through a much longer period.

on whether or not the situation is 'the case of being pressed by something due to gravitation'. And his judgement on this point made him ignore the upward force at a glance.

Table 2. The results of an analysis of sub-units of Myung-Ho's TPS

Situation	Background	Agency/ Cause Provider	Object	Action/ Cause	Result	Criteria
Force is being acted	Sea(10*)	Seawater (10)	Submarine (0)	Push down (10)	To be pressed (10)	-Whether an object under heavy thing(10) -Whether a place with gravitation(9)
Force is not being acted	Outer Space(10)	(Human Body**)	(Space Shuttle)	Fly it to outer space(5)	To be floating(due to lost weight)(10)	-Whether a place with gravitation (10)

* : importance degree

** : The content could be guessed through interpreting the scene though it was not described explicitly.

Similar results were also shown in the analysis of sub-units of his TPSs(see Table 2). In the case of 'force is being acted', Myung-Ho answered about sub-units of the TPSs as follows: 'sea(as the background)', 'seawater(as the agency)', 'submarine(as the object)', 'push down(as the action)', and 'to be pressed(as the result)', and whether an object is under a heavy thing and whether it is a place with gravitation(as the criterion). And he marked 10 points, maximum score, on the importance degree of four of the sub-units, leaving out the object. This shows that he regarded four sub-units (i.e. the background, the agency, the action, and the result) as important things when he considered the situation of force being acted. From these findings it was possible to guess the content of those four sub-units to be similar. In fact, the content of the first answer in Fig. 1 was similar to that of the second. Considering the sub-unit of the background and the action, we could say that both sea and air are something surrounding and pressing down an object with weight. Thus, the second answer in Fig. 2, the fire and 'it cannot press down', can be explained on similar lines because fire is something surrounding an object but without weight, and so cannot press down an object under it.

In the case of 'force is not being acted', Myung-Ho answered about sub-units of TPSs as follows: 'outer space(as the background)', 'fly it to outer space(as the cause)', and 'to be floating(as the result)', and 'whether it is a place with gravitation or not(as the criterion)'. And he marked the 10 points of importance degree on three sub-units (i.e., the background, the result, and the criterion). This kind of thinking has been previously reflected in the first and the second answers in Fig. 2.

From the analysis of sub-units, as shown above, it became clearer that Myung-Ho thought the situation where an object is being pressed down by something as a typical situation of 'force is being acted'. And it became apparent that he concentrated on gravitation and weight, and considered 'the background' factor as an important one to illustrate the situation where 'force is being acted'. These points also suggest that we need to analyze TPS's into their sub-units to acquire further information about students' ideas.

On the one hand, it was also found that Myung-Ho' TPSs could have been affected by past experience³⁾ as shown in the following episode.

Teacher: Why did the images of submarine, water and such things come up in your mind? Did you experience something in the past?

Myung-Ho: Well, it's nothing like that..... Ah, I learned how to swim in the past and enjoy playing in the water.

Teacher: You enjoy playing in the water?

Myung-Ho: Yes. That could be why I remembered them.

2. The Case of Hong-Min

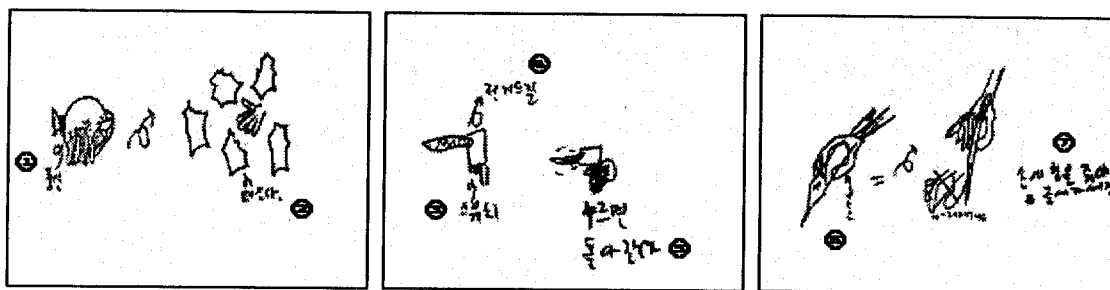


Fig. 3. The scene of Hong-Min's TPS which was responded in the 1th, 2th, and 3th investigation in relation to the situation where force is being acted on an object. The numbers in the figure were added by the authors in order to illustrate the meanings of Korean words: ① ballon, ② pops, ③ switch, ④ electronic drill, ⑤ turn it on and it works, ⑥ hand, ⑦ Writing with a pencil can be done if only force is being acted on hands

Fig. 3 shows answers of Hong-Min to the situation where force is being acted on an object. In the first answer, he drew a scene of popping a balloon by hand, and gave an explanation as follows: "When a person holds a balloon tightly, the air expands and some time later the balloon pops". This shows that as a typical case he considered the change of the shape of an object by human body, especially by hands, and considered also the force acted from the inner side. A similar idea was shown in the second answer illustrating the situation where a person turned on a switch of an electric drill by hand, thus supplying electricity for its working. The third answer, a scene of writing with a pencil, had also a common factor with the former ones in respect of something to be changed by hand.

Fig. 4 shows answers to the situation where force is not being acted on an object. In the first answer, he drew a scene of a fan which is not working and wrote as follows: "Because a fan is an electronic product, it does not operate without the force of electricity". In this situation, it can be said that there is no change in the object because something inside does not function due to no supply (in this case, electricity) from outside. The situation in the second answer can

3) In this study, experience include both direct experience such as swimming or pushing a stone, etc. and indirect experience such as watching a space shuttle through TV or reading articles about the submarine in newspapers.

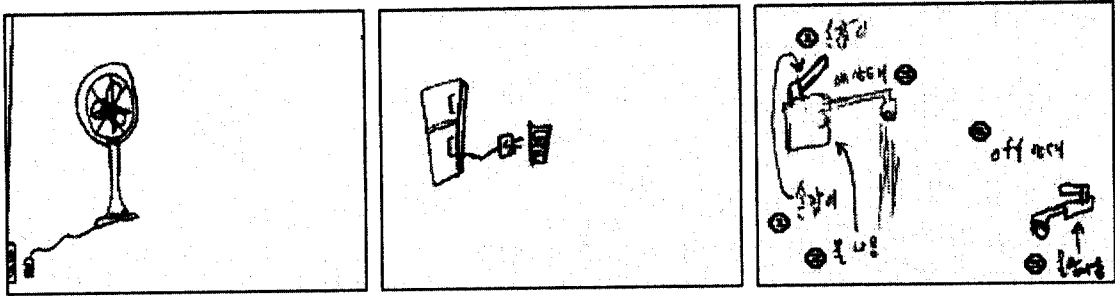


Fig. 4. The scene of Hong-Min's TPS which was responded in the 1th, 2th, and 3th investigation in relation to the situation where force is not being acted on an object. The numbers in the figure were added by the authors on the original figures in order to illustrate the meanings of Korean words: ① tap, ② water coming from the tap, ③ state ON, ④ state OFF, ⑤ water not coming from the tap

be explained similarly. The third answer, the scene of turning off a tap and no water coming from the tap, had also a common factor with the former ones in respect of something not being supplied from outside and thus not working.

On the whole, these above findings showed that Hong-Min's TPS's were stable as (a) 'the situation where with the use of hands the inside of something is affected to change the shape of an object', and (b) 'the situation where there is no change in the object because something inside does not function due to the lack of supply from outside'.

Table 3. The answers of Hong-Min to the questionnaire for misconception inspection

Item	Choice	Reason
1	②	Because the action of holding the ball with hands and throwing it up created force to make it go upward.
2	③	According to my experience, the ball falls a few seconds after floating in the air because the pulling-down force is not being activated.
3	①	In zero gravity even though the ball is floating, since it already fell from the highest position possible the pulling-down force is activated.
4	②	It is floating in air (hanging by a string), since a rock is heavy the weight activates a pulling-down force.
5	⑥	Because a book has weight it has a slight pulling-down force. (He drew it similarly with '①' in item 5, but the arrow is drawn smaller)

On the one hand, from Hong-Min's answers to the questionnaire for misconception inspection(see Table 3), it was found that he thought that force acts on an object in the same direction of its move, and that force is something to 'be created or activated'. It can be said that his view about force, that is, something to 'be created or activated', is based on the idea of 'force is created or activated in an object due to something outside functioning'. His TPS's, as mentioned the above, represented this idea, and provided clues to cause for him to think that way.

Table 4. The results of an analysis of sub-units of Hong-Min's TPS

Situation	Background	Agency/ Cause Provider	Object	Action/ Cause	Result	Criteria
Force is being acted	Laboratory (7*)	Hand(10)	Ballon(9)	Grip(8)	To be pop(9)	-Whether force is added from outside(9) -Whether inside force is emanated (7)
Force is not being acted	Anywhere there is a socket(10)	(<u>Human Body</u> **)	(<u>Fan</u>)	Pull a plug out(10)	To be not working(10)	-Whether force is supplied from something outside (9) -Whether force is added from outside(8) -Whether inside force is emanated (10)

* : importance degree

** : The content could be guessed through interpreting the scene though it was not described explicitly.

Hong-Min's view of 'force is something to be supplied' was exposed more definitely in the following analysis of sub-units of his TPS(see Table 4). In the case of 'force is being acted', Hong-Min answered about sub-units of the TPS's as follows: 'laboratory', 'hand', 'ballon', 'grip', and 'to be pop', and 'whether force is added from outside, and whether inside force is emanated'. And in the case of 'force is not being acted', he answered as follows: 'anywhere there is a socket', 'pull a plug out', 'to be not working', and 'whether force is supplied from something outside, whether force is added from outside, and whether inside force is emanated'. His view about force was exposed explicitly not only in the above criteria, but also in his marking on importance degree of each sub-unit. He marked 10 points on the importance degree of five sub-units, (i.e. 'hand', 'anywhere there is a socket', 'pull a plug out', 'to be not working', and 'whether inside force is emanated'), and these all had a relation with 'force is being supplied'.

On the one hand, Hong-Min considered that a balloon has a property to easily change its shape, and thus it is a suitable thing to show the result of the action of force. And it was also found that his TPS's were affected by his past experience of popping something in a class or at a party, accompanied by a feeling of fun.

Teacher: Wasn't it a scene of holding a balloon in your hands? Then why do you think it was that situation that came to mind and not something else?

Hong-Min: I'm not really sure....., there's other things I'm holding in my hands....., and even though all those things work, but since something set so strongly doesn't change easily, but a balloon does.

Teacher: Oh, so in representing something that changes easily, you came up with a balloon?

Hong-Min: Yes.

Teacher: But then, why do you think that a balloon came to represent that?

Hong-Min: Well, since we always do for science things. In the beginning of sixth grade, learning about the weight of air didn't we use balloons in stead of beach balls? I think I remembered it then.

Teacher: Did you maybe experience a similar situation?

Hong-Min: Ah, yes. When I was young there were a lot of balloons at a friend's birthday, I squeezed a balloon to scare my friends, but it popped. The kids ran away. It was fun. I remember that day.

Teacher: You remember exactly that situation?

Hong-Min: Yes.

It can be said that this above episode was one of the cases showing that TPS is affected by how he considered sub-units, and what his past experiences were.

3. The Case of Jae-Heui

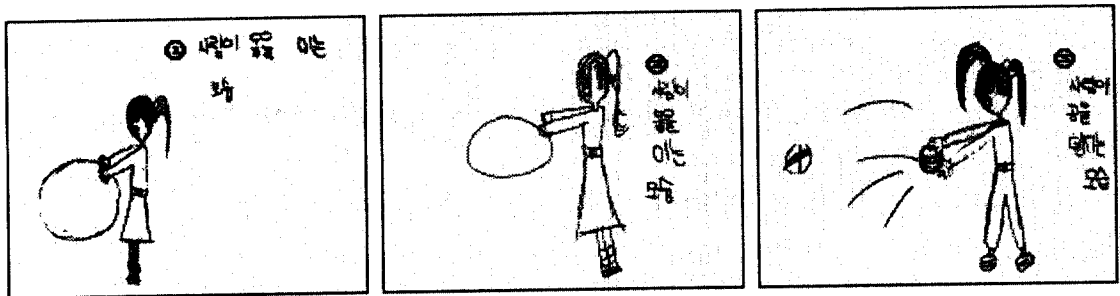


Fig. 5. The scene of Jae-Heui's TPS which was responded in the 1th, 2th, and 3th investigation in relation to the situation where force is being acted on an object. The numbers in the figure were added by the authors in order to illustrate the meanings of Korean words: ① a person pushing a stone, ② a person pushing a stone, ③ a person throwing a ball

Fig. 5 shows answers of Jae-Heui to the situation where force is being acted on an object. In the first answer, he drew a scene of a person pushing a stone, and gave an explanation as follows: "Because a person's energy passes into an object". The same situation and reason were shown in the second answer. Such an idea was also revealed clearly in the third answer. 'Pushing a stone' has just been substituted by 'throwing a ball', but the reason given by her was the same as the former ones. These show that she considered force as energy which can be passed from one to the other.

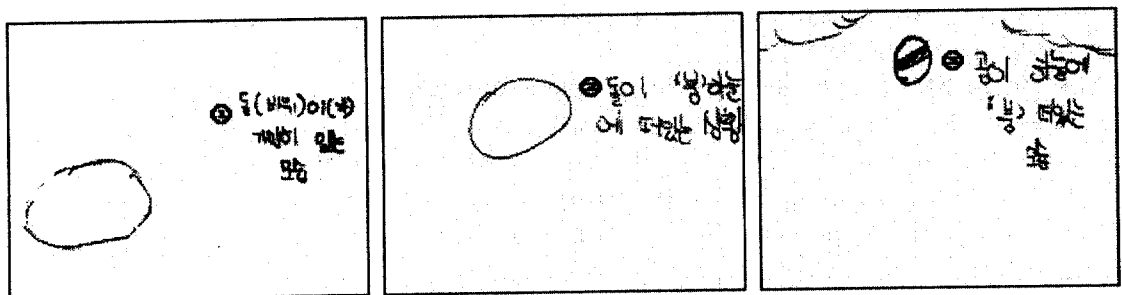


Fig. 6. The scene of Jae-Heui's TPS which was responded in the 1th, 2th, and 3th investigation in relation to the situation where force is not being acted on an object. The numbers in the figure were added by researcher on original figure in order to represent Korean words in English as follows: ① a stone(a rock) remaining stationary, ② a stone floating in the air, ③ a stone floating in the air

Fig. 6 shows answers of Jae-Heui to the situation where force is not being acted on an object. In the first answer she drew a scene where a stone remains stationary, and gave an explanation as follows: "Because there is no force directed at an object, and the object does not direct force at anything else". In the second and the third answers she drew a scene where a stone is floating in the air, and wrote as follows: "There is no force because the stone is not on a table but is floating in the air".

On the whole, Jae-Heui's TPS's were stable as (a) 'the situation where with a person's power, an object moves', and (b) 'the situation where an object remains stationary because there is no force directed at it, and at the same time that object does not direct any force at anything else'.

Table 5. The answers of Jae-Heui to the questionnaire for misconception inspection

Item	Choice	Reason
1	②	Because I think since a ball moves up the direction of the force is 'upward'.
2	③	I think when something is stationary no force is being used.
3	①	I think that when a ball falls down it will move in a 'downward' direction.
4	⑤	Even though a rock stopped moving it would have fallen down if not for the string. That is why I think the force at the bottom is weak and the force at the top is strong.
5	⑤	If the desk was not there the book would fall. But because the desk is supporting the book the force on the top is stronger and the force on the bottom is weaker.

On the one hand, from Jae-Heui's answers to the questionnaire for misconception inspection(see Table 5), it was found that she thought that force acts on an object in the same direction of its move, and that there is no force where an object remains stationary, but, if its remaining stationary were due to something to act on it with contacting, such as a desk does, she thought that there is some force in that case. This idea was reflected in her TPS's. And, her TPS's also provided, as the TPS's of Myung-Ho and Hong-Min did, clues to cause her to think that way in respect that they were stable as 'the situation where an object remains stationary because there is no force directed at it, and at the same time that object does not direct any force at anything else'. For example, the ball which remains stationary in the air is the case of not being acted by force because there is nothing contacting it. But the book on the desk, even if it remains also stationary, is the case of being acted by force because the book is contacting with the desk.

Her thinking along these lines was exposed more definitely in the analysis of sub-units of her TPS's, especially, in the case of 'force is not being acted' (see Table 6). She marked 10 points on the importance degree of 'in the space shuttle(as the background)' while she marked 1 point on 'stone', 6 points on 'to be floating', and 5 points on 'Whether an object comes to be floating'. It shows that she concentrated not on 'the process of coming to be floating', but only on 'the state itself of being floating', as shown in the following episode.

Jae-Heui: I don't think any force would be used if floating around.....

Teacher: Then what about when you're still?

Jae-Heui: When I'm still? The ground or something like that is already supporting me but if I get

Table 6. The results of an analysis of sub-units of Jae-Heui's TPS

Situation	Background	Agency/ Cause Provider	Object	Action/ Cause	Result	Criteria
Force is being acted	Anywhere (4*)	Human Body(8)	Stone(8)	Push(8)	To be stone force working(8)	-Whether there is a help from a person or any other object(3) -Whether an object remains stationary with out it acting on any other thing(7)
Force is not being acted	In the Space Shuttle(10)		Stone(1)		To be floating(6)	-Whether an object comes to be floating(5)

*: importance degree

rid of that, and I'm just floating in the sky..., oh I don't really know.

Teacher: Oh, this isn't related but you said you wanted to change your answer and I'm just curious why you came to change it. There is no right or wrong answer.

Jae-Heui: When I'm standing on the ground or something, that ground is already supporting me but if I was just floating around there's nothing supporting me and I don't think there would be any force being used.

In respect of these findings, it can be said that her explanation about TPS as mentioned above, "There is no force because the stone is floating in air", means not that 'there is no force, and thus a stone come to be floating in the air', but 'a stone is floating, and thus there is no force acting on or acted by it'. So, it can be said that the idea of Jae-Heui is somewhat different from the idea of Myung-Ho(see Table 2). And these result shows that an analysis of TPS into its sub-units makes it possible to differentiate ideas which looked similar into different ideas

On the one hand, it was found that her TPS was also affected by her past experience, accompanied by a feeling of fun and amazement.

Teacher: Anything? But then why do you think of all things, you thought of pushing a big rock?

Jae-Heui: I saw some people in the mountains doing that. I went up to the mountains, and there was this man pushing a rock. So I tried it, too. About three or four times.

Teacher: Oh, really? When? Where?

Jae-Heui: In sixth grade, at that mountain behind us. Almost at the top of the mountain a man pushed a rock and it moved a little. But when I tried it didn't move. Because I'm weak.....

Teacher: Really? You remembered that?

Jae-Heui: Yes. I think that's it. I was amazed that the rock moved. And it was funny.

4. The case of Ok-Sun

Fig. 7 shows answers of Ok-Sun to the situation where force is being acted on an object. In all of answers, she drew a scene of a person having an injection in the arm and gave an

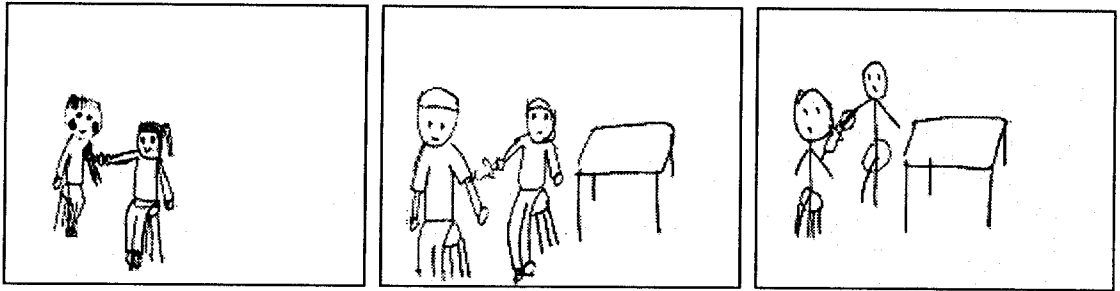


Fig. 7. The scene of Ok-Sun's TPS which was responded in the 1th, 2th, and 3th investigation in relation to the situation where force is being acted on an object

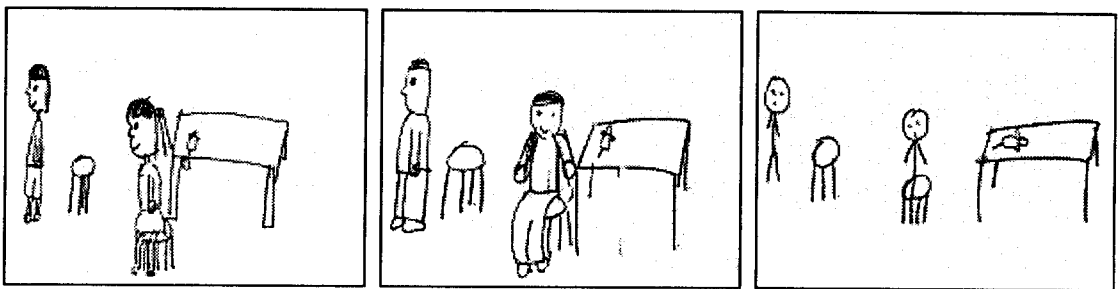


Fig. 8. The scene of Ok-Sun's TPS which was responded in the 1th, 2th, and 3th investigation in relation to the situation where force is not being acted on an object

explanation as follows: "Because a doctor applies pressure to a syringe and adds a force on it". The situation shown in her answers, especially the background of it, about the situation where force is not being acted on an object, was similar to these(see Fig. 8). And she gave an explanation as follows: "Because the syringe is put on the desk and a force isn't added on it".

These shows Ok-Sun's TPS's were stable as (a) 'the situation where a person is pushing something (syringe) and applying pressure', and (b) 'the situation where an object (syringe) is not moving at all and just sitting their'.

Table 7. The answers of Ok-Sun to the questionnaire for misconception inspection

Item	Choice	Reason
1	②	Because it is in the process of moving up and therefore the force being used is also going up.
2	③	I think because if a ball is stationary, it is not moving and therefor there will also be no force.
3	①	Because I think since the ball is coming down, that force will also come down.
4	③	I think because it is stationary there will also be no force.
5	③	I think if it is stationary, since it is not moving there will be no force.

From Ok-Sun's answers to the questionnaire for misconception inspection(see Table 7), it was found that she thought also that force acts on an object in the same direction as its move, and that there is no force where an object remains stationary. And this idea was reflected in her TPS's.

Table 8. The results of an analysis of sub-units of Ok-Sun's TPS

Situation	Background	Agency/ Cause Provider	Object	Action/ Cause	Result	Criteria
Force is being acted	Hospital(8*)	Doctor(10)	Syringe(10)	Push down(10)	To be pressed(10)	-Whether a syringe is pressed(10)
Force is not being acted	Anywhere (3)	(<u>Human Body</u> **)	(<u>Syringe</u>)	Put on still(10)	To be kept still(10)	-Whether an object is not moving(10)

*: importance degree

** : The content could be guessed through interpreting the scene though it was not described explicitly.

Her idea was exposed more definitely, as the others' idea were, in the analysis of sub-units of her TPS's. She marked 10 points on the importance degree of 'doctor', 'push down', 'to be pressed', 'whether a syringe is pressed', 'put on still', 'to be kept still', 'whether an object is not moving' as shown in Table 8. These shows that she concentrated on 'push down to be pressed' and 'to be stationary' in relation to the action of force.

On the one hand, it was found that her TPS was also affected by the past experiences, accompanied by an unfavorable feeling.

Teacher: I thought maybe there was a specific situation related to hospitals.

Ok-sun: No..... Ah, actually, there was when I was young. I don't remember too well, but anyway I remember something like that.

Teacher: You had an examination and got a shot?

Ok-sun: I was six, maybe, it's somewhat fuzzy. I think I might have cried....., I think I did.
[.....]

Teacher: Do you think that experience is influencing your thoughts?

Ok-sun: Yes.

IV. Conclusions

The purpose of this study was to illustrate the features of the TPS. For this purpose, an investigation of four elementary school students' TPSs in relation to the topic of the action of force, especially (a) 'the situation where force is being acted on an object' and (b) 'the situation where force is not being acted on an object' with a drawing-and-explanation type questionnaire and with interview. Their TPS's were then compared with their concepts checked by a choice-and-explanation type questionnaire.

From the cases of four students, the following points were ascertained. Firstly, the students' TPS's illustrated not only their conceptions about the action of force, but also gave more fruitful details of their ideas. All of the four students' TPS's represented their ideas and provided the clues of what caused them to think that way. For example, Myung-Ho's TPSs provided clues of what caused him to think when he focused on whether or not the situation is 'the case of being pressed by something due to gravitation'. And his judgement to this point made him ignore the upward force at a glance. And all of the students' TPS's illustrated the concrete situation related to the given concepts or situations. Students' past experiences including emotional

components were also reflected in their TPS's. For example, Jae-Heui's TPS's were affected by her past experience of pushing a stone with a feeling of fun and amazement.

Secondly, it was found that all of four students' TPS's were stable on the whole from the first answers through to the third answers. In the case of Ok-Sun, especially, all of her TPS's about the action of force were very similar. In the case of others, it was also shown that their TPS's were rather similar from the first answers through to the third answers.

Thirdly, It was found that analyzing TPS's into their sub-units was useful for further concrete information and understanding. For example, an analysis of TPS into its sub-units made it possible to differentiate ideas which looked similar into different ideas, as shown in the cases of Jae-Heui and Myung-Ho.

In summary, through this study, the following conclusions could be made. The students' TPS's illustrated not only their conceptions about the action of force, but also gave more fruitful information of their ideas including (a) clues of their conceptions, (b) concrete situations, (c) their past experiences including emotional components. And on the whole, the TPS's were stable, affected by their past experiences, and needed to be analyzed into their sub-units for further clarity.

The findings of this study provide some educational implications in the conceptual learning of science. First, it would be worth to note the TPS as one of the key components to be changed through conceptual learning of science. It is because the TPS has come to be stable through students' experience in their lives, and provides more fruitful information about their ideas. Thus, to adopt TPS as one of the components to be changed through conceptual learning of science means that we propose to pursue the change of students' habitual and spontaneous thinking in relation with experiences, feelings, and concrete contexts, etc. It could be a worthwhile trial. Second, it would be worthwhile to use the TPS to promote conceptual change of students during science lessons. Considering the features of TPS, the TPS will be useful to understand students' ideas and thinking, to provide anomalous or reinforcing situations to them, and to evaluate their idea after learning.

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