

A Study of Japanese Teacher's Practical Knowledge by Means of an On-going Cognition Method

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1. INTRODUCTION

Action research is a self-reflective form of research involving the investigation of one's own practice in order to improve one's lessons. McNiff et al. (2003) have listed the following as the main features of the action research processes.

- A commitment to educational improvement
- A special kind of research question: how can I improve my practice?
- Putting the 'I' at the centre of the research
- Action that is informed, committed and intentional
- Systematic monitoring to generate valid data
- Authentic descriptions of the action
- Explaining the action
- New ways of representing research
- Validating action research claims
- Making the action research public

The unique features in this list are "Putting the 'I' at the centre of the research" and "Making the action research public". The former is required as a matter of course in order to improve the teacher's own lesson practice. The latter is required in order to ensure the validity of the self-reflective research. The action research process is generally a cycle of actions involving planning, acting, observing and reflecting. The teacher repeats this cycle to improve his or her own lessons. Recently, action research by teachers has also begun to be conducted in Japan, in order to improve lessons. In this case study, the subject of the research is the teacher's practical teaching ability. In this context, practical teaching ability covers not only the teacher's specific "actions", but also the "acknowledgement" and "judgement" – that is to say, "teaching cognition" – that forms the background to those "actions." Therefore, it is necessary to objectify teaching cognition in order to improve teachers' practical teaching ability. However, because this teaching cognition is sometimes conducted unconsciously, amid the teacher's thinking processes, it is mostly accounted for by tacit knowledge.

McNiff, Lomax and Whitehead (2003) described a method of making tacit knowledge explicit which involves the teacher reflecting on having gone somewhere and come back. However, even using this method, it is teaching cognition that is objectified after the lesson. In that case, there is a possibility that re-interpretation by the teacher or observer will enter the picture. One means of objectifying teaching cognition in the teaching process is the on-going cognition method devised by Ikuta (2002).

2. WHY ON-GOING COGNITION?

The teaching process is based on the teacher's cognition towards teaching-learning events and the skill of the teacher to respond in accordance to the students' response. The teacher's cognition is a basic factor in this process (Shulman and Elstrin 1975, Shavelson 1983). Until now, this research has been mainly focused on these points:

- 1) The teacher or researcher discussing the teaching-learning process based on the events they remember well after the class.
- 2) Discussing the teaching-learning process using a protocol from the class.
- 3) Discussing the teaching-learning process using visual media from the class.
- 4) Replaying a visual or audio recording of the class, stopping it to discuss problems with the teaching-learning process.
- 5) Recording the teacher's inner speech while replaying a video and analyze it.

All of these methods have problems with the way they collect data. When relying on remembered information after class, well-remembered information becomes the main focus. The protocol method relies on written information, so when it is read, it can cause a change in the reader's memory when re-reading it. When replaying a video, the teacher and researchers may have time to think, therefore their interpretation of the teaching-learning process will not be the same as it was in class. Visually the view is also limited to the camera's field of view, which in turn affects how the data is seen.

In class, teachers must spontaneously recognize and decide how to teach. In order to study the teachers' cognition and skills, we must gather data in an on-going class. In this research I have focused on methods to gather data on the cognition processes in an on-going class.

This is a method in which the teacher or observer murmurs and records inner speech during the actual teaching process, and sorts these notes out after the lesson in order to gain an understanding of teaching cognition. In the teaching process, in which complex alternations constantly occur, teachers undertake specific teaching actions while also

conducting 'reflection in action', in a similar way to that done by other people who are described as experts. This 'reflection in action' is precisely the area in which the teacher's practical teaching ability is concealed.

3. RESEARCH OBJECTIVES

This research aims to gain an understanding of the teacher's teaching cognition in the teaching process and reveal its characteristics. However, as it is difficult for the teacher to execute the lesson while also conducting on-going cognition, this research focuses on the understanding of teaching cognition during the teaching process by an observer watching an actual class.

4. RESEARCH METHOD

4.1 THE RESEARCH SUBJECT

In this research, the observer was the author; a teacher employed at a state primary school (with 12 years teaching experience) who observed an actual class and engaged in on-going cognition.

4.2 LESSON OBSERVED

- Teacher (A): a teacher at a primary school attached to the local university (with 14 years teaching experience)
- Lesson: 5th grade lesson in arithmetic, focusing on quadrilaterals
- Date of the lesson : June 2nd, 2003

4.3 GOALS OF THE LESSON:

- To develop the ability to think about what wallpaper design will be formed when trapezia, parallelograms or rhombuses are tessellated.
- To be able to show clearly the relationship between the lines extended in a straight line and the position of the sides of the figures.
- To understand that the lines will extend in a straight line in one direction if one pair of sides is parallel and that the lines will extend in straight lines in both directions if both pairs of sides are parallel.
- To develop the prospect of being able to draw figures by applying the definition of a trapezium, a parallelogram and a rhombus.

4.4 OUTLINE OF THE LESSON:

First, the teacher handed out the quadrilateral C (trapezium), quadrilateral D (parallelogram) and quadrilateral E (rhombus) cards to each pupil and had them develop a mental image of the kind of wallpaper design that could be created using the cards. While looking at each card, he got them to draw on sketch paper the

wallpaper designs they had imagined. Based on these, he encouraged them to think about ways of extending the straight lines and the position of these straight lines. The pupils then began to visualize an image based on their favourite of the three quadrilaterals and drew this as a wallpaper design. After that, they displayed their designs to each other, in the order quadrilateral E, quadrilateral D and quadrilateral C. After they had showed each other their designs, numerous quadrilaterals were handed out and the pupils tessellated them and compared them with their own designs.

4.5 RESEARCH PROCESSES

4.5.1 THE ON-GOING COGNITION METHOD

As the observer, I took an on-going record while observing the actual class. I connected a pin microphone to a portable tape recorder and recorded my on-going utterances while observing the class. After the class, the records were matched with the teaching protocol. A video camera was set up at the back of the classroom, to capture a visual record of the teaching process.

4.5.2 MAKING TEACHING COGNITION EXPLICIT BY MEANS OF THE ON-GOING COGNITION METHOD

While reading the class protocol and the on-going protocol, I noted "objects" and "judgements", based on what I had seen and the judgements that I had made. As inner speech is abbreviated or omitted in many cases, it was supplemented with a few more words and collated, in order to make the observer's teaching cognition more explicit. Where necessary, work was conducted while reading the protocol and watching the video recording of the lesson.

4.5.3 REFLECTION ON TEACHING COGNITION BY MEANS OF THE ON-GOING COGNITION METHOD

My teaching cognition was objectified and the background, reasons for and effects of this cognition were described without resorting to predictions or conjecture. In addition, the characteristics of my teaching cognition by means of the on-going method were illustrated. This is summarised in Table 1.

Table 1. Class protocol, on-going protocol and reflection of on-going cognition

Class protocol		On-going protocol	Reflection of on-going cognition
Teacher's instructions	Pupils' reactions		
T1+++++++ T2+++++++	C1***** C2*****	O1 -----	My teaching cognition was objectified and the background, reasons for and effects of this cognition described without resorting to predictions or conjecture.

5. RESULTS AND ANALYSIS

5.1 TEACHING COGNITION REGARDING THE SUBJECT BEING STUDIED

Table 2 shows the class protocols from T2 to T21 and the on-going protocols. The subject being studied in this lesson was "Examining the relationship between quadrilaterals and wallpaper designs using tessellated quadrilaterals C (trapezium), D (parallelogram) and E (rhombus)" (T2). The teacher's specific action did not involve getting the pupils to think about the subject after actually tessellating the quadrilaterals, but rather getting them to form a hypothesis by means of images alone. In this lesson, the moment that the teacher first used the word "imagine", I murmured "imagine" (O4). This can be presumed to be because I received a rather abstract impression from the word "imagine" and it concerned me. We can then see consecutive teaching cognition observations as follows: "So, I wonder if that means that there is an order to these quadrilaterals?" (O5)

The theme of this class was to think about what wallpaper design will be formed when trapezia, parallelograms or rhombuses are tessellated. The wallpaper design means the kind of shape that will be formed with these quadrilaterals. The names of these quadrilaterals were not told to pupils. The teacher confirmed that the pupils had already learned 'general quadrilateral' and 'concave quadrilateral'. After this confirmation, he put trapezia, parallelograms and rhombuses in turn in the blackboard from the left.

The teacher instructs by saying, "By using your imagination. Imagine. After the first time, you'll say that it is easy to imagine tessellating the designs of quadrilateral D and quadrilateral E" (T9). At that time I whispered "So, I wonder if that means that there is an order to these quadrilaterals?" (O5). This means that I have confirmation that the pupils must learn each figure in turn to learn the figure of the quadrilateral. The

quadrilateral C (trapezium), quadrilateral D (parallelogram) and quadrilateral E (rhombus) must be extracted from general quadrilaterals in turn (fig.1). According to this structural relationship, pupils will be able to recognize the character of each quadrilateral. The observer saying "Imagine" means using the word 'imagine' is not so suitable for this theme. Referring to this point during the research conference, the teacher said he had no idea about the structure.

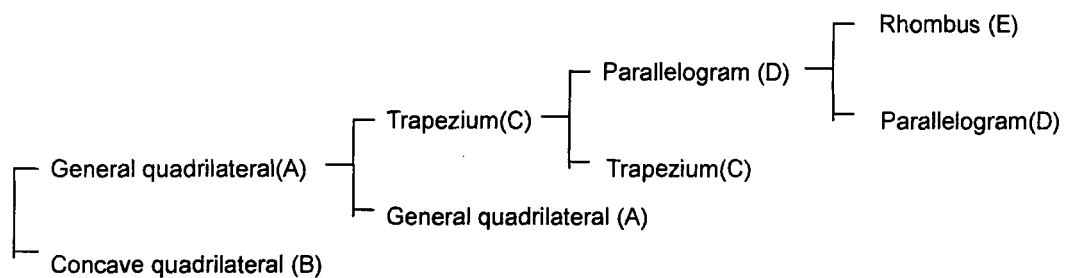


Figure1. The structural relationship between quadrilaterals

To continue, I murmured "Ah, so he's saying 'look at the paper and devise a mental image'?" (O6) "What are they supposed to draw on here? Will they draw a design?" (O7) "As it's drawn from the imagination, does that mean that they don't have to use a ruler?" (O8) Here, I did not immediately understand the meaning of the subject being studied, so I observed the lesson while concentrating on the teacher's words and the pupils' actions, and asking myself questions in an attempt to understand what was happening and how it was taking place. At the root of this can be presumed to be my own idea of the word "imagine". After this, I watched the pupils' actions for a while and at last was able to grasp the significance of the subject to some extent, saying, "Ah, so any one of the three is fine. They're selecting the one they like best and using that." (O10) However, I contrasted the abstract nature of the word "imagine" with the sight of pupils using rulers to try to maintain a degree of accuracy, and felt that there was a certain contradiction here. In other words, I was concerned that the activity itself, involving tessellating figures in an image in one's head rather than actually tessellating the physical objects, might end up becoming an abstract activity without a defined premise. This can be seen in the teaching cognition affirming that there was a pupil using a ruler: "Although the teacher used the word 'imagine', the pupil at the front by the window is using a set square to draw the figures." (O11) From this, we can see that I am trying to examine the adequacy of the subject being studied, based on my observation of the pupils as they are learning.

5.2 TEACHING COGNITION REGARDING THE PUPILS' REMARKS

Table 3 shows the class protocols from T43 to T56 and the on-going protocols. The pupils began to talk about the images they had created, based on a picture of a diamond shape, made from nine of the quadrilaterals E (rhombus). While listening to the pupils' remarks, I noted some of the words they used and repeated them: "Ah, she's used the word 'rhombus'." (O28) As the pupils had begun to use the word 'rhombus' naturally in their remarks, I inferred that they already knew some of the characteristics of rhombuses. After that, I repeated the pupils' words: "Diagonally, diagonally. What does that mean?" (O30); "They're parallel in the same place." (O31) As I did not understand the meaning of what the pupils were saying the first time they said it, I asked myself about it by repeating the parts that were unclear. I concentrated further on trying to understand what the pupil was saying, and finally understood: "Ah, the lines have overlapped." (O33) Thus, when the pupils were talking, my attention was focused on those pupils. This provides us with a picture of myself as the observer, trying to gain a correct understanding of the pupils' remarks. Nevertheless, this teaching cognition may well be something that all teachers do. In this example, as the pupils expressed diverse opinions regarding the subject being studied, which was considered only in terms of an image, and in particular, because it was necessary to understand the pupils' logic, this teaching cognition was accentuated. Moreover, teaching cognition regarding the pupils' remarks has an impact on such matters as making revisions to the way in which the lesson develops thereafter.

5.3. TEACHING COGNITION REGARDING LESSON DEVELOPMENT

Table 4 shows the class protocols from T131 to T160 and the on-going protocols. This scene took place after the pupils' presentations regarding quadrilaterals E (rhombus) and D (parallelogram) had ended and after one pupil had finished making a presentation about quadrilateral C (trapezium). Before the next pupil started speaking, I murmured, "Even if it's only in an image, I imagine that the pupils would feel more at ease if they had discovered the characteristics after tessellating the figures." (O61) Looking at the development of the lesson up to this point, I thought that, given the pupils' actions with regard to the subject being studied, they would feel more at ease if they had discovered the characteristics of the figures after actually tessellating them, rather than just conducting a lesson in which they merely devised a mental image of a tessellated design. That is my own conclusion about the subject being studied. Thereafter, while paying attention to the pupils' remarks, I mentioned my own ambivalence about the direction that

the lesson was taking: "...I don't know whether it's better to do the three together or do each one separately and then check it." (O71) While I felt that there were some problems in developing the lesson, of thinking simultaneously about three quadrilaterals, I was still unable to reach a conclusion as to whether or not it would be better to develop the lesson by checking each quadrilateral separately. However, just after this pupil had finished speaking, I understood that the pupils' thoughts had diverged more than I had imagined: "I suppose that's because it was too diffuse. But I wonder how to link the concepts?" (O74) In addition, I came to my own conclusion that, "I did feel that it was better to check each one separately." (O75) From this, we can see the way in which I gained a grasp of the pupils' situation with regard to learning and tried to revise the subject being studied and the development of the lesson.

5.4 TEACHING COGNITION REGARDING THE TEACHER'S ACTIONS

Table 4 will form the basis for this section. The pupils remarked that "the line's angular" (C75), but the teacher did not know to which line they were referring. The teacher asked again "Which line?" (T133) and checked twice before he at last understood to which line they were referring. When the teacher traced that line with coloured chalk, I remarked that, "I think it would be better to get the pupils to do that." (O64) This is most likely because I thought that there was a possibility that interpretation might become involved if the teacher drew it. After the pupils' presentations ended, the teacher said, "I don't really think that's a straight line." (T144) With regard to this, I remarked that, "I'd prefer to get the pupils to say that..." (O71) This is because of the pupils who tessellated the figures in the same way as the pupil who had made the presentation, there should have been some pupils who thought the same as the teacher. During the lesson, there are certainly times when it is better to let the teacher do something rather than getting the pupils to do absolutely everything. However, with regard to these two situations, I felt a little uncomfortable and felt that the pupils should have been the ones carrying out the actions. Thus, my belief that pupils should be at the forefront of teaching emerges.

6. CONCLUSION

The aim of this study was to gain an understanding of the teacher's teaching cognition in the teaching process and illustrate its characteristics. In order to do this, I used the on-going cognition method in an attempt to understand the teacher's teaching cognition in the teaching process as an observer. As a result, the following teaching cognition on the part of the observer was illustrated in four situations.

- Exploring the adequacy of the subject being studied based on the situation of the pupils

with regard to learning.

- Trying to gain a correct understanding of the meaning of the pupils' remarks.
- Gaining an understanding of the pupils' situation with regard to learning and trying to revise the subject being studied and the development of the lesson.
- Trying to bring the pupils to the forefront as much as possible.

I will now try to explain these four points, dealing initially with the former two points:

- Exploring the adequacy of the subject being studied based on the situation of the pupils with regard to learning.
- Gaining an understanding of the pupils' situation with regard to learning and trying to revise the subject being studied and the development of the lesson.

These two points of teaching cognition were evident in situations other than those presented in the examples outlined here. However, looking at the matter in light of the flow of the lesson, I was able to see that these are indeed relevant. From quite early on in the lesson, I was concerned by the word 'imagine'. Moreover, as I had not understood the meaning of the subject being studied, I paid attention to the words used by the teacher and the actions of the pupils, in an attempt to discover the meaning. While repeatedly asking myself questions in the process of observing the exchanges between the teacher and the pupils, I gradually began to understand the meaning of the subject. However, as I came to understand the meaning of the subject, I contrasted the abstract nature of the word 'imagine' with the actions of the pupils as they tried to maintain some accuracy and began to examine the adequacy of the subject being studied. I listened to the remarks made by the pupils during the lesson and viewed with concern the subject being studied. As a result, I came to the conclusion that the subject being studied should be revised, feeling that having the pupils actually tessellate the figures while formulating a hypothesis would put the pupils more at ease than merely building a mental image. After this, I acknowledged that, as a result of the pupils' being shown three quadrilaterals simultaneously, being asked to think about them in terms of which they liked, and then having to present the images that they had visualised, in the order quadrilateral E (rhombus), quadrilateral D (parallelogram) and quadrilateral C (trapezium), the pupils' thoughts had become too diffuse. Accordingly, I referred to a revision of the development of the lesson, suggesting that it might be easier for the pupils to understand the concept if they examined the characteristics of the shapes by actually tessellating them and then all the pupils could check each quadrilateral separately rather than merely visualising an image of them.

However, such teaching cognition may be peculiar to this particular observer. To put it another way, it may be that I was able to acknowledge this precisely because I was observing both the teacher and the pupils.

Next I will address the latter two points:

- Trying to gain a correct understanding of the meaning of the pupils' remarks.
- Trying to bring the pupils to the forefront as much as possible.

During the teaching process, I repeated the pupils' remarks. In these examples, I interpreted the teaching cognition thusly: I was asking myself questions in an attempt to correctly understand the meaning of the pupils' remarks, which I did not understand at first. This is based on the fact that I was, at first, trying to understand the pupil's logic. In particular, in this lesson, the pupils were able to think freely, so various thoughts emerged. Therefore, I concentrated on the pupils' remarks in order to try to understand accurately the way in which the pupils viewed the subject. This kind of teaching cognition could well be something that all teachers do. However, this teaching cognition affects how the lesson develops thereafter. This is because revisions to the development of the lesson may be made as a result of the pupils' remarks.

Moreover, I also acknowledged that there were some actions performed by the teacher that I would have preferred to have had the pupils perform. These were: the situation in which the teacher traced the line mentioned by the pupils, and the situation in which the teacher noted a particular point in the presentation of one of the pupils. I judged that, in these situations, it is possible that the teacher's interpretation enters the picture and that there were probably pupils who had the same thought as the teacher.

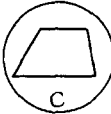
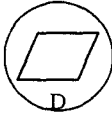
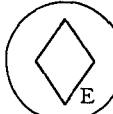
Both of these points of teaching cognition have an effect on the pupils' actions. If one tries to bring the pupils to the forefront as much as possible, it is obviously necessary to try to understand their thoughts correctly.

In this study, I have illustrated the procedures, processes and results of my efforts to understand my teaching cognition. I believe that the best method of doing this is to publish details of my study to third parties and ask them to examine its adequacy. Moreover, I believe that I can further clarify the characteristics of my teaching cognition by comparing my on-going cognition with that of the people who collaborated in my research and observed the same lesson.

In the future, I would like to analyze numerous other examples using the same procedures, objectify my teaching cognition and examine the adequacy of this method. Furthermore, I would ask third parties to collaborate in my research and examine the

adequacy of the research process as a whole.

Table 2. Class protocol & On-going protocol (T2-T21)

Class protocol		On-going protocol
Teacher's instructions	Pupils' reactions	
<p>T 2 : What is the relationship between ...the wallpaper designs ... and quadrilaterals? (Write on a blackboard) "What is the relationship between wallpaper designs and quadrilaterals?"</p> <p>T 3 : Well, we might be able to imagine that this quadrilateral becomes this type when we see it. If it does so, then we seem to be able to find the relationship between the wallpaper designs and the quadrilaterals.</p> <p>T 4 : Well, today...it is quadrilateral C(trapezium). (The figure is put on the blackboard.) , and quadrilateral D (parallelogram). (The figure is put on the blackboard.) After that... quadrilateral E (rhombus). These three quadrilaterals still remain and... Does everybody see the relationship between them? What is it?</p> <div style="display: flex; justify-content: space-around; align-items: center;">    </div> <p>T 5 : Can you figure it out?</p> <p>T 6 : When everybody can see this relationship, it is wonderful. Anyway, let's try. I'll pass these quadrilateral cards to you, the Pro Deliverer...Please give them out quickly. ...This is E, D, and C. (The cards are passed to the pupils.)</p> <p>T 7 : Three sheets per person please.</p> <p>T 8 : Do you need more pieces to tessellate the figures?</p> <p>T 9 : How can we tessellate even though we don't have pieces to do it? By using your imagination. Imagine. After the first time, you'll say that "It is easy to imagine tessellating designs of quadrilateral D(parallelogram)</p>	<p>(The pupils in charge of distribution pass out the cards.)</p>	<p>O 2 : Well, Pro deliverer? It sounds good.</p> <p>O 3 : Pupils, work in an orderly manner. It will go faster.</p> <p>O 4 : Imagine...</p>

<p>and quadrilateral E (rhombus)".</p> <p>T 10 : Now, can you imagine it? But, it doesn't make just any image. Can you see it? What earthly design does it become when the quadrilaterals are tessellated on a plane? What does it look like if quadrilateral C, D, and E are tessellated? How are the lines extended? Are the lines parallel? Are the lines perpendicular? Do you see any shapes? Use your imagination. Can you do that? Let's try it.</p> <p>T 11 : Now, I'll distribute the drawing papers. Please use them if you were able to imagine the shapes in your mind. Please start.</p> <p>(The drawing papers are distributed.)</p> <p>T 12 : Yes?</p> <p>T 13 : You don't have D? I'll give it to you now.</p> <p>(The teacher distributes one drawing paper.)</p> <p>T 14 : And, you must use the drawing paper distributed with one-figure. Draw it large, in a clear manner, and firmly.</p> <p>T 15 : Ah, you have already drawn three. That's great. Ok. Well, this one. One for one. I'll distribute two more drawing papers.</p> <p>T 16 : You don't have D. (The teacher passes the card to the pupil who doesn't have quadrilateral D.)</p> <p>(Two more drawing papers are distributed.)</p> <p>T 17 : Can you do it?</p> <p>(The teacher walks around classroom to offer guidance to pupils.)</p> <p>T 18 : You can do fast when using your imagination. (To the pupil who is using the ruler.)</p>	<p>C 1 : I don't have D.</p>	<p>O 5 : So, I wonder if that means that there is an order to these quadrilaterals?</p> <p>O 6 : Ah, so he's saying 'look at the paper and devise a mental image'?</p> <p>O 7 : What are they supposed to draw on here? Will they draw a design?</p> <p>O 8 : As it's drawn from the imagination, does that mean that they don't have to use a ruler?</p> <p>O 9 : Um...Many pupils are drawing freehand.</p>
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<p>T 19 : You may not use a ruler. Use your imagination.</p> <p>T 20 : And,...When you draw fast, you can find it. The state of the line is this. There is a parallel. Draw it quickly when you can see this.</p> <p>T 21 : Do you have three drawing papers?</p> <p>(The teacher walks around classroom to offer guidance to pupils.)</p>	<p>C 2 : Yes.</p>	<p>O10 : Ah, so any one of the three is fine. They're selecting the one they like best and using that.</p> <p>O11 : Although the teacher used the word 'imagine', the pupil at the front by the window is using a set square to draw the figures.</p> <p>.....</p> <p>(The memo of the first child on the window side is examined.)</p> <p>O12 : The line...one line is not zigzag. However, straight lines are combined by different respective lengths and a certain shape is made.</p> <p>O13 : What does this mean?</p> <p>P 1 : This? Well. I thought it would be a different figure at first, but, here was 4.5 centimeters and here it was 4 centimeters in length. Therefore, even if the line is extended straight, the length of the line is different. As a result, I thought it would be a different shape.</p> <p>O14 : Indeed. Here is one line and it is a straight line. Where will it zigzag? When saying this...</p> <p>P2 : First, it shows that when quadrilateral A and quadrilateral B were tessellated quickly, the line was extended in a zigzag line. However, for this quadrilateral the line is not extended in a zigzag.</p> <p>O15 : What? Where isn't the zigzag?</p> <p>P 3 : Look at it like this.</p> <p>O16 : Ah, I see. Here?</p> <p>P 4 : At this time though the line was not straight, and became zigzag because here it becomes straight.</p> <p>O17 : Indeed. Thank you.</p> <p>.....</p> <p>O18 : Well, as for the pattern, I imagined a "Pattern block", though it does not mean that all three quadrilaterals fit in the "Pattern block".</p>
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Table 3. Class protocol & On-going protocol (T43-T56)

Class protocol		On-going protocol
Teacher's instructions	Pupils' reactions	
T 43 : Let's hear from someone who examined E...Yumi, come here. Bring your sheet.		O27 : Now, though, there are pupils who are not examining E...
T 44 : Please come here so you can see.	C 9 : Well, I combined some quadrilaterals E and I made...	
	C 10 : This is the shape. And, I thought about the parallel here. I combined the rhombuses like this. Then, I thought I should continue similarly like this.	O28 : Ah, she's used the word 'rhombus'.
T 45 : Yes. And what type is it? (The teacher picks up the chalk.)	C 11 : Well, I think that the line that is extended is not a zigzag.	O29 : In this case, I think that felt-tipped markers are better than chalks.
T 46 : The line that is extended is not zigzag.	C 12 : It is not a zigzag. Diagonally, it is diagonally...	O30 : Diagonally, diagonally, What does that mean?
T 47 : It is not zigzag. Do you think that it is straight?	C 13 : Maybe. ...I think so...um.	
T 48 : Are you still not sure of this?	C 14 : Yes. (She nodded.)	
	C 15 : Then, about the parallelism...for instance, here and here...I think that the same sides are parallel in the same figure though I have not examined it yet	O31 : They're parallel in the same place.
T 49 : (The teacher points at the E card on the blackboard.) Here and here?	C 16 : Well. When the same figure is like this...for this case, it lines up again here. And, I think that here becomes parallel to here.	
T 50 : You are imagining such a shape. Ok, where is it parallel?	C 17 : And, the same figure is tessellated again next to this figure. Um...the same side in the same figure.	O32 : In the figure below...I think that explaining using the figure below is more comprehensible.
T 51 : Where is parallel when you do this?	C 18 : Well, here and...It(another figure) overlaps here...another side overlaps here. Here is parallel.	
T 52 : Then, this. Here is parallel to here when looking at this figure	C 19 : (She nodded.)	O33 : Ah, the lines have overlapped.
T 53 : Where is it in this figure (Teacher indicates pupil's drawing paper)? Where is it in this pattern?		
T 54 : Here? Ok? (The teacher	C 20 : Here...	

<p>asks for confirmation for tracing with a red chalk) Here and here?</p> <p>T 55 : Here and here. I see. The next one, not the sides in the next one. If this is straight, all straight lines become parallel. However, you still doubt whether the line is straight.</p> <p>T 56 : We understand. Thank you.</p>	<p>C21 : Here and here.</p> <p>C22 : (She nodded.)</p>	<p>O34 : Why isn't the teacher having the pupil describe all the points? About the perpendicular and the shape?</p>
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Table 4. Class protocol & On-going protocol (T131-T160)

Class protocol		On-going protocol
Teacher's instructions	Pupils' reactions	
T 131 : Norifumi, what do you think about this (C)? Bring your sheet up.		
T 132 : Please move to a place where you can be seen.	C 75 : Well...I... spread the plane in C. And...I think that the line is angular rather than zigzag.	O61 : Even if it's only in an image, I imagine that the pupils would feel more at ease if they had discovered the characteristics after tessellating the figures.
T 133 : Which line?	C 76 : Well, I thought that the extending zigzag is similar to A and C was different from it.	
T 134 : Which one? This one? Is it this what you are talking about?	C 77 : Well...(He traced the line of the drawing paper drawn by himself.)	O62 : Where? Where is it angular? Good.
T 135 : Is this it?	C 78 : This line...This is the line...	
T 136 : May I draw it like that?	C 79 : And, well...	O63 : Where? Where? Where?
T 137 : Can you see it? Yellow... You can't see it. (The teacher traced it with red chalk.)		O64 : Ah, I think it would be better to get the pupils to do that.
T 138 : This?	C 80 : And, about parallelism...Well, I think that this side and this side are externally parallel at intervals of one in externals. Um...And about perpendicularity...	O65 : It will not be seen.
T 139 : Wait... wait a minute. Which are parallel? This? Well...	C 81 : I think that this and this are parallel externally.	O66 : What is "at intervals of one"?
T 140 : This and this are parallel externally. I see.	C 82 : About the shape...About the perpendicularity, I did not think that there were any perpendicular angles because there were no 90 °externally.	O67 : Well...Perpendicularity. Maybe this pupil might say that the lines are perpendicular if there are 90 ° in the figure.
T 141 : There were no 90 °? Did anyone else examine it?	C 83 : ...	
T 142 : Anything else?	C 84 : And... Well, I think that shape is a hexagon. I felt that quadrilateral C looked like quadrilateral A when the shape is a hexagon. I also thought that C and A were originally the same or similar shape.	O68 : Maybe the teacher should now have them examine it quickly.
T 143 : This and this. C and A. He thought that they are similar. What does everyone else think? Thank you.		O69 : Hexagon...Shape is a hexagon.
T 144 : Well, though he said, "This line is zigzag...angular", when I		O70 : C and A are similar. Ah, because the shapes of the wallpapers are similar. I see.

<p>heard him, I don't really think that's a straight line. Didn't you? This line? This horizontal line?</p> <p>T 145 : What do you think? Did anyone imagine that this line would be extended straight?</p> <p>T 146 : You did? Mika, come here. Bring it.</p> <p>T 147 : Please.</p> <p>T 148 : Wait a minute. Where is it straight?</p> <p>T 149 : Oh, Oh, Oh.</p> <p>T 150 : It is parallel in the horizontal and the vertical direction. In which direction is the line extended straight?</p> <p>T 151 : Ok, Ok.</p> <p>T 152 : Then, this is straight in the horizontal direction? And this is straight diagonally?</p> <p>T 153 : Then, this is different from Norifumi...Norifumi, did you say that this was not straight?</p> <p>T 154 : You did not think about it.</p> <p>T 155 : You did not think about it. I understand.</p> <p>T 156 : This is diagonal. It is straight in the diagonal and horizontal direction.</p> <p>T 157 : Everyone's image is different respectively. It is interesting.</p> <p>T 158 : Ami?</p>	<p>C 85 : ...</p> <p>C 86 : (5 or 6 people raised their hand.)</p> <p>C 87 : Well, I am a little different from Norifumi. Though Norifumi said that here is zigzag, I think that here is straight. Norifumi said that a little while ago...</p> <p>C 88 : I think that here is straight, and here is parallel, though Norifumi said that here is zigzag. And, I think that there is not zigzag like in quadrilateral A though Norifumi said that the horizontal direction seemed to not be straight. I think that quadrilateral C is maybe parallel in the horizontal and the vertical direction.</p> <p>C 89 : I think that the line is extended straight diagonally though it is not the same as the square and the rectangle.</p> <p>C 90 : Yes, I do not think that it is straight there when the shape that I drew is seen.</p> <p>C 91 : Yes.</p>	<p>O 71 : I'd prefer to get the pupils to say that...I don't know whether it's better to do the three together or do each one separately and then check it.</p> <p>O 72 : I think that it is likely to be spread the same because the opposite side is parallel. Ah, I see.</p> <p>O 73 : Indeed, maybe I think that it becomes so if we move it left or right because the length of the side is the same. Ah, I see.</p> <p>O 74 : I suppose that's because it was too diffuse. But I wonder how to link the concepts?</p> <p>O 75 : I did feel that it was better to check each one separately.</p>
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<p>T 159 : Mika...no. Norifumi first tessellated like this, and then turned it around and then up and down. Mika tessellated it the same.</p> <p>T 160 : Thank you. You found the difference.</p>	<p>C 92 : Well, I found the difference between Norifumi and Mika. Norifumi's idea is that the first step becomes so and the following second step is the opposite. And Mika's idea is that Quadrilateral C of the first step is connected without the direction changing the same.</p>	<p>O76 : Oh, does she have something to say?</p> <p>O77 : It is what I said a little while ago.</p>
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Key

T: the teacher

C: the pupils

O: the observer

Numbers behind T, C and O: the order of speaking

: subject of on-going cognition

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