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# Implementing multidisciplinary study and research paths in Japanese lower secondary school teaching

# Mise en œuvre de pistes d'études et de recherche multidisciplinaires dans l'enseignement du secondaire inférieur japonais

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## Abstract

This paper reports on results of teaching experiments with a study and research path carried out in Japanese lower secondary school classrooms. The generating question relates to the change of world population. Based on these results, we discuss the conditions and constraints for implementing inquiry in ordinary teaching in.

**Keyword:** ATD, Study and Research Course, Questioning the world.

## Résumé

Dans cet article, nous présentons quelques résultats de l'expérimentation de parcours d'étude et de recherche qui est conduite dans les classes d'un établissement secondaire au collège au Japon. La question concernant le changement de population mondiale est utilisée. Nous discutons, en nous appuyant sur ces résultats, les conditions et les contraintes pour la mise en place d'une enquête dans une classe ordinaire au Japon.

**Mots-clés** : TAD, Parcours d´Études et de Recherche, Questionnement du monde.

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The notion of *didactic paradigm* (CHEVALLARD, 2015) proposed within the Anthropological Theory of the Didactic (ATD hereafter) allows us to recognize, from a broader point of view, the different ideas underlying teaching. In particular, the paradigm of *questioning the world* promoting scientists' attitudes in teaching has opened our eyes to the mathematics teaching in the light of broad scientific inquiry, removing the barriers between disciplines. Further, the *Study and Research Path* (SRP hereafter) based on such paradigm formulates the structure and functioning of scientist's inquiry within ATD. This theoretical formulation takes into account the mechanisms of inquiry which has not been explicitly dealt with in other theoretical frameworks. We consider that it may provide us with new insights how the inquiry-based teaching of mathematics and also other disciplines might be designed and organized in the classroom.

Today in Japan, it is required to implement the multidisciplinary studies and the inquiry-based teaching, and more strongly than before (e.g. MEXT, 2017). This is not only the case in Japan. Implementing inquiry in day-to-day teaching is also an issue to be addressed in the international community of mathematics education research (MAASS & ARTIGUE, 2013). We are therefore interested in the implementation of multidisciplinary SRP in the ordinary classroom to clarify its potentials and limitations in Japan and in other countries. In this paper, we investigate this point through the teaching experiments conducted in a Japanese lower secondary school from a wider perspective, that is to say, rather than focusing on a specific aspect of SRP, we report the overall results of these experiments and discuss inductively the conditions and constraints for implementing such inquiry in ordinary teaching in Japan.

## Preliminaries on inquiry

Before going into the details of the teaching experiments, we briefly describe how the inquiry is perceived and dealt with in educational research and in Japanese national curricula.

### Inquiry from different perspectives

The idea of implementing inquiry in teaching is not new. Dewey's theory of inquiry (Dewey, 1938) modelling scientist's inquiry, has often been used as a reference for inquiry-based teaching. And there are several theoretical frameworks that support the implementation of inquiry in teaching (ARTIGUE & BLOMHØJ, 2013). In Japan, apart from Dewey's theory which is well known, there is a perspective of implementing researchers' inquiry in the classroom, which is called *Researcher Like Activity*, proposed by the influential educational psychologist Ichikawa (1998) from the University of Tokyo. This framework suggests to implement different activities usually carried out by the researcher, including not only the process of finding a problem, solving it, reporting the result, etc., but also the activity of reviewing papers, panel discussion, etc.

What is different among theoretical frameworks about the inquiry is the way to characterize scientific inquiry: what are the principal elements that constitute the inquiry, how are they functioning, in what structure, etc. Among these, the idea of SRP provides a new insight for characterizing the inquiry by clarifying the dialectic nature of inquiry between questions and answers (*questions-answers dialectic*) and also the dialectic between searching of information from different resources (*media*) and working with questions, obtained answers, data, experiments, etc. (milieu) (*media-milieus dialectic*). In this paper, we also adopt these points for designing and analysing inquiry-based teaching in Japanese classrooms.

## Inquiry in Japanese lower secondary school curricula

As we noted earlier, it is strongly required today in Japan to implement multidisciplinary studies and inquiry-based teaching. This does not mean that there was no multidisciplinary study or inquiry so far. In the Japanese national curricula, multi-disciplinary study has been emphasized since around 2000, and a subject called 'Periods for multidisciplinary studies' (*sōgōtekina gakusyū no jikan* in Japanese) was created and implemented from primary to upper secondary school in 2002. As the name of the subject implies, it aims at multidisciplinary studies. According to the official curricular document (MEXT, 2008), it is requested that students carry out inquiry-based learning and acquire certain competences of working autonomously, such as finding a problem, learning, thinking, judging, solving the problem, etc. However, in reality, this subject is dissociated from ordinary subjects, and is often used for career education or out-of-school activities in lower and upper secondary school. There is very little room for mathematics, and even for scientific inquiry.

In the new national curricula announced in 2017, the multidisciplinary studies are emphasized not only in the 'Periods for multidisciplinary studies', but also in ordinary subjects such as mathematics (MEXT, 2017). Hence, we now have a much more substantial setting for multidisciplinary studies and scientific inquiry, and it is required to carefully study how we can implement such teaching and learning in ordinary classrooms.

## Methodology

In order to better understand how the multidisciplinary SRP could be implemented in Japanese lower secondary school, we design a sequence of lessons from the perspective of SRP and carried out teaching experiments, as it is usually done in the *didactic engineering* (BARQUERO & BOSCH, 2015). Based on the data collected in the experiments and their analysis, we discuss the *conditions* that support the implementation of SRP in Japan and the *constraints* that hinder it.

## Initial question: world population problem

The initial question $Q_0$ we have chosen is the following one which relates to the world population.

> $Q_0$: When is the number of all people in the world who have lived until the year 1900 equal to the number of people after the year 1900?

This question is supposed to generate several multidisciplinary questions, related to the discipline of social studies including history, anthropology, etc., and also to mathematics. In fact, in order to find the number of people who have lived before 1900, it requires first of all to know the definition of humankind and from what time the humankind exists on earth.

From the mathematical point view, an idea to answer this question is to think about the population *p* as a function of year *y* and the length of life *l* as a function of year y as well, and then solve the following equation:

$$\int_{y_0}^{1900} \frac{p(y)}{l(y)} dy = \int_{1901}^{x} \frac{p(y)}{l(y)} dy.$$

Of course, grade 8 students would not formalize their ideas as this equation. And one may not directly get to this idea before investigating other ideas. But we consider that the question $Q_0$ allows them during the inquiry to employ some mathematical ideas they have already learnt (linear function, linear equation, area, etc.) and to investigate some new ideas accessible to them (more general function, equation, integral, etc.).

The question $Q_0$ is a slightly modified version of the question proposed by Yves Chevallard and Marianna Bosch (2016) in the workshop of ATD organized at Osaka, Japan in 2016. The original question in the workshop was formulated differently, as follows. “They say there are more people now alive that all that have lived before 1900. Is that possible? On which year could this be possibly true?”

Our question asks to compare two numbers, of people having lived before and after 1900, while the original task asks to compare the amount of people before 1900 and the population in a specific year. We consider that our initial question $Q_0$ directs students to think more about some specific mathematical ideas related to functions, equations, etc., which they have already learnt to some extent.

## Teaching experiments

The teaching experiments was carried out with grade 8 students (13-14 years old) in a public lower secondary school in Japan. A total of four periods of classes in the computer room were designed and experimented with five different grade 8 classes. The first author was the main teacher of these classes. He is a teacher of this school, but is not teaching otherwise this year, due to his in-service training at the university of the second author.

About 32 students in each class were divided into 7 to 8 groups with 3 to 4 students for group work. The inquiry was carried out in the three first periods of class, and the last period was dedicated to the presentation of the results of the inquiry.

In the introduction of first period, the teacher explained general features of researcher’s scientific activities, as they were supposed to be carried out in the class. Specifically, the teacher told students to investigate the initial question and their own questions with group members by means of anything they needed, such as Internet, calculator, and textbook, etc. Two PCs are given to each group. In the second and third periods, it is allowed for the students to observe other groups and discuss with them. During the inquiry, the teacher moved from one group to another to support students.

We collected, as data, PC screens of all group by the software *AG-desktop recorder* (http://t-ishii.la.coocan.jp/download/AGDRec.html), the video data of certain students' activities (five groups), and their worksheets.

## Analytical tools

We analyse the data collected in the teaching experiments mainly by means of two concepts of ATD which characterise the structure and functioning of SRP. The first one is the *questions-answers dialectic* which allows us to make explicit the complex process of inquiry and also its multidisciplinarity which is one of the main issues in our study. The second tool is the *media-milieus dialectic* which allows us to identify the dynamics of students' autonomous activities, that is to say, not only what kinds of resources students obtain from the media, but also how they interact with them and develop their own ideas based on them.

## Students' study and research paths

Each group follows its own study and research path. There is a variety of paths and none of them are identical. We present here only two of them in order to show how the multidisciplinary inquiry was going on overall.

### Group B: resolution by the area

Group B was sincerely working and asking several questions during inquiry. The number of interactions with media is relatively smaller than for other groups, but the students of this group carefully read the information obtained on the Internet and tried to understand it, that is to say, there were more interactions with milieus.

In the beginning of inquiry, the students were interested in the change of world population and the population explosion, and asked the following questions:

$Q_1$: How much is the actual world population?

$Q_2$: How many people have lived before 1900?

$Q_{2\text{-}1}$: When is the origin of humankind?

$Q_{2\text{-}2}$: What happened in 1900?

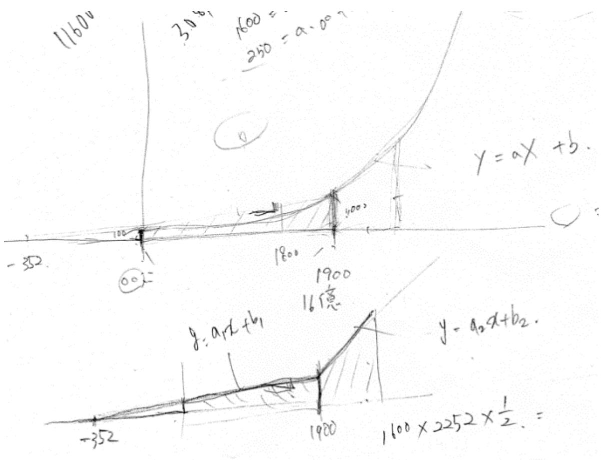
$Q_{2\text{-}3}$:: Why did the world population grow suddenly?

$Q_{2\text{-}4}$: What is population explosion?

These are the principal ones asked in the beginning. There are also other small questions. The same index in the list means that the questions are derived from the main one. (e.g. $Q_{2\text{-}i}$ are derived from $Q_2$). Most of these are questions related to social studies. Students were searching for the pre-established answers $A_i^{\Diamond}$ on the Internet, and thoroughly reading them. In the second period, they started creating a table with the data obtained from the entry of 'World population' of Japanese Wikipedia, and tried to find the answer by means of functions as Figure 1.

Figure 1

*A part of the worksheet of Group B*




Group B presented a final answer $A^{\heartsuit}$ to $Q_0$ in the fourth period, constructed on their own, which we briefly outline here. Although the group obtained different numerical data from Internet, the data they finally used were the following:

D1: World population of AD 0 is 250,000,000.

D2: World population of AD 1900 is 1,600,000,000.

D3: World population of AD 2016 is 7,300,000,000.

Group B identified the functional relationship between year and world population from these data, and modelled the change of population by two following linear functions:

$y = 0.71x + 250$ … (i)

$y = 49x – 91500$ … (ii)

The first one is established with the two coordinates (0, 250) and (1900, 1600) obtained from data $D_1$ and $D_2$ (250 is used for 250,000,000), and the second from $D_2$ and $D_3$. The students consider, with the graph of functions shown in Figure 1, that the year to answer $Q_0$ is determined by finding out when the area of triangle in the left-hand side is equal to the area of trapezoid of right-hand side. To find this year, they first get the intersection point between the graph of the first function and the $x$-axis, by substituting y = 0 in the equation (i) and solving the linear equation: $x = –352$ which is the year of the birth of humankind (or, before that, the population can be considered negligible). This answer allows them to calculate the area of the triangle, which is 18,016. Then, they find out that the area of trapezoid is (16 + 133) × 240 ÷ 2 = 17880 when the year is 2140, and (16 + 134) × 241 ÷ 2 = 18075 when it is 2141. Their final answer $A^{\heartsuit}$ was thus the year 2141.

During the activities of building up their own answer, there are a lot of interactions between students and milieus. In particular, in order to determine which data to use, how to model, how to calculate, etc.

In the inquiries of other groups, we could also identify the active questions-answers dialectic and media-milieus dialectic. Most students were working hard and autonomously with their group fellows. However, most of their inquiries did not proceed as Group B did. Some groups provided an answer with much ambiguity and others could not get any answer. We present now one of them.

**Group C: resolution by the number of birth**

Group C were, from the beginning of inquiry, searching for the appropriate data that can be used to calculate an answer to Q0. In this process, the students of this group studied the history of humankind. The questions they asked were similar to those of Group B. One may see a different discussion on the history of humankind as what follows:

172 S3: Since when does humankind exist?

173 S2: Not sure.

174 S3: since 5 million years ago?

175 S2: It's too big.

176 S3: since 65 million years ago.

177 S3: here, since 65 million years ago.

178 S3: Humankind is a mammal, a primate. Otherwise, if it's an ape-man (Australopithecus), it's 4 million years ago.

179 S2: Humankind is a new-man (Homo sapiens), no?

180 S3: Humankind is a new-man?

181 S2: Is it? I don't know.

…

For the purpose of collecting relevant data, it is required for students to study the history, that is to say, the historical ideas appeared here with the rationale (*raison d'être*) which would be sometimes missing in the teaching based on the *paradigm of visiting monuments* (Chevallard, 2015): why do we need to know about Homo sapiens, specific years, etc. This is one of the main advantages of multidisciplinary inquiry, which may provide rationales not only for mathematical knowledge but also for knowledge of other disciplines.

The students of this group spent a lot of time to find and fully understand the data given in websites. For example, they were searching for the answer to the question '$Q_4$: How many people have lived on earth so far?' and found a pre-established answer '$A_{4\text{-}1}^{\Diamond}$: the actual population is one fifth of the number of whole people that have lived in the last 6000 years' in a website (https://matome.naver.jp/odai/2138339969046725701) which cited the text of Wikipedia. This website also provides the concrete numbers: '6,800,000,000 (year 2009) × 5 = 34,000,000,000. By adding the actual population, the number is 34,000,000,000 + 6,800,000,000 = 40,800,000,000'. As the idea given here was not clear enough, the students doubted these numbers, and then searched again on the Internet and found another number (http://d.hatena.ne.jp/Zellij/20111104/p1) which is 'A4-2◊: the total number of humans who were born on the earth so far is 107.6 milliard'. And this time, in order to better understand it and obtain further data, they went even to the original English page (http://www.prb.org/Publications/Articles/2002/HowManyPeopleHaveEverLivedonEarth.aspx) and tried to understand what is written there. Japanese students are usually not good at English and often hesitate to use it.

However, as a consequence of spending a lot of time for finding and understanding data, there was a small amount of time left for developing their own answer, which was not fully elaborated and verified at the end of inquiry. In order to develop their own answer, the students used the data given in this last website and Wikipedia in a strange way, established an equation and solved it. Concretely, supposing that the number of people before 1900 is equal to the number of people born after 1900 in x years counting from the year 1900, they established the equation (number of people before 1900) = (number of people born during one year) $\times x$ + (the population of the year 1900)

with the following data:

$D_1$: Number of people before 1900: 1,656,000,000,000;

$D_2$: World population of the year 1900: 3,522,000,000;

$D_3$: Number of births each year: 70,000,000.

The solution obtained was $x=23{,}609$, and therefore their final answer was AD 25509 by adding 1900. The data used above are not appropriate with respect to the data given in the websites. $D_1$ is much bigger than the number of people who have ever lived on earth, given in the website (107,602,707,791). It was probably taken from the population of the year 1900 (1,656,000,000). It would have required more time than was available to validate the calculation, and to receive feedback from others.

## Discussion

The teaching experiments and the analysis of data allow us to discuss several conditions and constraints for the implementation of multidisciplinary SRP in the day-to-day teaching of Japanese lower secondary school. In what follows, we are going to discuss three aspects that seem important in this respect.

### Germ of scientist's attitudes and its constraint

In the teaching experiments, we could identify germs of scientists' attitude among students, which is a main aim in the paradigm of questioning the world. At the beginning of inquiry, several students were thinking that the answer exists somewhere, and could be found on the internet. Some students even asked for the answer directly from the teacher. However, as time goes by, they started noticing that the question is not easy to answer and requires some efforts. Students' answers to the questionnaire proposed at the end of fourth period shows that nearly 90% of the students could be actively engaged in the inquiry. And several students made a comment like ‘it was fun, while it was hard’ or ‘I tried hard without giving up’. These comments imply that faced with the task which was not easy for them, students could more or less behave in a *Herbartian* way, with a “receptive attitude towards yet unanswered questions and unsolved problems” (CHEVALLARD, 2015).

On the other hand, in many groups, students often used the data obtained from the media without doubting their validity with a scientist’s attitude. Even the group C presented above, who often questioned the data from media, did not examine precisely the data they used. One may point out here a time constraint that hinders a further inquiry on data. Since there were only three periods for getting the results of inquiry and students have to present them in the fourth period, there was only a small room left for further investigation and critics of the data. This phenomenon could be also a result of the didactic contract we discuss below.

## Didactical contract hindering fruitfulness of SRP

We identified in the data a didactical contract which is specific to mathematics teaching and not to scientific inquiry. It was for students to find an answer to the initial question $Q_0$ proposed by the teacher, as it is in ordinary mathematics class. In scientific inquiry, the result obtained after a lot of investigation is not necessary an answer to $Q_0$, but very often a partial answer to $Q_0$, the answer to another question, or even another question without answer. In contrast, especially in the third period of our experiments, the teacher often notified students that there is a presentation in the fourth period and they have to prepare and present their answer to Q0. Due to this contract, the SRP realized in the experiments did not broaden to investigate different interesting questions deeply. It was rather like a finalized SRP (Chevallard, 2009) which has a specific target knowledge to teach.

This discussion raises a question on the constraints related to the *chronogenesis*—the evolution of new questions and knowledges obtained from the media—in the multidisciplinary inquiry. We may identify some elements that lead students and also the teacher to stay with the initial question $Q_0$. The first element is mathematics teacher's intention related to the goal of inquiry, which is to engage students in mathematical activities in addition to the activities of social studies. Asking an answer to $Q_0$ was a solution for him. The second element is the teacher's way to intervene students' inquiry. As the inquiry was organised in the ordinary classroom with more than 30 students, the teacher communicates with students not like a supervisor of master or PhD research works, but like a teacher in an ordinary classroom setting where the teacher gives a hint or checks their answer by moving from one group to another. The teacher therefore could not work more deeply with one group and indicate a direction in which to go, according to the students' interest.

## Conception on scientific inquiry

As we have mentioned in the earlier sections, the overall spirit of Japanese national curricula conforms with the idea of inquiry based on the paradigm of questioning the world. The inquiry is emphasized in Japanese lower secondary school curriculum and it seems that SRP could largely contribute to it. However, the idea underlying SRP is new for Japanese educators, and requires a new way to perceive scientists' inquiry. In particular, the role of question is often underestimated in Japan. There is a cultural element that hinders understanding of this main characteristic of SRP. In Japanese language, the term question is not often used in scientific works. For example, the English expression research question is usually translated into the Japanese expression signifying 'research task' (*kenkyū kadai*). The term inquiry is translated into the Japanese term (*tankyū*) which does not mean 'questioning', but 'seeking'. In fact, in the class of *Period of multidisciplinary studies* in Japan, students often look for several information using Internet, summarize it and present it in a sophisticated way. However, as far as the first author knows and can judge, as a teacher who has been teaching mathematics and this multidisciplinary class, it is very rare for students to deepen the question as the SRP carried out in our study. We can also notice this in students' written comments to the questionnaire at the end of class, which often say that this was the first experience to investigate a tough question such deeply. Therefore, the conceptual change on the inquiry in teachers and teacher educators would be a condition for implementing SRP in the day-to-day classroom. This point raises an issue of teacher education. Many lower and higher secondary mathematics teachers in Japan have never experienced scientific inquiry during their university study.

## Conclusion

The discussion above raises several issues for further studies related to the implementation of SRP in the day-to-day classroom. In particular, we need to further investigate, from the scientific point of view, how the constraints from different levels of the scale of codetermination affect the different aspects of SRP (*mesogenesis*, *chronogenesis*, and *topogenesis).*

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