

OECD Education Working Papers No. 94

Learning Study: Its Origins, Operationalisation, and Implications

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https://dx.doi.org/10.1787/5k3wjp0s959p-en

OECD

Unclassified **EDU/WKP(2013)9**

Organisation de Coopération et de Développement Économiques
Organisation for Economic Co-operation and Development **04-Nov-2013**

English, French

DIRECTORATE FOR EDUCATION AND SKILLS

EDU/WKP(2013)9
Unclassified

Cancels & replaces the same document of 31 October 2013

LEARNING STUDY: ITS ORIGINS, OPERATIONALISATION, AND IMPLICATIONS

(Education Working Paper N° 94)

by Eric C.K.Cheng and Mun Ling Lo

This paper has been prepared by Eric C.K.Cheng and Mun Ling Lo of the Department of Curriculum and Instruction, The Hong Kong Institute of Education, in Hong Kong.

Learning Study is a collaborative, action-research approach to improve the effectiveness of student learning by enhancing the professional competence of teachers. This is achieved through the collaborative construction of the pedagogical content knowledge enabling them better to teach specific objects of learning. Through inquiry and authentic learning by the teachers, it takes account of students' prior knowledge in the lesson planning and so creates an authentic learning environment for the students. This paper explains how the Learning Study approach relates to the set of approaches known as "Lesson Study" and how it incorporates the principles for high quality learning proposed by the OECD project on Innovative Learning Environments (ILE) in its design and implementation. It examines how Learning Study helps to integrate the factors comprising innovative learning environments. It analyses the critical conditions that support its development and practice in schools and in professional learning networks and education systems in general.

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ABSTRACT

Learning Study is a collaborative, action-research approach to improve the effectiveness of student learning by enhancing the professional competence of teachers. This is achieved through the collaborative construction of the pedagogical content knowledge enabling them better to teach specific objects of learning. Through inquiry and authentic learning by the teachers, it takes account of students' prior knowledge in the lesson planning and so creates an authentic learning environment for the students. This paper explains how the Learning Study approach relates to the set of approaches known as "Lesson Study" and how it incorporates the principles for high quality learning proposed by the OECD project on Innovative Learning Environments (ILE) in its design and implementation. It examines how Learning Study helps to integrate the factors comprising innovative learning environments. It analyses the critical conditions that support its development and practice in schools and in professional learning networks and education systems in general.

RESUME

L'étude sur l'apprentissage est un travail de recherche-action collaborative visant à améliorer l'efficacité de l'apprentissage des élèves, tout en renforçant la compétence professionnelle des enseignants. Cette étude est l'aboutissement d'une construction collaborative de la connaissance du contenu pédagogique, facilitant la transmission des objets spécifiques d'apprentissage. Grâce à un processus d'investigation et une authentique réflexion mené par les professeurs, les connaissances préalablement des élèves sont prises en compte pour la planification de leurs cours, créant ainsi un environnement d'apprentissage authentique pour les étudiants. Ce document explique par ailleurs comment l'étude sur l'apprentissage intègre, dans son design et sa mise en œuvre, les exigences de haute qualité d'apprentissage identifiées par le projet des Environnements Pédagogiques Novateurs (ILE) de l'Organisation pour la Coopération Économique et le Développement (OECD). Elle décrit comment l'étude de l'apprentissage permet d'intégrer les facteurs composant les environnements pédagogiques novateurs. Elle analyse en outre les conditions critiques qui soutiennent son développement dans les organisations scolaires et les systèmes d'éducation.

THE APPROACH OF LEARNING STUDY: ITS ORIGINS, OPERATIONALISATION, AND IMPLICATIONS

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1. Introduction

It is generally believed that effective learning depends on the existence of an authentic learning environment which would facilitate the learning process, and this has been an important item on the research agenda in education. An OECD project conceptualized the factors needed to develop an innovative learning environment and identified four dimensions for enhancing student learning. These are the student as a learner, the teacher as a learning professional, the resources and facilities needed for learning, and the content of the learning (Dumont & Istance, 2010). The project identified several factors that are necessary for the creation of such an environment, including the employment of formative assessment for effective learning (Wiliam, 2010), capitalizing on collaborative learning (Slavin, 2010), addressing the prior knowledge of the learners in order to tackle individual differences in students (Mayer, 2010), using an inquiry approach to learning (Barron & Darling-Hammond, 2010), and developing a kernel of practice on how the innovation envisaged in the visionary models can be implemented in everyday practice (Resnick et al., 2010). It has been argued that an authentic learning environment which incorporates these factors will construct a scaffold that students can use to climb to new levels of development.

Since each of the above factors was studied separately, their integration and implementation in a real classroom environment and the dissemination of the results of that experience throughout the teaching communities still represent major challenges for educators and teachers. Each factor may seem to be theoretically sound when considered in isolation, but in practice the different factors may interact with and contradict each other. How these factors can be integrated within a real school context to create an innovative learning environment is a significant research agenda that needs to be addressed. In this paper, we show how the Learning Study approach can help to integrate these factors and thus have an impact on student learning in real classroom situations and suggest some strategies to create a professional learning community within a school. The Learning Study approach is a theory-based collaborative action research which opens up research-based opportunities to help for teachers to apply the variation theory (Marton & Booth, 1997) in order to improve their teaching skills and to enhance student learning. The Learning Study approach is inspired by the ideas of Japanese Lesson Study, and involves the design of experiments (Brown, 1992) and in particular the in-depth study of specific lessons.

Using variation theory as a guiding principle in the pedagogical designs for effective learning, the Learning Study approach provides a platform to help teachers to apply the factors of the four dimensions in their classroom practice so as to develop an innovative learning environment that can lead students to new levels of development. Moreover, the Learning Study approach also helps to create a professional learning community that will support teacher learning within a school. It can also facilitate the building of a teachers' learning network to disseminate good pedagogical practices that enhance the quality of teaching and learning in an educational system. The Learning Study approach has now been in practice for more than ten years, and it has been found to have a positive impact on the learning of both students and teachers (Lo, Pong & Chik, 2005; Cheng, 2009; Lo & Marton, 2012).

This methodology is easily transferable between different education systems, and it is now commonly practiced in many countries, including Sweden, Brunei and the UK.

This paper first describes what the Learning Study is and then examines how it helps to put into practice some of the quality learning factors proposed by the OECD innovative learning environment project on the nature of learning. It also proposes a model for building a Learning Study community and network that can promote both the teachers' professional development and the student learning. It is hoped that this study will help to generate deeper insights for those schools and government officials who are interested in enhancing student learning and the skills of teachers, and also suggest some practical ways of tackling the challenges that could arise from such efforts.

2. The origins of the Learning Study approach

The commonalities and differences between Lesson Study and Learning Study

The Learning Study first emerged in Hong Kong in 1999. As mentioned above, it was inspired by the Japanese practice of Lesson Study, so we must first clarify the commonalities and differences between the two. Both Lesson Study and the Learning Study are action research approach that conducted by teachers to examine their own practices. Strictly speaking, Learning Study is a kind of Lesson Study. However, there are two major differences between them: 1) the Learning Study approach has a narrower focus than Lesson Study, and its focus is always on how the intended learning can best be achieved. Lesson Study, on the other hand, may have other foci, for instance it may look into how certain innovative strategies can be implemented, e.g. how to carry out co-operative learning, or how to manage the classroom; 2) all learning studies are informed by a learning theory, but are not necessarily restricted to any particular learning theory. But, so far, it has happened that all learning studies are based on a conceptual framework that is premised on variation theory. Although some lesson studies may also be informed by learning theories, this is not necessarily so.

What is Lesson Study

'Jugyou kenkyuu', a method used for the teacher professional development, has a long history in Japan (Yoshida, 1999; Watanabe, 2002). After Stigler and Hiebert published their findings in the Third International Mathematics and Science Study (TIMSS) (Stigler & Hiebert, 1999), and presented this method as the reason why Japanese students did very well in the TIMSS and other comparative studies, 'Jugyou kenkyuu', which they renamed as 'Lesson Study', became widely known. Over the past ten years, the practice of Lesson Study has been spreading rapidly in different countries, and there is growing evidence to suggest that it can enhance both instruction and student learning.

Lesson Study is seen as a form of action research and professional development activity in which teachers collaborate to create effective lessons and to examine their own practices (Fernandez, 2002; Lewis, 2002). A Lesson Study involves a group of teachers meeting regularly over a period of from a few months to a year to work on the design, implementation, testing and improvement of one or several research lessons (Stigler & Hiebert, 1999). The focus of the research lesson lies in a specific teacher-generated problem, goal or vision of pedagogical practice, which is carefully planned in collaboration with one or more colleagues, observed by other teachers, recorded for analysis and reflection, and discussed by all the members of the Lesson Study group, other colleagues, administrators or invited commentators (Lewis & Tsuchida, 1998).

The stages of a Lesson Study, which are expected to lead to increased professional knowledge and skills, are as follows:

- Defining and researching a problem
- Planning the lesson
- Teaching and observing the lesson
- Evaluating the lesson and reflecting on its effect
- Revising the lesson
- Teaching and observing the revised lesson
- Evaluating and reflecting a second time
- Sharing the results (Stigler & Hiebert, 1999)

It is well known that adaptations to any imported innovations develop a life of their own. Thus, the level of success of attempts to adapt the practice of 'Jugyou kenkyuu' to the situation in other countries has varied widely, in particular because most of the information about it is published in Japanese. For example, Lewis, Perry and Murata (2006) noted that despite the widespread adoption of the process in the US, "the whole edifice of US lesson study actually rests on just two examples of full Japanese lesson study cycles" (p.3). In other words, the American process is based more on the perception of the ideal rather than on a fidelity approach. This is true for all countries which have sought to apply the lesson study approach. It also explains why the interpretation and practice of lesson study vary so widely across countries. Lesson studies in the US are exemplified by the works of Catherine Lewis, Clea Fernandez and Yoshida. The lesson study projects led by Lewis, for example, involved a large number of US teachers. Positive teacher development outcomes were reported, including their increased understanding of the subject knowledge and the students' perspective, the sharing of teaching ideas, and the development of a collaborative culture among the teachers participating in the project (Lewis et al., 2006). In 2004, at least 250 schools in 29 States were involved in this kind of research (Lewis, Perry & Hurd, 2004). As the bulk of the literature on Lesson Study comes from the US (and not from Japan), the US model has had the greatest influence on other countries. For instance, the lesson studies in Singapore and Indonesia are based on this model.

The origin of the Learning Study approach and its impacts

The Learning Study approach was inspired by the design experiments and the in-depth studies of specific lessons made by Japanese and Chinese teachers (Pang, 2006), but supplemented by a systematic theoretical framework premised on variation theory. It always takes the object of learning as the point of departure. It is sometimes described as a hybrid form of the Japanese Lesson Study and as a design experiment (Marton & Pang, 2006: 196). Carlgren (2012) reframed it as a model for clinical studies of teachers' professional tasks which is more focused on constructing knowledge concerning the objects of learning as well as the teaching-learning relationship.

Learning Study was initiated by Marton and Lo, who were interested in making use of variation theory to help teachers to plan lessons that would lead to better learning. They undertook a pilot project on ways of catering for individual differences among students in Hong Kong in 1999. Subsequently, more researchers from the University of Hong Kong and the Hong Kong Institute of Education joined in a three-year project (2000-03), Catering for Individual Difference – Building on Variation (CID(v)), headed by Lo, Pong and Marton. The procedure for Learning Study has now been tested and refined in over 300 Learning Study cases in more than 200 schools over a period of 10

years. It has been reported to have had a positive effect on teachers' professional development (e.g. Lo, 2009; Lo, Chik and Pang, 2006; Cheng, 2009). Furthermore, there is evidence that a Learning Study approach can cater for the differences between individual students and in this way to reduce the performance gap between high- and low-performance groups (Lo, Pong and Chik, 2005). In the three-year (CID(v)) project, a longitudinal study was carried out in two schools. For the groups of students whose teachers were involved in learning studies for all of the three years, overall improvements in the Hong Kong Attainment Test (HKAT) scores were found in both schools. (The HKAT is a standardized test administered annually to all Hong Kong students.) It was also found that the gap between the low and high-scoring groups narrowed (Lo, Pong & Chik, 2005), showing that it is possible to help lower-achieving students to catch up with their higher-achieving peers. We believe that these changes were a result of the teachers learning to teach more effectively by adopting a Learning Study approach. A subsequent three-year project, the Variation for the Improvement of Teaching and Learning (VITAL) Project, involving 120 primary and secondary schools, produced evidence that corroborated the results of the earlier project (Lo et al., 2008). Significant gains in the post-test scores compared with the pre-test scores were found in 114 cases (95%), and 63 of the cases had a significantly higher incremental score in the last teaching cycle than in the first cycle. There were also cases in which the incremental scores of the second and third cycles were significantly higher than those in the first cycle. These findings indicate the effectiveness of the cycle method of Learning Study in helping teachers to improve their pedagogical practices (Lo et al., 2008). The effect of closing the performance gap between high and low achievers can be explained by the fact that each research lesson was planned with the aim of resolving the difficulties that students of all attainment levels were facing, and thus helping all of the students to learn equally well. In some cases, delayed tests were administered to the students after several months and after a year. The results showed that the effects of the learning studies approach for some of the students were felt far beyond the impact on the single research lesson (Elliott, 2012).

As mentioned earlier, the major differences between Lesson Study and Learning Study lie in the focus of the study as well as the theoretical lens used to gain a clearer understanding of teaching and learning. In the next section, we explain how these features contribute to the success of the Learning Study approach by integrating the factors for building authentic learning environments and applying them in practice.

3. Special features of the Learning Study approach

Taking the object of learning as the point of departure

According to Brentano (1995), every psychological act has content and is directed at an object. Therefore we cannot discuss learning without considering what is being learnt (we refer to this as the 'object of learning'). When learning takes place in its natural environment, generally referred to as situated learning (Brown, Collins and Duguid, 1989), there is no need to pay special attention to the object of learning as knowledge is distributed in the environment through the presence of the knowers and the artefacts. However, in the context of classroom learning, the teacher has to create the learning environment, and it is obvious that it would be impossible for students to learn a specific object of learning if that object is absent from the learning environment. However, most popular learning theories consider learning only on a general level, without reference to any particular object of learning. Therefore, a learning theory that focuses on how the specific object of learning can be handled is important in order to help teachers in their task in the classroom, and help students to learn effectively. In this respect, variation theory helps to fill the gap.

The contribution of variation theory to Learning Study

Variation theory proposes a special way of viewing learning, and provides an explanation of why some students learn better than others. It can also cater for individual differences and this can be empowering for teachers. Variation theory evolved from phenomenography, in which a person's experience of specific phenomena is studied. The most important idea of variation theory is that learning is a function of discernment, and discernment is a function of variation. Readers who are interested in the history of the development of phenomenography, its major concepts and its research findings, can find further details in the work of Marton (1981); Marton (1986); Marton & Booth (1997); and Bowden & Marton (1998). A brief introduction to variation theory is given below.

Variation theory posits that our awareness has a structure. What we focus on will be at the forefront of our awareness and be discerned, and what we do not focus on will recede into the background. Since every phenomenon or object has many features, we may not be able to focus on all of the features at the same time. How we understand an object depends on which features we focus on and discern simultaneously (Marton and Booth, 1997). For example, if we focus on the fingerprints of our hands, our hands may be seen as a tool for personal identification; if we focus on the space that can be made with the hand and fingers, it becomes an object of art; if we focus on the structure of the joints and how it can be used to lift things, it becomes an effective machine. People may focus on different features of an object and so come to identify different meanings for that object. Therefore, if we want another person to see the object in the same way as we do, they must focus on the same features that we do. These are the 'critical features' for a particular way of seeing the object. Learning results when there is a change in the way that people see and make sense of the object. This deepens their understanding of the object, and viewing it from different perspectives can widen or completely change their view of the object. This is brought about by people noticing features that they had previously taken for granted. In the classroom teaching and learning context, this means that teachers must be aware of the critical features that contribute to the intended way of understanding the object of learning, and must help their students to focus on those features.

In the context of teaching and learning in the classroom, the object of learning refers to what it is worthwhile for the students to learn within the time constraints imposed by the nature of schooling. The direct object of learning refers to the content, i.e. what the teacher intends to teach in the lesson, and the indirect object of learning refers to how the learners are expected to make sense of and make use of that content. The indirect object of learning can be specific or general. For example, the 'three phases of water' is a direct object of learning. 'Being able to recall the 'three phases of water' is an indirect object of learning that is specific. 'Being able to produce scientific explanations of everyday phenomena, such as the formation of mist, fog and dew using the three phases of water' is an indirect object of learning that is general. The general aspect of the object of learning refers to the capabilities, attitudes or skills which are to be nurtured through the learning of the specific aspects of the object of learning. Both the direct and the indirect objects of learning must be covered in a Learning Study.

Sometimes, the learner will take certain aspects for granted, and for these to be discerned and brought to the forefront of the learner's awareness, the learner must experience variations in those aspects. According to Marton (2009), a person cannot discern the features of an aspect if they have not experienced variations in those features. For example, if there were only males in this world, the concept of maleness would not be discerned. It is only possible to discern maleness when it is contrasted with femaleness, i.e. a variation in gender. Then the concept of gender (an aspect) can be discerned, and male and female become two features of this aspect. Lo and Marton (2012) assert that the implication of variation theory for teaching is that the learning cycle should start with the learner's encounter with the undivided whole, which is how objects and events appear in daily life. Thereafter the teacher should help the learner to discern and separate the various aspects by letting them vary one

at a time. Finally they would present simultaneous variation in all the aspects, so that the whole is discerned again, but this time, the learner would be able to identify all the critical aspects in relation to each other and to the whole. Thus, in order to help students to learn effectively, the teacher must first identify a worthwhile object of learning and the critical features that the students must discern in order to see the object of learning in the intended way. They would then design patterns of variation (what to vary and what to keep invariant) to help the students to discern the critical features/aspects. Variation theory posits that systematically varying certain aspects and keeping certain aspects constant helps learners to discern any new aspects of an object and to construct new meanings. This has been supported by various empirical studies (Marton & Morris, 2002; Marton & Tsui, 2004; Pang & Marton, 2005; Pang, 2010). Thus, in the Learning Study approach, patterns of variation are used to help students to discern the critical features identified for specific objects of learning.

Variation theory spells out the necessary conditions for learning. If we view learning in this way, then we can explain why students learn differently and in different ways. Since it is necessary to discern and focus on all the critical features in order to understand the object of learning in the intended way, the students' inability to learn could be explained by their not focusing on *all* the critical features. The reason why this happens is that they may not have had the learning experiences that enabled them to do so, rather than because they are less intelligent. In order to help students to learn, it is necessary for the teacher to identify all the critical features required for the intended way of seeing the object of learning, and then to provide learning experiences that would allow the students to discern those critical features and to focus on them simultaneously. The students' previous ways of seeing may be incomplete, and in some cases this may even contribute to learning difficulties because it represents a barrier to the new ways of seeing. Thus the teacher should explore the students' initial ways of seeing the object of learning, in particular if they appear to have learning difficulties, and identify any critical features they are missing, before planning learning activities to help them to learn. Fortunately, the results of phenomenographic research show that qualitatively different ways of viewing an object of learning are always limited.

4. The process of inquiry in the Learning Study approach

With respect to the methodology to be used, a systematic process of inquiry which involves the planning, implementation and evaluation of a research lesson is central to the Learning Study approach. Each Learning Study takes an initial object of learning as the point of departure for creating a joint enterprise for the inquiry process. The different steps shown in Figure 1 are activities that help the teachers to finalize the intended object of learning. Three types of variation guide the inquiry process:

- V1. Variation in the students' understanding of the object of learning
- V2. Variation in the teachers' own ways of understanding and dealing with this object of learning in the past
- V3. Variation as a guiding principle of pedagogical design

Planning the research lesson

The planning stage includes choosing the topic, defining the object of learning and identifying critical features of the object of learning. Suitable approaches and teaching strategies are then selected and a lesson plan is generated for the research lesson. V1 is usually discovered by interviewing the students or through the use of diagnostic tests during the planning stage. V2 is identified during the

collaborative Learning Study process, for instance during team meetings in which teachers share their views and experiences. The investigation of V1 helps teachers to identify gaps in the students' prior knowledge, and the possible misconceptions and difficulties that students might encounter, as well as the teachers' own short-comings in dealing with this topic in the past. These all help teachers to identify the critical features of the object of learning and to design patterns of variation (V3) to help students to focus on these aspects (Lo, Chik and Pang, 2006). Then learning activities that can best demonstrate the patterns of variation are designed. During this stage, of course, other teaching theories and strategies are also used where appropriate to facilitate learning, e.g. the communicative approach in English, the investigative approach in Science, and group activities that allow the students' voices to be heard and their comments attended to.

Teaching the research lesson in cycles

After the planning stage, the research lesson is taught by one of the teachers in the group and observed by the others. The lesson is videotaped for detailed analysis later. During this process, the teachers also learn from each other (V2). V1 is also revealed during the lesson by listening carefully to the students' responses. This echoes the argument by Wiliam (2010) that the learning environment should be designed so as to be responsive to the evidence of learning as it takes place. Immediately after the lesson, some students are interviewed about what they perceive they have learnt in the lesson and a diagnostic post-test is administered to all participating students. The data on V1 thus obtained serve as important discussion points for the post-lesson conference and for the teachers to reflect on and suggest improvements. A second teacher will revise the lesson plan, taking into account the suggestions and the post-test results, and teach the revised lesson to another class. This lesson will also be video-taped, discussed and revised. This process is repeated until all the teachers have taught the lesson to their respective classes.

Evaluating the research lessons

When the cycles of teaching are completed, the teachers gather for the final evaluation stage. This involves data triangulation among the test scores, student interview data and analysis of the teaching enactment from the video clips. The aim is to find a relationship between how the teachers handled the object of learning and the students' learning. The teachers will then suggest further improvements and revise the lesson design for future reference. During this stage, the teachers learn from V1, V2 and V3.

After completing the process of inquiry, the teachers are encouraged to reflect on what they have learned through using the Learning Study approach and conducting a public presentation to other teachers, thus turning their tacit knowledge into transferable explicit knowledge (Nonaka & Takeuchi, 1995). Finally, the whole experience is written up as a case study which becomes a transferable and shared inventory of the school. Figure 1 illustrates how variation theory is employed as a guiding principle of Learning Study throughout the process.

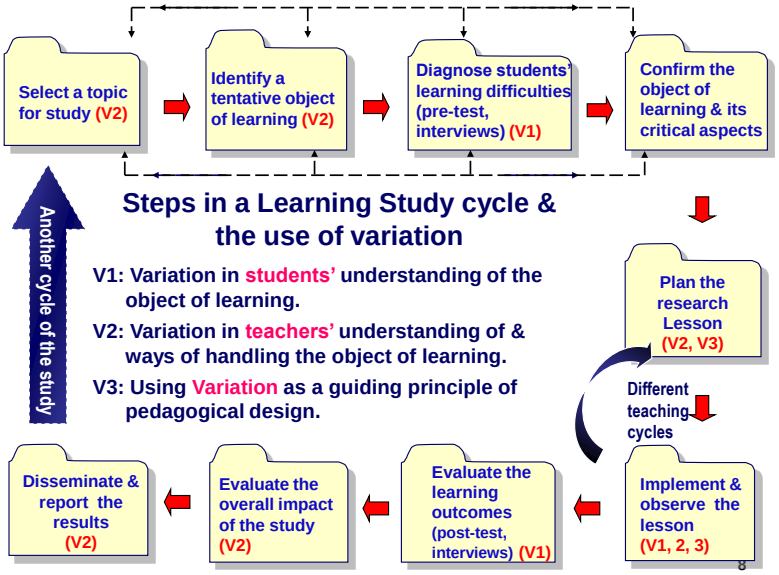


Figure 1: Steps in a Learning Study and the use of variation

In the next section, one case study will be described in detail to reveal the nuances and the complexity involved in carrying out a Learning Study.

5. A case study to illustrate student learning and teachers' professional development

This Learning Study project was conducted in a primary school in Hong Kong, with the first author as its facilitator. It involved five mathematics teachers, all of whom had received formal initial teacher education. Their profiles are shown in Table 1.

Table 1. Enactment of patterns variation

Enactment of patterns variation	Cycle 1	Cycle 2	Cycle 3
The lesson starts with a question.	The teacher asked, "Can you calculate the perimeter of the figure when the lengths of a and b are unknown?" (See Figure 3)	The teacher asked "Can you write down the formula for calculating the perimeter of Figure 3 when the lengths of some of the line segments are unknown?" "Could you find out the perimeter of the polygon from the formula?"	The teacher asked "Can you use letters to represent the length and write down the formula for calculating the perimeter when the lengths of some of the line segments of a side are not provided?" The teacher did not ask students if they could find out the perimeter of the polygon from the formula as in cycle 2.

CF 2	The teacher asked the students to find out the relationship of the line segments of the top side and the base side by moving different coloured segment lines parallel to the base side. Then students wrote down the formula and calculated the answer. Pattern of variation 2 enacted	The students were told to find out the relationship of the line segments and wrote down the formula. The teacher guided them to identify the relationship of the coloured line segments of the top side with the base side by writing down an equation: the sum of the length of the line segments which made up the top side = the length of the base side. From the formula, students found out the unknown lengths. Pattern of variation 2 enacted.	The teacher emphasized the use of the "parallel sliding method" to find out the relationship between the line segments. This is done by sliding the line segment parallel to its corresponding side to turn the polygon into a rectangular shape. The teacher told the students that parallel line segments could be used as a reference and compared with each other. The teacher also explained in detail that the students could find out the length of the side with segments of unknown lengths by sliding it in parallel with a known side until they overlap. The teacher asked the students to find out the relationship between the coloured line segments. Pattern of variation 2 enacted.
CF1	Nil	The teacher asked the students if they could find out the length of a and b, respectively, from the formula 15 = b + a in Figure 3. The teacher guided students to find out that there were many possible combinations for a and b. Therefore, it is not correct to measure or to guess the length of the unknown lines in the figures. Pattern of variation 1 enacted.	
CF3	The teacher asked the students to write out the formula that can be used to find the perimeter of the compound rectangle, like (15 + 5) × 2. However, the teacher did not explain how this formula could be arrived at by using the relationship between the line segments.	The teacher asked the students to write down the formula containing unknown letters, like (15 + 5 + 3 + 2 + a + b). Then the teacher asked the students to think how to find out the unknown lengths. The teacher also consolidated the students' concepts by means of a worksheet. Pattern of variation 3 enacted.	

The teachers spent around two hours in each meeting sharing, discussing and negotiating the object of learning over the course of nearly a month. They shared the following common difficulties in teaching primary 4 mathematics.

> *My students have problems visualizing dimensions of polygons and figures for calculation. Some students use a ruler to measure the lengths of the figures instead of referencing the opposite parallel line to seek the dimension; others even estimate the lengths by sight. (Mr. W)*
> *Some primary 5 students are not clear about how to calculate the area and perimeter of a compound rectangle; this may reflect the fact that they do not have a solid understanding of how to calculate the perimeter of a compound rectangle, which they should have learnt in primary 4. (Ms. H)*

It was finally agreed that the object of learning was 'the method to calculate the perimeter of a compound rectangle' (see Table 2) since all the teachers encountered difficulties in teaching this topic.

Table 2. Object of Learning: The method to calculate the perimeter of compound rectangles

Object of Learning:	**The method to calculate the perimeter of compound rectangles**
Critical:	1. The figures shown in questions are normally not drawn to scale, so it is not correct to measure or to guess the length of the unknown lines in the figures.
Features:	2. Moving a line any distance parallel to its original position will not change the length of the line.
	3. To calculate the perimeter of a compound rectangle, it is not necessary to know the individual length of each line segment which makes up the side of the perimeter, as long as the total length of the side can be found by referencing the length of a line parallel to it.

Some students were asked to find the perimeter of a compound rectangle as shown in Figure 2. The teachers expected them to find the sum of side 'a' and side 'b' to be 9cm by referencing a line parallel to it. The subsequent interviews revealed two types of students employing two different categories of thinking process in solving the questions (see Figure 2). Type A students knew that the perimeter of the compound rectangle is the sum of all its sides, but they were not able to find the length of the unknown side by referencing a line parallel to it, and thus they were unable to calculate the perimeter. Type B students also knew that the perimeter of the compound rectangle is the sum of all its sides; they were able to identify the length of the unknown side as a + b by referencing a line parallel to it, but surprisingly, they assigned a value of 5 and 4 by sight perception to a and b, respectively, in order to calculate the perimeter. They knew that a + b = 9, but they had the misconception that 'a' and 'b' must be quantified with a numerical value for the calculation and thus assigned values to them.

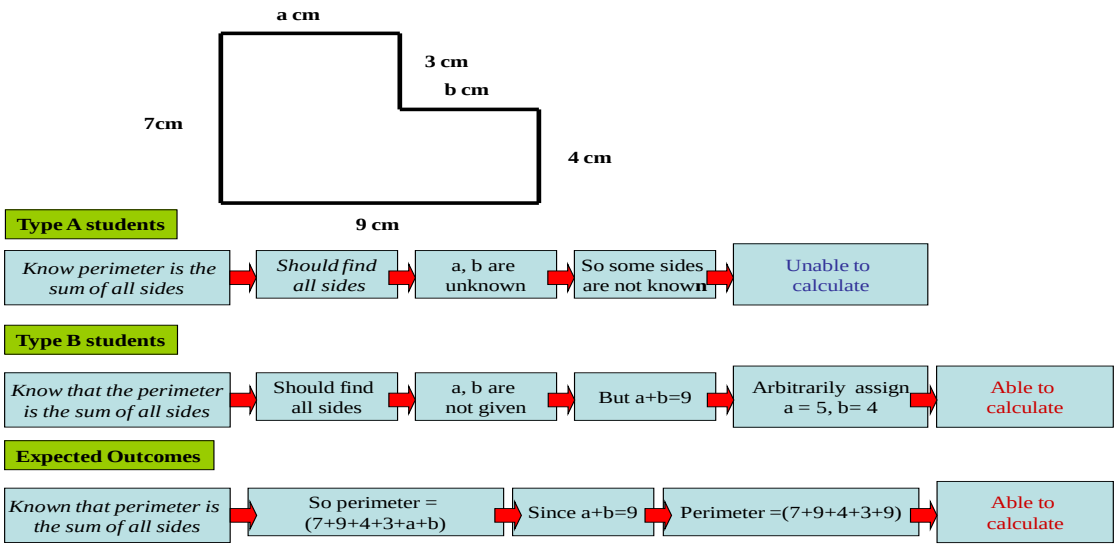


Figure 2: Students' thinking process on the topic

Based on the above information about students' different ways of solving the problem (referred to as V1 in the Learning Study framework), the teachers worked out the pattern of variation (V3) required to bring about discernment of the critical features, and designed a diagnostic test paper to measure how students understood the object of learning before and after the research lessons changed. The teachers were all eager to contribute their teaching notes and handouts and share their knowledge to design, implement and revise the research lesson. The minutes of the meetings demonstrate their willingness to suggest improvements to the lesson plan as different teaching strategies, namely problem-based learning, teaching models, and thinking aloud, were all shared in the first few meetings, along with past lesson plans. The teachers suggested at least three approaches for tackling the object of learning. The following excerpt from a meeting captured some of the suggestions:

Reforming a rectangle by moving its edge(s) parallel to the compound rectangle could help students to calculate the perimeter more easily than other methods. (Mr. L)

But I think referencing the given length by moving parallel lines could help students to learn to read dimensions, and could also tackle the common misconception which our students seem to have of trying to estimate by sight or even guessing the value for the edges. (Ms. K)

I think since the opposite sides of a rectangle are equal in length; students should learn to substitute these values into the perimeter equation for solving the problem. (Mr. W)

Table 3 illustrates the pattern of variation that the teachers devised to help students discern CF1, namely that it is not correct to measure or to guess the length of the unknown lines in given figures as these were not drawn to scale. The teachers planned to show the diagrams in Figure 3 and ask students the values of 'a' and 'b'.

Table 3. Pattern of variation 1 to help discern CF1 of the research lesson

Critical Feature to be Discerned	Varied	Unchanged
CF1 The figures shown in questions are normally not drawn to scale, so it is not correct to measure or to guess the length of the unknown lines in the figures.	The length of a and b are varied.	The same figure is used and the total length of a + b = 15.

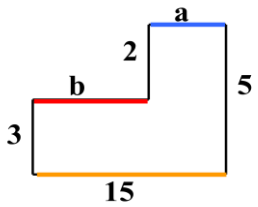


Figure 3: Same figures with varied values of lengths a and b, keeping the sum equal to 15

Table 4 shows the pattern of variation the teachers planned to help students to discern CF2, namely that the sum of the length of the two line segments of the top side of the compound rectangle are equal to the length of the base side if they are parallel. The teachers planned to refer to Figure 4 and draw students' attention to the sum of the length of the top line segment each time the lengths were varied.

Table 4. Pattern of variation 2 to help discern CF2 of the research lesson

Critical Feature to be Discerned	Varied	Unchanged
CF2 The total length of the top sides of the compound rectangle is equal to the length of the base side if they are both parallel to the base side.	The length of any two top sides varied: 4 and 3 6 and a b and a.	The length of the base side (7) is equal to the sum of the length of the top sides of the compound rectangle, 4 + 3, 6 + a or a + b, if they are both parallel to the base side.

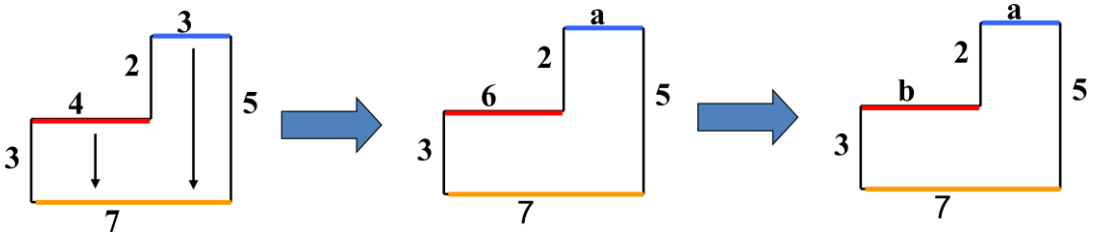


Figure 4: Same figures with varied values of lengths of line segments while the sum of the length of line segments is equal to 7

Table 5 shows the pattern of variation to help discern CF3, namely that it is not necessary to identify the length of each segment of the top side to calculate the perimeter of a compound rectangle, given that the overall length of the top side can be identified by referencing the length of the base side if they are parallel. The teachers planned to use Figure 5 to bring out the pattern of variation.

Table 5. Pattern of variation 3 to help discern CF3 of the research lesson

Critical Feature to be Discerned	Varied	Unchanged
CF3 To calculate the perimeter of a compound rectangle, it is not necessary to know the individual length of each line segment as long as the total length of the side can be found by referencing the length of a line parallel to it.	With unknown variable. Without unknown variable.	The rule for perimeter calculation is unchanged: the sum of the length of each side.

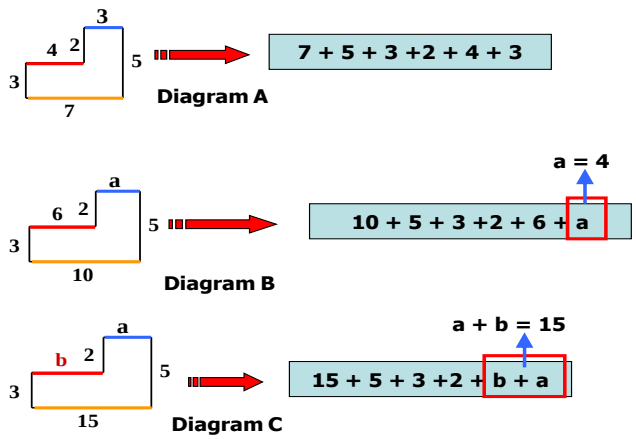


Figure 5: Figures with different lengths of line segments making up the top side but the same rule for perimeter calculation

Although the three patterns of variation were formulated collaboratively, their enactments in the three teaching cycles were different. Table 6 compares the enactment of the three patterns of variation by the three teachers.

Table 6. Enactement of the patterns of variation in the three teaching cycles

The lesson starts with a question.	The teacher asked, "Can you calculate the perimeter of the figure when the lengths of a and b are unknown?" (See Figure 3)	The teacher asked "Can you write down the formula for calculating the perimeter of Figure 3 when the lengths of some of the line segments are unknown?" "Could you find out the perimeter of the polygon from the formula?"	The teacher asked "Can you use letters to represent the length and write down the formula for calculating the perimeter when the lengths of some of the line segments of a side are not provided?" The teacher did not ask students if they could find out the perimeter of the polygon from the formula as in cycle 2.
CF 2	The teacher asked the students to find out the relationship of the line segments of the top side and the base side by moving different coloured segment lines parallel to the base side. Then students wrote down the formula and calculated the answer. Pattern of variation 2 enacted	The students were told to find out the relationship of the line segments and wrote down the formula. The teacher guided them to identify the relationship of the coloured line segments of the top side with the base side by writing down an equation: the sum of the length of the line segments which made up the top side = the length of the base side. From the formula, students found out the unknown lengths. Pattern of variation 2 enacted.	The teacher emphasized the use of the "parallel sliding method" to find out the relationship between the line segments. This is done by sliding the line segment parallel to its corresponding side to turn the polygon into a rectangular shape. The teacher told the students that parallel line segments could be used as a reference and compared with each other. The teacher also explained in detail that the students could find out the length of the side with segments of unknown lengths by sliding it in parallel with a known side until they overlap.

			The teacher asked the students to find out the relationship between the coloured line segments. Pattern of variation 2 enacted.
CF1	Nil	The teacher asked the students if they could find out the length of a and b, respectively, from the formula 15 = b + a in Figure 3 The teacher guided students to find out that there were many possible combinations for a and b. Therefore, it is not correct to measure or to guess the length of the unknown lines in the figures. Pattern of variation 1 enacted.	
CF3	The teacher asked the students to write out the formula that can be used to find the perimeter of the compound rectangle, like (15 + 5) × 2. However, the teacher did not explain how this formula could be arrived at by using the relationship between the line segments.	The teacher asked the students to write down the formula containing unknown letters, like (15 + 5 + 3 + 2 + a + b). Then the teacher asked the students to think how to find out the unknown lengths. The teacher also consolidated the students' concepts by means of a worksheet. Pattern of variation 3 enacted.	

The differences in enacting the patterns of variation in the three teaching cycles resulted in a difference in post-test scores (see Table 7). A total of 106 primary 4 students participated in the research lessons. Table 7 shows the number of students and the mean pre-test and post-test results of each teaching cycle. Results of the analysis of covariance (see Appendix 2) show that the interaction term cycle * pr_ol shows no evidence of violation of the equal slopes assumption: the F value is 0.442, with a significance level of 0.644. The homogeneity of regression assumption is not rejected, and thus one can proceed to estimate the effects of the enactment of patterns of variation in the teaching cycles on the post-test scores given the pre-test scores. The tests of between-subjects effects show that there is some evidence of cycle effect: the F value is 9.106, with a significance of 0.000. Using the default Type III sums of squares, the test for the covariate is a test of the common or pooled within-cells regression of post-test scores on pre-test scores. This regression coefficient estimate appears in the parameter estimates tables as the B coefficient for pre-test scores. In the GLM parameterization, the intercept parameter estimate gives the estimate value of the last category of the cycle (cycle = 3) when the covariate is equal to 0. The cycle = 1 and cycle = 2 coefficients subtract the cycle 3 predicted value from the cycle 1 and 2 predicted values, respectively. The estimated marginal means displays the estimated means and standard errors for each level of cycle when the covariate is at its mean value.

Table 7. Number of students and mean pre-and post-test score by cycle

Cycle	No. of students	Mean pre-test score	Mean post-test score	Gain score
1	31	21	40	19
2	37	36	74	38
3	38	29	60	31

In the past, it was very easy for the teachers to conclude that since the mean pre-test score of the cycle 1 class was the lowest, the class must be of lower ability and so their learning would not be as good as that of the other brighter classes. However, after doing a Learning Study, the teachers saw this result in a different way. They tried to account for the difference in gain scores by looking at what the teacher actually taught in the research lesson.

To understand why cycle 1 was less effective than cycles 2 and 3, we compared the teaching enactments in the three cycles. Effective pedagogical content knowledge for perimeter calculation can be extracted from comparing the delivery of the introduction and teaching activities. Cycles 2 and 3 were more effective because the teachers learnt from observing the first lesson and gained insights on how the lesson could be improved in subsequent cycles.

Questions asked in the introduction part of cycle 1 were judged to be superficial. They were not able to support the higher order thinking of students; for example, when students were stuck because they saw that both a and b were unknown, the teacher's questions did not lead students to use the algebra they have learnt to substitute a + b by 9, which was known.

The pattern of variation that was designed to deal with CF1 was not enacted in cycle 1 because the teacher forgot to do so. In both cycles 2 and 3, this was successfully enacted and students' attention was drawn to the formula 15 = b + a in Figure 3. The students were thus able to discern that it was not correct to estimate or measure the length of an unknown line segment in the diagram, and also that this was not necessary.

The pattern of variation 2, which aimed to help students discern CF2, was enacted in all the cycles, but the extents of guidance provided were different. The teacher in cycle 1 demonstrated how to move the lines of the top side to the base side to illustrate their relationship, but no numerical values were assigned to the line segments. In cycles 2 and 3, the same demonstration was performed, but numerical values were assigned to all the line segments of the figure. Also, in cycles 2 and 3, once CF1 was dealt with, the rest of the learning became more meaningful to the students as they realised that they needed to find ways to work out the unknown length of the line segments. The pattern of variation 2 enacted in cycles 2 and 3 allowed the students to discover how the parallel sliding method enabled them to find the length of the top side.

The pattern of variation 3, which aimed to help students discern CF3, and the consolidation part were only enacted in cycles 2 and 3. The teachers asked students to calculate the perimeter of a compound rectangle by formulating the expression 15 + 5 + 3 + 2 + a + b first, and then invited students to think of a way to find out the unknown a + b. Students were expected to find the length of a + b by referencing the base side. The third pattern of variation enacted in cycles 2 and 3 also served the function of fusion for integrating the learning points of activities 1 and 2. These were not enacted in cycle 1.

Thus, all three patterns of variation were enacted in cycles 2 and 3, while only one pattern was enacted in cycle 1. According to variation theory, students in cycles 2 and 3 were given better opportunities to learn than those in cycle 1, and they should perform better in the post-test. This was confirmed by the result of the ANCOVA-test. The absence of any significant difference in the post-test scores between cycles 2 and 3 reflects that there is no significant difference in the enactment of patterns of variation between cycles 2 and 3 which might have contributed to a higher post-test score.

A distinctive feature of Learning Study cases in Hong Kong is that variation theory was being used consciously to create patterns of variation in the planning of the lessons. The findings of this case study support the use of variation theory as a guiding principle of pedagogical design for effective learning. Learning Study can provide a platform to help teachers put this pedagogy into practice.

Teachers' Professional Development

Throughout the project, the teachers learned and used a common language - the jargon of variation theory - to talk about teaching and learning, referring to the object of learning (OL), critical features (CF), variation in students' understanding of the OL (V1), variation in teachers' ways of dealing with the OL (V2), and using variation as a guiding principle of pedagogical design (V3). They learned to negotiate patterns of variation to help students to discern critical features and together planned teaching activities that could best allow students to experience the variation patterns themselves. In doing this, they had to draw on their own experience and knowledge of teaching. To enact the patterns of variation, the teachers developed a repertoire of ways of interacting, teaching demonstrations, talking, and articulating assumptions and personal mental models, all of which combined to become part of their collective practice. Learning Study can provide teachers with a platform for knowledge sharing, constitute a social fabric of learning and enhance collaboration.

Teachers are the main agents of change, and the classroom will not show any significant change for better learning unless teachers' mindsets are changed and they have the necessary knowledge and skills to manage the learning environment for students. Learning Study is not only designed for student learning, but also designed explicitly for teacher learning and change.

Since Learning Study is guided by variation theory, teachers gained a better understanding of the theory and learned how to apply it in practice.

> *Compared with before, I am more aware of how students think and how they learn, and I will more consciously check if any misconception is involved. Now, I ask more questions to explore their understanding of the object of learning before teaching. Identifying their ways of seeing the teaching content is the most valuable thing that I have learnt in the Learning Study project.*
>
> *Through the pre-lesson and post-lesson tests, I can diagnose students' difficulties with respect to the teaching content, and this provides insight for us to formulate the lesson plan.*

In addition, teachers were positive about their experience of the Learning Study and how it can help them improve their teaching.

> *I have experienced the entire process of action research for the first time in my teaching. Learning Study provides the chance for us to analyse the pros and cons of the teaching strategies.*
>
> *Learning Study is a logical and systematic process which helps us apply variation theory in the classroom. During the research lesson, students actively asked questions and engaged in deep thinking.*
>
> *I have learned how to run Learning Study in my school. It is essential to evaluate the effectiveness between cycles and seek improvement. Learning Study, like action research, could be applied in other subjects.*

The above findings support the claim that Learning Study contributes to teacher learning. Similar results have been reported by other researchers (Pang 2006; Lee, 2008; and Siu, 2008). However, Davies and Dunnill (2008) point out that the demands of Learning Study are strict and that this limits its practicability as a routine part of teaching practice. While we agree that making the Learning Study approach a routine part of teaching practice may not always be feasible, the main purpose of engaging

teachers in Learning Study is to provide them with prolonged, supported, hands-on experience of inquiry into their own teaching, which we believe will help change their teaching and learning conceptions and will sensitize them to students' learning difficulties. The evidence so far shows that these objectives have been achieved. For example, a questionnaire survey of principals and teachers from 120 schools who participated in the VITAL Project from 2005 to 2008 received responses from 334 teachers in 80 schools (70% response rate). The results showed that more than 80% of the teachers agreed that they will focus more on how to deal with the object of learning and the critical aspects when teaching. Over 80% of the teachers also agreed that they had become more sensitive to students' learning difficulties and were more ready to collaborate with their colleagues through such methods as mutual lesson observation, analysis and discussion. Some teachers made the following comments in the open-ended questions section:

[The] Learning Study has given me a chance to appreciate my weaknesses and other people's strengths.

The experience gained from one Learning Study is equal to three years of teaching experience (By a novice teacher).

I had taught mathematics for 12 years (when I started a Learning Study) and I thought that there was no room for me to improve myself. I think I was at a plateau and I taught in the same way without problems from year to year, so the room for improvement was really very little. However, I now find that there is actually a lot of room for me to improve after experiencing Learning Study.

In the past, I always thought that it would be difficult to teach low-achieving students well. After I saw the pre- and post-test results, I began to believe that students can make progress regardless of whether they were high-achieving or low-achieving before. I also believe that every student can learn better if the object of learning can be managed appropriately.

We have already discussed how Learning Study provides a platform for teachers to enquire about students' understanding of what is to be taught, to share and testify to their own personal practical knowledge, and to disseminate the findings of pedagogical content knowledge. The following section illustrates how Learning Study was institutionalized in a school and discusses the leadership strategies that were applied to effectively create a Learning Study community in the school.

6. A case study on institutionalizing Learning Study in school

As an example, one interesting case involves a secondary school (we will call it LS College) in which the principal took Learning Study seriously enough to include it in his school's 2001 development plan. The school is the first to adopt Learning Study as the major means for teachers' professional development in Hong Kong. LS College was established in 1994. After the Hong Kong government introduced a curriculum reform for meeting the demand for human capital in the knowledge society, external pressure for school improvement intensified. In 2001, the ability range of the school's student intake increased, while both the population and total number of students in Hong Kong decreased; schools were facing serious challenges for survival and significant competition emerged between schools at that time. In response, the principal sought support from tertiary education institutions to provide school improvement projects aimed at teachers' professional development, enhancing student learning effectiveness, and ultimately building a professional learning community. He selected Learning Study as a catalyst for building a learning community because its focus is on improving teaching and learning, which was in line with the direction of the school's development that was introduced in 2003. Since the introduction of Learning Study, the teaching and

learning have shown continual improvement, a fact which is reflected in the result of the government quality assurance audit. These distinctive features of LS College are relevant to the study and that is why it is selected as the case school.

The idea of institutionalizing Learning Study at the school was initiated by the principal. He considers teaching as a profession and values teachers' professional development at the school.

> *Teaching is a profession. A profession should create knowledge to deal with job problems. Learning Study involves cycles of teaching for provoking teacher reflection and leveraging pedagogical content knowledge for innovation and enhancing student learning. We hope that we can create pedagogical content knowledge through Learning Study to carry out our profession. Learning Study was therefore adopted and conducted at our school. (principal)*

While researching school improvement projects from universities, he learned that Learning Study can improve teaching and learning and therefore he supported its implementation at his school. He created a sense of urgency for the change and communicated to the teachers a vision of improving student learning by launching the Learning Study project. He alerted the teachers in his school to the crisis the school was facing at that time due to the need to compete for students with other stronger schools in the school district.

> *The total number of students in our school district dropped and fierce competition between schools emerged at that time. Our school was facing challenges for survival. In response to this competition and to tackle the challenges generated by the external environment, we should maintain the competitive advantages of the school by enhancing the effectiveness of teaching and learning. We insist that improving student learning should be the vision of our school. (principal)*

The principal planned to promote Learning Study by forming a powerful guiding coalition team, but found that he could not rely on his deputy for this.

> *Initially my vice-principal disagreed with my idea of conducting Learning Study. He was afraid that the possible failure of the project would waste teachers' energy and time and discourage them from participating in other professional development activities. I therefore had to set up another team to implement my idea. (principal)*

Instead of forcing his deputy to do this unwillingly, he chose another senior teacher (Mr. L), who is responsible for the curriculum development of the College, to carry out this mission. Mr. L accepted the responsibility to learn about Learning Study and then promote the concept of Learning Study to all the departments. He was therefore enrolled in a 90-hour mentoring course at The Hong Kong Institute of Education (HKIEd) to acquire the skills to facilitate such a learning community.

The principal and Mr. L wanted to start the project in the department offering the least resistance and consulted with subject heads to obtain consent.

> *As there are many different subjects at the school and each subject has a different culture, we considered teachers' attitudes toward the project to achieve a higher chance of success. Those subject departments with good community relationships, mutual trust and a willingness to help each other were strategically selected to initiate Learning Study. (Mr. L)*

Eventually, the principal chose the department of Chinese and the department of mathematics for the project because of their existing collaborative culture.

At the time when Learning Study had not yet been promoted, the teachers of the two subjects were already planning lessons collaboratively, and professional discussions were held on issues relating to teaching and learning. Therefore, these two subjects were chosen as the starting point for the promotion of Learning Study since it was more likely that the project could be successfully conducted with a better sharing of the insights and experiences among teachers. (Mr. L).

Consultants from the HKIEd were invited to support the school's progressive reforms for improving teaching. With their support, Learning Study was finally carried out in the departments of Chinese and mathematics. Novice teachers were able to learn from subject experts and the subject head in the learning community.

Sometimes, teachers from the same subject department know each other well and do not want to confront each other. Even if they have different views, they are courteous and will not criticize their colleagues. External parties serving as constructive critical friends could therefore be in a better position to give alternative opinions to help teachers to improve teaching. Therefore, our school invited experts from the HKIEd to serve this purpose. (Mr. L)
External comments and suggestions on our collective lesson plan helped to improve our professional competency. (Chinese teacher, Mr. I)

A teacher empowerment strategy was adopted by LS College to cultivate a Learning Study community. Teachers were empowered to choose their own topic for the research lesson.

Frontline teachers and subject heads are familiar with students' needs so they should be empowered to conduct Learning Study. For instance, they can make decisions on the grade to choose, the time to conduct the lesson, the way to conduct it, etc. This policy was aimed at encouraging teachers to participate in the Learning Study on a continuous basis. (Mr. L)

Resources and administrative support were provided by the school to facilitate the development of the Learning Study community. The school financed the Learning Study, supported teachers in attending Learning Study training courses, and scheduled common time slots for meetings in teachers' timetables, as well as making arrangements for all teachers participating in the learning studies to observe the research lessons and to carry out post-lesson conferences. Additional audio and visual equipment were bought to record the research lessons for analysis.

In the first two years of conducting the Learning Study, the schedule was based on the availability of the learning community, so that more opportunities for discussion could be created and the teachers' professional development could be enhanced based on the Learning Study. Furthermore, equipment was also bought for teachers to videotape their lessons. Therefore, over the past four years, the school has been well planned, whether in terms of the space and time created for teachers or the provision of equipment. (Mr. L)

If the money spent can help solve education problems, it is worth investing. However, many education problems cannot be solved by money. Therefore, we put many resources into buying services from universities and related organizations in order to enhance the teachers' professional development. (principal)

Teachers of the Learning Study community presented their findings on the staff development day each semester in order to disseminate the outcomes gained from the Learning Study with colleagues from other panels, so that their confidence and commitment to Learning Study could be enhanced. In this way, Learning Study was progressively promoted to other subjects.

Knowledge-sharing activities were conducted on the staff development day. The findings of each Learning Study case were disseminated to all teachers for enhancing their confidence in conducting Learning Study. If other teachers have a positive attitude towards Learning Study, they would be willing to take it up. (Mr. L)

Learning Study was promoted progressively at the subject level through a progressive divergence development strategy of dots, lines and surfaces.

The results gained in these two subjects can act as a point of reference for other colleagues. The target of the school is long-term. It is hoped that Learning Study can be promoted to teachers throughout the whole school, and hence the teachers' professional development can be enhanced. (Mr. L)

I had reservations before the implementation of the project, but it has provided me with a new perspective on understanding teaching and learning. I think each teacher should try to conduct at least one Learning Study case. (vice-principal, who also participated in a Learning Study as a geography teacher)

Eventually, Learning Study was institutionalized at the school for teachers' professional development. Table 8 shows the progress of development of Learning Study in each selected subject at the school.

Table 8. Track record of completed Learning Study cases

School Year	Subjects	Level	Topic
2003-2004	Chinese Language	S2	Speaking：one minute speech
	Mathematics	S3	Probability
2004-2005	Chinese Language	S3	Speaking：group discussion
	English Language	S4	Writing: paragraph development
	Mathematics	S2	Congruent triangles
	Geography	S1	Map reading
2005-2006	English Language	S1	Verb "to be"
	Science	S1	Particle theory of matter
	Geography	S2	Differentiating spurs and valleys from their contour lines
2006-2007	Chinese Language	S4	Information retrieval competency
	Mathematics	S1	Rule of index
	Science	S2	How to connect parallel circuits

Comparing the quality assurance reports from the Education Bureau between 2000 and 2008, the overall teaching performance of the school has improved (Table 9). In 2000, before introducing the Learning Study, the school went through an Education Bureau Quality Assurance Inspection, one of the components of which involved observing the teaching of a sample of over 30 randomly selected teachers and grading each lesson on a four-point scale. After running Learning Study for seven years, the school went through an external school review (a different but similar review; the component on teaching was the same) in 2008. The turnover rate amongst teachers at the school had been low in the intervening period, with only three or four teachers being replaced. The table below compares the quality of the observed lessons in the two separate assessments. The percentages are the number of lessons obtaining the grade specified.

Table 9. Teaching performance based on Quality Assurance Inspection

	Excellent	Good	Satisfactory	Poor
Quality Assurance Inspection in 2000	4.3%	33.3%	52.7%	9.7%
External School Review in 2008	6%	57%	37%	0%

The above comparison clearly suggests that the teachers at this school have improved. This is also reflected in the students' learning outcomes. The principal reported that before the introduction of Learning Study, Education Bureau data, which measures the value added by school education, showed that secondary 5 students' performance in the best six subjects was ranked 8 (in the top 11% of schools in Hong Kong). In 2006, students at the same school were ranked 9 on the same metric (placing the school in the top 4% of all schools in Hong Kong).

7. Implementation strategies for creating a Learning Study community

Obviously, support from learning-focused leadership was a necessary condition for creating the Learning Study community, the implementation strategies employed by LS College are in line with Kotter's (1996) model which is elaborated below.

Kotter's model for leading change provides school leaders with practical guidelines for creating a professional learning community and implementing successful changes. The model involves 'de-freezing' the organization for change, making the change happen, and 're-freezing' the organization with the new approach. To de-freeze the organization, school leaders are advised to establish a sense of urgency, form a powerful guiding coalition team, create a clear vision expressed simply, and communicate the vision with teachers. They should also focus on making the change happen by employing teachers to act on the vision, creating short-term wins, and consolidating the improvements. In this way, a new working approach can eventually be institutionalized in the school.

The principal created a sense of urgency for members to focus on the problems threatening the survival of the school, thus paving the way for a vision to be shared with the staff members. By alerting teachers to the organizational problems and communicating a clear and sensible vision, the transformation effort was easily translated into a list of procedures for conducting Learning Study projects. Without a shared vision, teachers would consider conducting Learning Study as an assigned task rather than an opportunity for learning, thus resulting in a waste of manpower, time and resources.

The strategy of forming a powerful guiding coalition team was important for empowering a team of members to act on the vision and to deal with obstacles to change. Through teamwork and dispersed leadership, the school was able to build professional capacity to solve problems and make decisions expeditiously, as suggested by Senge (2000). The strategy for creating short-term wins aimed to deliver the successful experience of the showcases for publicly recognizing those who made the change possible, and for consolidating other teachers' confidence in the effect of change for enhancing student learning. This was a proactive strategy that looked for ways to obtain clear performance improvements and helped leaders to re-freeze the new culture in the school organization. The principal asserted that a collaborative culture was an essential condition for creating a learning community in the school. He perceived that the existence of a collaborative culture and the practice of professional dialogue in the mathematics and Chinese departments provided a conducive environment for change, and so invited the teachers of these two departments to pioneer the Learning Study projects.

As anticipated, the Learning Study cases from these two departments were successfully conducted and became a model for generating short-term wins. To boost confidence and strengthen the commitment of teachers to Learning Study, a short-term win was created when the findings and outcomes gained from the Learning Study projects were presented to colleagues from other departments at the staff development day. This annual event, along with occasional public presentations, served to disseminate the effective teaching practices developed by teachers.

The strategies of inviting expert support and providing resource support were in line with the implementation strategies for the provision of professional development and assistance for the change process proposed by Hall and Hord (2006) were necessary conditions for maintaining the development of the Learning Study community.

The above case provides insights for us to develop a kernel for introducing an innovation in teaching and learning in school. The term 'kernel routine' is used to denote an organizational routine that has the potential for transforming school practice by 'seeding' and 'propagating' new forms of practice in schools (Resnick and Spillane, 2006). A kernel routine not only anchors school practice in teaching and learning, but also connects other organizational routines in school to form an infrastructure to support practice (Resnick et al., 2010, chapter 12). In some schools in Hong Kong, the transformation of full-blown learning studies into condensed studies to be carried out annually by teachers, using the Learning Study framework for collaborative lesson planning as a regular practice, and using variation theory as the analytical framework for lesson observation and evaluation are already taking place and becoming an organizational routine. Learning Study has the potential to help develop a kernel routine for integrating variation theory into teachers' everyday practice.

What should school leaders do?

We can draw the insight that school leaders must have a personal vision of how leadership will be provided for the school before working with staff to develop a shared vision for the entire school (Owens, 2004). They should be sufficiently open-minded to accept divergent opinions and should be committed to their role as agents of change, because any changes in a school must be accepted, appreciated and nurtured by the leader. Teachers have to be supported and equipped so that they are able to make the changes happen, therefore school leaders need to exercise shared and supportive leadership to sustain collective learning that keeps the shared vision alive through communication and actions, and align plans for professional development to support the change. They should promote and publicize the ideas put forward by members of staff and reinforce work and initiatives across different boundaries, actions which are crucial to strengthening the professional development of both individual teachers and the whole school (Mark & Louis, 1999).

School leaders are not only responsible for institutionalizing policies and resources that support collective learning, but also for nurturing a culture that ensures the productivity of collective learning. They should also foster a collaborative culture and trust in order to facilitate an organizational learning environment in which members of staff are able to present their points of view and thoroughly discuss them before decisions are made. They have to cultivate an organizational culture that facilitates both formal and informal learning processes, which are intrinsic to a learning community (Marsick & Watkins, 1996; Marsick, 1987). The essence of building a shared vision among teachers is to sustain an on-going process that aims to inculcate in the whole school a sense of commitment and ownership and a desire to achieve recognized goals.

School leaders may formulate policies for teachers' professional development via the development of a Learning Study community. Teacher participation in profession-related Learning Study training activities should ideally be stated in the school's annual plan as an essential feature fully supported by the school authority. They should also create a school structure and routines that support a Learning Study community and encourage regular collegial interaction. The following section describes the strategies and policies that create the conditions and capacity to allow Learning Study to flourish in the Hong Kong education system.

8. Building a learning network in a school system

Scaling up Learning Study by building learning networks and formulating education policies to sustain the good pedagogical practices introduced by Learning Study could enhance the quality of an education system. The theory of a loose-tight coupling of school systems may provide insights to government officials, policy makers and educators to formulate policy to disseminate and sustain these practices in the school system. The concept of coupling has been used to describe the relationships between schools and the central district authority (Fennell, 1994). The theory of a loose-tight coupling provides a way of conceptualizing school systems in terms of the interrelatedness of supporting professional development and monitoring educational quality between a school and the education authority.

Loose coupling refers to the weak tie between various elements in a strongly disconnected education system (Weick, 1976) that maximises the professional autonomy of an individual school within the system (Weick, 1982; Ainley, Reed, & Miller, 1986). It describes the professional autonomy to employ discretion in performing educational work in the light of professional judgment. The professional identities and competency of school leaders and teachers is recognised, and support by the education authority is reflected in a relationship of interdependence between the education authority and the schools. Tight coupling refers to the hierarchical structures and quality control that are built to facilitate and enhance the achievement of educational goals. It is operated in a school system through education ordinances and quality assurance mechanisms to direct the behaviour of school leaders and teachers. Loose coupling and tight coupling often appear together and are used in a relative sense. A number of researchers (Willower, 1982; Mickey, McDonald, & Bloom, 1983; Herriott & Firestone, 1984; Firestone, & Wilson, 1985) have indicated that school systems may be better understood as a mixture of loose and tight coupling, although this can refer to different relationships in different situations.

In loose coupling, the education authority may provide resources and formulate system-wide policies to support the professional development of in-service teachers, including inviting experts in the field to provide school-based supporting services. The VITAL project provides such an example. This was a project funded under the school-based policy of the HK government to support the development of learning studies in 120 primary and secondary schools. The government provided the

funding support and the educational officers facilitated the administrative procedures but did not interfere with the actual learning studies. What it did was to show schools that learning studies were supported and endorsed by the Government. The setting up of the Quality Education Fund to support educational initiatives in Hong Kong is another example that embodies the idea of loose coupling. To ensure the sustainability of learning studies in schools, and support teachers in sharing their pedagogical content knowledge and understanding of variation theory in a learning network, the Centre for Learning Study of the HKIEd obtained funding support from the Quality Education Fund to conduct a two-year project entitled the Teaching Analysis and Lesson Observation Network (TALON). In this project, ten groups of teachers and researchers worked together, each group engaged in a Learning Study to design a public lesson. The ten lessons were aimed at finding more effective ways of teaching certain topics which teachers reported were difficult both to teach and to learn. The lessons were taught openly to a learning network of teachers, and then thorough discussions were carried out among the participants using variation theory as an analytical tool. This project helped to improve teachers' abilities in performing learning studies and carrying out lesson observation and analysis using the analytical framework based on variation theory, so that a high-quality lesson observation culture could be nurtured, which in turn would improve teaching and learning in schools. All information about the public lessons, including lesson plans, videos of pre- and post-lesson interviews with students, the open lesson, and the discussion sessions was put on the web for open access. The number of teachers participating in the lesson observation and analysis was around 1300, cumulatively.

Tight coupling is a result of enforcing education ordinances, formulating education policies, and exercising quality assurance control to maintain the quality of education. School inspections, which embody the idea of tight coupling, are conducted by an education authority to evaluate the overall performance of the school and present recommendations for improvement. Since the development of a set of evaluation tools is indispensible to a quality assurance mechanism in the education system (Fitz-Gibbon, 1996), it could be beneficial to the schools' development if the critical conditions for nurturing a Learning Study community are set as the indicators; for example, identifying student learning difficulties, setting appropriate objects of learning and identifying critical features in teaching and learning, formulating school-based policies for professional development, exercising learning-focused leadership, forming learning networks with other schools and disseminating good teaching practices to the school system. School leaders will then be guided by the indicators for conducting self-evaluation and formulating a school plan (Cheng 2011), the critical conditions will be institutionalized and become the organizational routine to support practices, and eventually, the learning community will be built within the system. In fact, this is already happening. It is reported that terms such as 'object of learning', 'critical features' and 'student learning difficulties' are now being used by those carrying out school assessments.

The World Association of Lesson Studies has been formed to facilitate communication between those involved in lesson studies and Learning Study researches. Some learning studies have been shared. For example, in Runesson and Gustafsson's (in press) study, some Swedish teachers used documented Hong Kong research lessons as a resource and adapted the insights gained by the Hong Kong teachers to the specific group of learners and other conditions in the Swedish context. This shows that Learning Study is not culture-specific, and pedagogical content knowledge gained can be shared across different countries. If policy makers, researchers, educators, school leaders are serious about how to create the learning environment for enhancing student learning, they should consider institutionalizing the mechanism of the Learning Study in their school organization and school system.

9. Conclusion

We mentioned at the beginning of the paper that an OECD project identified a number of factors for creating an innovative learning environment which can move students to new levels of development. The challenge of integrating these factors and putting them into practice in real classrooms seems to be tackled successfully by Learning Study. The student as a learner is catered for by attending to the variation in students' understanding of the object of learning (V1), and in agreement with Mayer (2010), the prior knowledge of the learner is used to tackle individual differences in learning. The teacher as a learning professional is enhanced by addressing the variation in the teachers' own ways of understanding and dealing with this object of learning in the past (V2). The resources and facilities for learning are tackled by making use of variation as a guiding principle of pedagogical design (V3), and through (V2) so that teachers can contribute their experience and wisdom, informed by variation theory and the learning outcomes of the cycles to improve the resources and facilities for learning. The content of learning is fully attended to by the careful selection and study of the object of learning (OL) to identify its critical features (CF) through the Learning Study process, and by ensuring that these are embedded in the learning environment through patterns of variation. We have shown, using an example of a Learning Study case, that Learning Study incorporated these principles in its design and implementation. At the school level, we have shown, using a specific example, how a kernel for implementing innovation from visionary models to everyday practice (Resnick et al., 2010, chapter 11) was achieved, and we have explained, using the Kotter model, why the school was successful in institutionalizing Learning Study. The implementation of management strategies in school policy, cultural and leadership domains could be one of the ways to promote a Learning Study community. At the system level, a loose-tight coupling theory for supporting a learning network in the education system is recommended. The education authority could formulate policy strategies that create the conditions and capacity to allow the dissemination and sustainability of pedagogical practices introduced by Learning Study if they really want to improve the quality of education.

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