

Variation Theory and the Improvement of  
Teaching and Learning



GOTHENBURG STUDIES IN EDUCATIONAL SCIENCES 323

# Variation Theory and the Improvement of Teaching and Learning

Mun Ling Lo



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## Foreword

“He cannot, England know, who knows England only”. This apparently contradictory aphorism exemplifies, and captures nicely the basic idea of Variation Theory. You cannot know what something is, without knowing what it is not. If you have only heard English all your life, you cannot know what “English” means. It is simply “language” for you (and not *a* language). Similarly, you cannot understand the base-ten system without having come across number systems with other bases, and you cannot understand what linear equations are without having come across other kinds of equation. In the same way, you cannot understand what “a lively style of writing” is by considering only examples of a lively style; you would need to have encountered more and less lively styles.

Making the meaning of things your own is certainly not the only kind of learning there is; but as we act in accordance with what things mean to us, our acts are only as powerful as our meanings of the world around us. One and the same thing often has a limited number of different meanings for different people. In order to acquire more powerful meanings of something, our students need our assistance. And we need to ask what it takes to develop a new meaning. The taken-for-granted answer to this question is that by encountering different instances that have a certain meaning in common but differ otherwise, we can see what is the same among the different cases, and thus the shared meaning appears to us.

The problem with this account of the origin of meanings is that it is in error. If you do not know what English is and you hear 100 people speaking English, you will have no better idea of the meaning of “a language”. If you do not know what “a lively style of writing” is, and you read 100 articles, all of them written in the same lively style, you will still not know what “a lively style of writing” means. According to Variation Theory, meanings do not originate primarily from sameness, but from difference, with sameness playing a secondary role. Learners are usually offered examples that have the focused meaning in common, e.g. “a lively style of writing”, but which differ as far as unfocused meanings are concerned, here the content of different pieces of writing. Variation Theory suggests that we turn this pattern around and let the focused meaning - the liveliness of the piece of writing - vary, while the unfocused meaning - here, the content of the piece of writing - remains invariant. Once the learners have

discerned the focused meaning, we turn the pattern back to what is usually taken for granted and thereby enable the learners to generalize the meaning (of a lively style of writing) they have gained, across different examples (of content, for instance).

It is the patterns of variation and invariance among examples, instances, cases, illustrations and so on, which is the aspect of teaching that Variation Theory singles out as a key to better learning. Why such a perspective is adopted, how it is applied in hundreds of cases and with what results, is what we can read about in this excellent book.

The author of this book, LO Mun Ling, is one of the most brilliant educationalists I know. She combines in her work the highest level of scientific rigour with unparalleled faithfulness to the practice of education. Once a school-teacher, she became an outstanding scholar, a University Professor, still remaining a school teacher in heart, and one of the very best.

Gothenburg in June 2012

Ference Marton

## Preface

This book has a relatively narrow focus, aiming to explain how Variation Theory can be applied to improve teaching and learning in schools.

In our experience, some teachers teach better than others. This is an intriguing phenomenon that has stimulated great interest among and investigation by teacher educators and educational researchers. It is believed that if we can understand why this is happening, then we might find the key to teaching for better learning. Learning must be directed towards an object (i.e., an object of learning), and so even if the learning environment is luxurious and high tech, the teachers are kind and caring and the students highly motivated, if the object of learning is very complex and difficult, learning is still unlikely to take place without the teachers' help to tease out the critical aspects and make them available for students. I was lucky to have the opportunity to learn about Variation Theory from Professor Ference Marton in 1998. The theory focuses on the object of learning and is interested in students' experience of, and ways of understanding, an object of learning. Under the leadership of Professor Ference Marton, we engaged in a project that used of Variation Theory as an explanatory framework to account for why some teachers are more effective than others in bringing learning about for their students. We found that Variation Theory helped us to explain why certain teaching enactments did and did not help students to learn effectively, and that this was related to the kinds of patterns of variation that were being enacted in the classroom. We felt at the time that if we were able to use Variation Theory to explain the effect of teaching on student learning, then it would have the potential to be developed into a powerful theory that could be applied in planning lessons and teaching to achieve effective learning, and tried to accomplish this in subsequent projects. It is important for teachers to continue learning to better themselves, and the most effective learning is in the classroom context. Developing a community of learners in schools in which teachers work with their peers to investigate their own teaching and how they can improve through action research will result in the most effective teacher learning. Back in 1999, the Japanese Lesson Study was considered an effective model for teacher development (Stigler & Hiebert, 1999), and we felt that this would be the best model for teachers to work together and learn how Variation Theory can be applied to teaching. As a Lesson Study usually focuses on one lesson and requires a long time (from several months to a year) to study in depth how the lesson should be delivered, it suited our purpose of

helping teachers to understand Variation Theory and testing and developing Variation Theory to improve teaching. We developed a special kind of Lesson Study by adapting the procedure of the Japanese Lesson Study, taking inspiration from the idea of teaching study in China and adopting a theoretical framework based on Variation Theory. After 10 years, we have made great advancements in this area.

However, there is always a gap between theory and practice, and after engaging in Learning Study many teachers feel that they still do not fully understand Variation Theory and are handicapped when trying to apply it in practice. The main purpose of this book is thus to help teachers to understand how Variation Theory can be applied in practice. The target readers are teachers and educational researchers who are interested in improving classroom teaching and learning. I hope that education administrators and policy makers who are interested in improving the quality of learning will be inspired too. This book does not discuss Variation Theory purely in theoretical terms, but rather attempts to explain Variation Theory through the use of actual classroom examples, which are carefully chosen to illustrate how different elements of the theory can be applied.

All learning theories aim to explain learning, and all useful learning theories should be able to find application in classrooms to improve learning and to predict and explain the effect of teaching on student learning outcomes. However, theories are not ‘truths’; all have limitations. No single theory can be used to explain all kinds of learning. In fact, because of the complex nature of learning in classrooms, there will never be one theory that suits all purposes. Almost all learning theories have their own special features and purposes. This book does not intend to explain or examine other learning theories, although sometimes they are mentioned to show their commonality and differences with Variation Theory at the practical level.

Hong Kong in June 2012  
LO Mun Ling



## Acknowledgements

This book includes a large number of illustrative examples. These are actual classroom examples that we have developed in our Learning Studies over the past ten years. I wish to acknowledge my debt to each individual teacher, scholar and researcher who has contributed to these studies, and I am truly grateful to these pioneers for their contribution. With this book, I am proud to be able to share pedagogical content knowledge that is generated by teachers themselves. This book was originally written in Chinese and was published by the Anhui Educational Publishing House in November 2011. I am very grateful to the Publisher for granting the right to Gotenburg University Press to publish this book in English. I would also like to thank Mr Cheung Man Wai, principal of a secondary school in Hong Kong, for reading and commenting on the manuscript, and Professor Gao Wei and Ms Chan Man Sze for their editing work on the original Chinese manuscript. I would also like to thank Ms Chan Man Sze, Ms Rita Chan and Ms Shirley Lo for helping with the initial translation of the book, Ms Chan Man Sze for helping with the formatting and editing of the English version, and AH Editing for editing and polishing the language. I would also like to acknowledge that the examples used in this book are drawn from Learning Studies from projects that were funded by various funding sources, including the Quality Education Fund, the Education Bureau of the Hong Kong SAR, as well as many schools' own funding sources. The translation of the book from Chinese to English was financially supported by a grant to Ference MARTON and PANG Ming Fai from the Swedish Research Links scheme of the Swedish Research Council. Above all, I would like to thank Professor Ference MARTON for his comments on the English version, which helped further refine and polish the text. I am extremely grateful to them as this book would not have been possible without their contributions.

LO Mun Ling



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## Chapter 1

# From Variation Theory to Learning Study

What kind of teaching really results in effective learning? Despite keen debate among policy makers, educationalists and education practitioners, no consensus has been reached on this very important question, and opinion remains divided.

### Looking at learning theories at three levels

The above question can be explored on three levels: the philosophical level, the theoretical level and the practical level. At the philosophical level, the questions of interest relate to our worldview, the relationship between people and the world and the relationships among people. The focus is on philosophical questions such as why people learn and where knowledge comes from. At this level, the different ‘isms’ of different schools of thought are full of conflict, and it is difficult to resolve them to arrive at a consensus.

#### Example 1.1

Some schools of thoughts, as represented by Plato (BC 427-347) and Fodor (1975), argue that one cannot learn new knowledge because knowledge comes from within from the powers of mind, and so we have to recall or search for the knowledge that already exists in our mind through learning (Marton & Booth, 1997, p. 8). Individual constructivists hold that we construct our own world and then explain the external world by using our internal world (Cobb, 1994). Social constructivists, in contrast, explain that meaning is generated through the interaction of humans in society, and that we explain our internal world by using the external world (Marton & Booth, 1997, p. 8). Marton and Booth (1997, p.13), as representatives of the thinking of phenomenography and Variation Theory, argue that there is only one world: the world that is constituted as an internal relation between the world and us. As we are all different, we experience the world differently because our experience of the world is always partial.

At the second, theoretical, level, learning theories are produced based on the first level’s philosophical thought. Studies at this level focus on the nature of learning and are interested in questions such as ‘what is learning?’ and ‘how can effective

learning take place?' Most of the answers are given on an idealistic, theoretical level, but begin to point towards practice.

At the third, practical, level, instructional theories are derived from learning theories, and their application to teaching and learning situations tests the practicability of learning theories in real contexts. In my opinion, all learning theories should ultimately be extended to learning and teaching principles if they are to be useful to teachers. For teachers, this is the most important and influential level. However, in the past 20 years, development at this level has been slow.

Example 1.2

Tobias and Duffy (2009) point out that very little progress has been made by constructivists to develop constructivism from a learning theory into an instructional theory. They claim that there is no obvious evidence to show that the learning principles derived from constructivism really lead to effective learning. They suggest that 'constructivism remains more of a philosophical framework than a theory that either allows us to precisely describe instruction or prescribe design strategies' (p. 4).

To link the theoretical and practical levels, we must be able to conceptualise how abstract theoretical principles can be actualised in concrete teaching and learning situations (e.g., when teaching the content of a particular lesson), and to explain how actions taken during teaching and learning at the practical level use learning theories as guiding principles.

Today, the work of cognitive psychologists, neuroscientists, educational researchers and expert practitioners has provided us with an understanding of how people learn that has practical implications for teaching. As Hammond et al. (2001) express it, 'What the teacher does is to dip into a deep basket of intersecting theories, research and personal as well as professional knowledge and decide how they come together in his or her classroom' (p. 18). Teachers usually utilise a variety of classroom practices that are based on all of these ideas about learning, but few are interested in the philosophical derivation of these implications or care about the conflicts and incompatibility at the philosophical level of the theories from which practice is derived. The main concern of most teachers is whether the teaching strategies produced from learning theories are practicable and useful in actual classroom situations. In fact, there are many commonalities between the teaching strategies suggested by the various learning theories.

## CHAPTER 1

### Example 1.3

The dominance of constructivism has been strongly felt in the last ten years, both in teacher education programmes and in the rhetoric of reform (for example, the reform documents of the Hong Kong SAR government used constructivism as a guiding principle). However, Kirschner, Sweller and Clark (2006) criticise the teaching strategies derived from constructivism, all of which are founded on the minimum guided approach, arguing that these strategies, which include discovery learning, problem-based learning, experiential learning and inquiry-based learning, are not effective. Their rationale is based on the information processing model, which is grounded on the generally accepted theory that there is a limited channel for linking the working memory to the long-term memory, which infers that these teaching strategies will overburden learners' working memory load. They give examples as evidence of the failure of teaching strategies based on constructivism, and point out that direct instruction is more effective than constructivist instruction (Kirschner, Sweller & Clark, 2006). Their paper triggered a counterattack by constructivists, resulting in a heated debate between the two sides (e.g., Schmidt et al. 2007; Hmelo-Silver, Duncan & Chinn, 2007; Kuhn, 2007; Tobias & Duffy, 2009). The debate revealed that both sides may have misunderstood the teaching strategies promoted by the other. In fact, there are quite a lot of commonalities between direct instruction and constructivist instruction. For example, Klahr (2009) points out that what many call 'direct instruction' is, in fact, very close to what good constructivist pedagogy recommends (p. 297). According to Rosenshine (2009), direct instruction does not mean teaching by direct transmission, but refers broadly to teacher-directed effective teaching, including revision to find out about students' prior knowledge before the teaching of new knowledge, clear and explicit lesson plans, opportunities for individual student work to practice and apply new knowledge and giving students constructive feedback and continuous revision. Direct instruction thus does not necessarily imply that students are devoid of opportunities for active participation.

An important principle of constructivism is to give a minimum of direction and guidance to the learner. For example, the important constructivist strategy of scaffolding aims to provide guidance only when it is absolutely necessary, and to slowly diminish or eliminate such support when the learner starts to get to grips with the learning. This may lead to the misconception among teachers that in constructivist instruction, teachers are not supposed to tell students anything. As Donovan, Bransford and Pellegrino (1999) point out,

*A common misconception regarding 'constructivist' theories of knowing (that existing knowledge is used to build new knowledge) is that teachers should never tell students anything directly but, instead, should*

*always allow them to construct knowledge for themselves. This perspective confuses a theory of pedagogy (teaching) with a theory of knowing (p. 11).*

In fact, appropriate and timely instruction is necessary, and most constructivists support discovery learning under the direction and support of the teacher, rather than pure discovery by the students working by themselves. As Klahr (2009) points out, ‘Even the most zealous constructivist would acknowledge that there exist combinations of time, place, topic, learner, and context, when it is optimal to simply tell students something, or to show them something, or to give them explicit instruction about something’ (p. 291). Thus, the debate may be fuelled by a problem of communication caused by the two sides using different terms to describe similar processes. In fact, the two sides may be situated on two very close points on a dimension of variation, with complete student-directed learning at one pole and teacher-directed transmission learning at the other pole.

Mayer (2009) contends that the search for ‘schools of learning’ has been an unproductive approach for the science of learning. He suggests that

*Our field would be better served by trying to figure out research-based answers to how learning and instruction work rather than by engaging in high-level philosophical arguments about which “ism” is the best (p. 197).*

If we focus on the insights on teaching and learning generated by different learning theories, rather than arguing about the differences among these theories at the philosophical level, then we will indeed find that many of the teaching approaches, strategies and designs suggested are similar and compatible. For instance, in a large-scale research project called ‘How People Learn’, Donovan et al. (1999) summarised a dizzying array of research from widely disparate disciplines, transcending the coded vocabulary of different communities of scholars to come up with three important learning principles that are commonly agreed upon and supported by research.

1. Students come to the classroom with preconceptions about how the world works. If their initial understanding is not engaged, then they may fail to grasp the new concepts and information that they are taught, or may learn them for the purposes of a test but revert to their preconceptions outside the classroom.
2. To develop competence in an area of inquiry, students must (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in



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the context of a conceptual framework, and (c) organise knowledge in ways that facilitate retrieval and application.

3. A 'metacognitive' approach to instruction can help students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving them.

These three core learning principles give rise to three implications for the enterprise of teaching and teacher preparation.

1. Teachers must draw out and work with the existing understanding that their students bring with them.
2. Teachers must teach subject matter in depth, providing many examples in which the same concept is at work to give a firm foundation of factual knowledge.
3. The teaching of metacognitive skills should be integrated into the curriculum in a variety of subject areas (Donovan et al., 1999, p. 10-17)

These learning principles do not derive from constructivism, information processing or any other particular learning theory alone. The same principles have been generated by many different learning theories and from the work of cognitive psychologists, neuroscientists, educational researchers and expert practitioners, although the rationales for the derivation of the principles may be totally different. The teaching principles and strategies implied by Variation Theory are compatible with the three principles. This is discussed in detail in Chapter 5. However, it must be noted that for the second principle, the compatibility is there, but only under a certain condition of using that principle, and this is further elaborated in Chapter 4, p. 88 – 89 and in Chapter 5, p.112.

From the perspective of teaching, teachers can choose teaching principles and strategies derived from any learning theory and use them in the classroom, as long as the strategies help students to learn better. However, as Hammond et al. (2001) point out:

*A theory is a way of thinking and a model of how things work, how principles are related, and what causes things to work together. A theory is not just an idea. It is an idea that is a coherent explanation of a set of relationships that has been tested with lots of research (p. 15).*

It will be beneficial for teachers' professional growth if they can trace the rationale for the principles and teaching strategies back to the philosophical and theoretical levels. This will help to prevent teachers from applying recommended principles blindly in contexts that are markedly different from the contexts in which the principles were originally derived.

Example 1.4

In my many years as a teacher educator, I have encountered many Hong Kong teachers who have a firm belief that whatever students are learning, they should only be shown the 'correct' version. They believe that showing an 'incorrect' version will cause confusion, and that some students will learn the wrong version instead of the correct version. In open lessons, I have seen more than once teachers being critical of the way that other teachers put students' common mistakes on the blackboard for discussion in class. I believe that this teaching principle is related to the transmission model of teaching from earlier times, when teachers saw their main responsibility as preparing clear and concise notes and explaining them to students in class. They expected students to recite the notes and reproduce them in the examination without missing a single word. Consequently, providing students with the simplest information was preferred. However, if we really want students to understand what they are learning and develop their analytical and problem-solving skills, teaching them to distinguish between right and wrong concepts should be a teaching focus. Teaching must not only stick to one rule. Teachers must understand the rationale behind the teaching principle and the context in which it was derived.

Further, teachers can only make suitable adaptations of these principles to suit their pupils and teaching situations if they understand the rationale behind their derivation. Teachers can also help to test and further develop the theory, and derive new pedagogical principles in practice. This is what this book is about: it gives a brief introduction to a learning theory – Variation Theory – and then explains how it can be applied in practice to classroom teaching and learning. The sections that follow explain why Variation Theory has the potential to help teachers to improve teaching and learning.

## The importance of content in learning

Franz Clemens Brentano (1838–1917) is best known for his reintroduction of the concept of intentionality – a concept derived from scholastic philosophy – to contemporary philosophy in his lectures and in his work *Psychologie vom Empirischen Standpunkte* (*Psychology from an Empirical Standpoint*). He noted that

every psychological act has content and is directed at an object (the *intentional object*) that transcends thought itself. For example, we cannot think without something being thought about. If we are thinking about a cat, then our thoughts are directed towards a cat, and ‘cat’ transcends the thought itself. Similarly, we cannot love without something being loved, and we cannot learn without something being learned. In light of this, we cannot talk about learning without first clarifying ‘what’ we are learning. This ‘what’ of learning is referred to as the ‘object of learning’.

One of the aforementioned learning principles is that ‘teachers must teach subject matter in depth’. This highlights the importance of content. However, few learning theories provide guidance to teachers on what content to choose and how to deal with such content to help students to learn. Content and how to deal with it should not be arbitrarily determined, but should be deliberately designed with the aim of achieving worthwhile educational objectives. However, many learning theories nowadays still focus to a great extent on particular aspects of instructional theories (e.g., being teacher centred or student centred, use of information technology and use of an inquiry approach) and teaching arrangements (e.g., small classes, group work, individualised teaching, collaborative learning). What teachers most need, but often find to be lacking from most schools of learning, are empirical studies that can be generalised to generate a strong theoretical basis that provides appropriate guidance for teachers on how to choose appropriate content, and that supports students to learn.

#### Example 1.5

Social constructivism holds that learning is most effective when the learner is in an authentic environment and knowledge is distributed among the environment, the equipment used and the participants. For instance, if a person wants to learn to be a sailor, the best way is to be an apprentice on a ship. If a person wants to be a tailor, the best way is to learn from a professional tailor. It is not important to be aware of the object of learning or what knowledge learners need to know, as knowledge is distributed in the environment (Lave, 1988; Jönsson, Linell, & Säljö, 1991; Chaiklin & Lave, 1993; Hutchins, 1995). Basically, social constructivists believe that teaching is never effective. Given an appropriate environment, learning will take place naturally, for example, all young children learn to speak their mother tongue by three years old. The influence of such thinking on schooling is that schools and teachers no longer pay attention to the object of learning. Constructivist studies on teaching and learning tend to focus on how students learn rather than on how teachers should teach to help their students learn.

Individual constructivism advocates that teachers should not provide students with guidance except when it is absolutely necessary. In Hong Kong, this has been misunderstood by many teachers to mean that no guidance should be provided and that teachers should not 'teach'. This has led teachers to pay attention only to the activities that they will use to motivate students' interest to learn and the kinds of worksheets they should produce to give instructions to students about the arrangement of activities when preparing their lessons. They no longer study what they should teach and how they should identify students' learning difficulties. Important questions such as the content that will best achieve the target objectives are no longer addressed.

Advocates of 'direct instruction' place more emphasis on content. Rosenshine (2009) points out that with direct instruction, guidance and support can be designed to help students to master even ill-structured tasks such as reading comprehension, writing and mathematical and scientific problem solving. One approach to developing these guides and supports is to study and find out how experts' understand the tasks and what strategies they use to do so, and then to teach these strategies to students (Kintsch, Van Dijk, 1978; Bereiter & Bird, 1985; Larkin & Reif, 1976). However, there are still weaknesses with this type of teaching or instructional procedure, as it makes reference solely to the experts' view of what to be taught and how to go about teaching it. As experts may have very different ways of seeing from novices (Dreyfus & Dreyfus, 1980; Borko & Livingston, 1989; Leinhardt, 1989; Bransford, Brown & Cocking, 2000), there will be a great difference between experts' views and students' views. If teachers are unaware of students' ways of understanding what is to be learnt, it will be hard for them to understand the difficulties faced by students in their learning. Without student input in helping teachers make decisions about what has to be learnt, this way of teaching will neither be able to build on students' prior knowledge nor be truly student-centred.

It seems that for most schools of learning, the three levels (philosophical, theoretical and practical) have not yet been reconciled. A learning theory cannot be applied in practice without considering what actually happens in classrooms. In the classroom, a teacher must teach students the content that the students have to learn, or the object of learning. Pong and Morris (2002) point out that some meta-analyses of the results of studies on student achievement and evidence from studies of curriculum reform suggest that insufficient attention is paid to the impact of the actual practice of teaching on pupil learning, and so such studies are of limited use. They argue that '*one key feature of teaching, how teachers make available the object of learning to their pupils, has been neglected and is a critical influence on pupil learning*' (p. 9). Marton and Tsui (2004) report on a number of empirical studies that compare lessons on the same object of learning taught by different

teachers, and show that the way in which the teachers dealt with the object of learning had a profound effect on the learning outcomes of the students. They point out that content tends to be underplayed in Western educational thinking, resulting in the resurgence of two illusions. The first is the old dream of finding ‘the art of teaching all things to all men’ (p. 228), which has given rise to the promotion of certain teaching methods or arrangements such as cooperative learning, IT-supported forms of learning and project work. They argue that studies clearly show that ‘*there are specific conditions necessary for learning specific objects of learning*’ and that ‘*no general approach to instruction can ever ensure that the specific conditions necessary for the learning of specific objects of learning are brought about*’ (p. 229). Thus, in trying to improve classroom learning, the specific object of learning must always be the point of departure. The second illusion is that people can be equipped with ‘generic capabilities’ that can enable them to solve all problems and deal with all situations. They note that generic capabilities are ‘*ways of dealing with different topics, content, knowledge; they do not refer to what people have or what they are; they refer to ways in which people act. Generic capabilities are domain specific.*’ (p. 229). Generic capabilities are developed through handling something specific, that is, through studying specific content upon which such capabilities can be built. All of these studies point to the importance of taking the object of learning seriously.

Variation Theory takes the object of learning as the point of departure, and highlights some necessary conditions for learning that are related to how the object of learning should be dealt with. It thus has the potential to become a valuable source of principles for pedagogical design that are directly useful for practising teachers.

It is well known that teachers often have difficulty visualising how a theory about learning can be applied in actual practice in the classroom. To help teachers to understand how a theory works and to make real changes in the classroom, it is useful to take the lesson as the point of departure (e.g., Nuthall, 2004; Stigler & Hiebert, 1999). Inspired by Chinese teaching studies (Ma, 1999; Gu, 1991) that conduct in-depth investigations of the object of learning to gain a profound understanding of the subject matter, and the Japanese Lesson Study (Stigler & Hiebert, 1999; Lewis, 2002; Fernandez, 2002; Watanabe, 2002), which involves teachers working collaboratively together to improving the teaching and learning of a lesson, Marton and Lo initiated the idea of ‘Learning Study’, and used it as a platform to help teachers to put Variation Theory into practice. In Hong Kong, Learning Study became the main tool in a pilot project (1999) and subsequently the three-year main project ‘Catering for Individual Differences – Building on

Variation' (CID(v)) (2000-2003). This project was funded by the Hong Kong Curriculum Development Institute and aimed to find ways to cater for individual differences in mainstream primary schools in Hong Kong. Later, other researchers from the University of Hong Kong and the Hong Kong Institute of Education joined the research team. The research team adapted the procedures of Japanese Lesson Study and developed a conceptual framework based on Variation Theory to guide the studies, renaming this kind of Lesson Study 'Learning Study' to reflect the Hong Kong focus and its particular features. It is a 'Learning Study' in three senses. Each study aims to help students to learn a particular object of learning. As teachers have the most control in guiding interactions in the classroom, they can narrow down or open up the opportunities to learn for students. Teacher learning is thus essential for improving student learning. To help teachers to use Variation Theory as a pedagogical tool, researchers' learning is also important. Thus, in addition to trying to improve student learning, the Learning Study also acts as a platform for teacher learning and researcher learning. The CID(v) project was highly successful and the results were documented by Lo, Pong and Chik (2005). Later, more Learning Study projects were carried out by the research team at the Centre for Learning Study and School Partnership (CLASP) of the Hong Kong Institute of Education. The following sections first give a brief overview of Variation Theory, focusing on some of the elements that are important for teaching and learning in the classroom. The way in which Learning Study integrates Variation Theory into its procedure so that the theory can both be applied and tested is then explained, and its impact is examined. Chapter 2 discusses each of the elements of Variation Theory that are of practical importance in teaching and learning in detail and illustrates them with authentic examples taken from actual lessons.

## Variation Theory

Marton and Booth (1997) summarise the research and development of phenomenography, which provided the basis for the development of Variation Theory. Phenomenography is interested in the 'qualitatively' different ways in which people experience the same thing or phenomenon. Observation and experiments are used as research methods to study human experience, and the concepts of 'category of description' and 'outcome space' are used as the analytical framework to explicate the differences (Marton & Booth, 1997, p. 24-128). 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 (1988); Marton & Booth (1997); and Bowden & Marton (1998).

Some of the most important elements of Variation Theory that have a significant influence on teaching and learning are introduced in this section.

### Structure of awareness

According to Marton and Booth (1997):

*Our awareness has a structure to it. At any instant certain things are to the fore – they are figural or thematized – whereas other things have receded to the background – they are tacit or unthematized . . . There are different degrees of how figural, thematized or explicit things or aspects are in our awareness' (p. 98).*

If our awareness had no structure, then everything would be in focus to the same degree at the same time, which would in fact mean that nothing was in focus or brought to the forefront of our awareness. There is a limit to our capacity to focus (Miller, 1956), and we cannot focus on all of the features of everything simultaneously. We can only focus on a limited number of aspects of a phenomenon or object at a time. This results in some aspects coming to the forefront of our awareness and moving into focus while other aspects that are not in focus recede to the background. The understanding and meaning that we attach to a phenomenon depends on which aspects of the phenomenon come to our focal awareness. Gurwitsch (1964) makes a distinction between three elements of awareness: 1) the theme – the object of focal awareness; 2) the thematic field – the aspects of the experienced world that are related to the object and in which it is embedded; and 3) the margin – all that which is coexistent with the theme without being related to it. The relationship among the three elements is fixed at an instant. However, it can also be changed at any time. Using the terms of Variation Theory, the theme would be the 'object of learning', the thematic field would be the 'external horizon' of the object of learning and would be related to the object of learning, and the margin would also be the external horizon of the object of learning, but would only be marginally related or not at all related to it.

#### Example 1.6

A man is reading a book in a library. When he is reading a sentence, the sentence and its meaning are in focus and come to the forefront of the man's awareness. The sentence is



the object of learning. To fully understand the meaning of the sentence, he may need to use his prior knowledge of vocabulary and grammar, and to consider what learning this sentence means to him. He may also need to draw meaning from what he read of the text before this sentence to help him make meaning. By doing this, he links with the external horizon of the object of learning. However, at that moment, he is still very marginally aware that other things exist, such as the environment in which he is situated – the library – and that he will be having dinner with his friends this evening. However, these things are in the margins and have receded to the background. They will come to the fore again at an appropriate moment, for example when he suddenly finds that people in the library are leaving so looks at the watch and finds that it is already six o'clock. At that moment the fact that he is having dinner with his friends will be in focus and come to the fore, and the content of the book that he is reading, which was formerly to the fore, will recede into the background. He packs his belongings and leaves.

### Breaking the natural attitude

As soon as a person is born, he or she gains different kinds of experience of the world. All students will already have experienced most of what is being taught in schools, and so will have developed a certain way of seeing an object of learning based on their prior experience. In the past 30 years, many educational researchers have been interested in how students understand science concepts and theories. They have found that before entering the classroom, students have already constructed their own conception of and beliefs about the world (particularly in relation to natural phenomenon). Usually, these kinds of conception and beliefs contradict the science concepts that teachers intend to teach, thereby raising a barrier to learning for students (Gardner, 1991). Marton and Booth (1997) suggest that we habitually live in what the phenomenologists call the 'natural attitude':

*Reality has, as a rule, a taken-for-granted character. We tacitly believe that the world is what we see, the same world that always has and always will be seen, and the same world that others see. Reality and experience of the world are taken to be one (p. 148).*

Most teachers tend to assume that if they explain the content to their students clearly, then the students will see the content in exactly the same way as the teachers. Unfortunately, this is rarely the case. This has led many teachers to complain, 'My teaching is so clear, why didn't the students learn? I really don't understand why they don't understand!' The first step to improve teaching is to break this natural attitude and recognise that students will have a different



understanding of the same content, and that this is a natural phenomenon. Teachers should try to find out students' views because these are the cause of different learning outcomes. If teachers wish to help students to see the object of learning in the same way as they do, they must first try to uncover students' own ways of seeing the object and the differences between their views and those of the students. They can then consider how to design their teaching to change the students' views so that they become consistent with theirs.

### ‘Ways of seeing’ and ‘relevance structure’

A common term used in Variation Theory is ‘ways of seeing’, which has a special meaning. In Variation Theory, a person is said to have learnt with respect to a phenomenon when that person is ‘*capable of being simultaneously and focally aware of other aspects or more aspects of a phenomenon than was previously the case*’ (Marton & Booth, 1997, p. 142), Marton, Dahlgren, Svensson and Saljo (1977) refer to this ‘*as a change in the eyes through which we see the world*’ (p. 23). As powerful ways of acting originate from powerful ways of seeing (Marton & Tsui, 2004, p. 7), teachers must help students to develop powerful ways of seeing if they want to improve their students’ capability to solve problems and deal with new issues that they will encounter in the future.

When people find themselves in a particular situation, they may, influenced by their past experience, focus on certain features of the situation that they feel are more relevant to them, and they may see the situation in a particular way. The situation has a certain ‘relevance structure’ for them, which means what the situation calls for and what it demands from their experience (Marton & Booth, 1997, p. 143).

#### Example 1.7

Marton, Beaty and Dall’Alba (1993) conducted a longitudinal study of 29 university students for five years in an attempt to find out their views of learning and their progression as learners. They identified six distinct conceptions of learning and further divided these into two groups: the first group regards learning as a task (the learning act and its consequences), and the second group focuses on the object of learning (finding meaning through learning tasks). In each group there are three distinct conceptions, giving six categories of description in total.

## VARIATION THEORY AND THE IMPROVEMENT OF TEACHING AND LEARNING

Group 1:

- A. Learning as increasing one's knowledge.
- B. Learning as memorising and reproducing.
- C. Learning as applying.

Group 2:

- D. Learning as understanding.
- E. Learning as seeing something in a different way.
- C. Learning as changing a person.

As the students in the study had different conceptions of the meaning of learning, their ways of dealing with learning tasks were also different. The first group saw learning as merely a task: once the task has been accomplished, it could be forgotten. They would study and revise hard for an examination, but after the examination, all would be forgotten. These students only achieved superficial learning. In contrast, the view of the second group was that learning was far beyond being merely a task. What they saw was the new horizon that opened up to them from the learning task. Their learning was much deeper. This shows that the ways in which people respond and act depend on how they see the object of learning in relation to themselves.

### Example 1.8

Hounsell (1984) conducted a study to analyse how fourteen university students majoring in History understood the requirement of essay-writing. He regarded essay writing as occupying a central position in higher education because it is both a tool of coursework assessment and an avenue of learning (p. 103). Through studying how the History students dealt with their essays, their views on three important elements of learning History – 'data', 'organisation' and 'interpretation' were inferred. Hounsell found that all of the analysis was directed at three qualitatively distinct conceptions of essay writing, which can be summarised as 'argument', 'viewpoint' and 'arrangement'.

Students who held the first conception (that is, those who viewed the essay as an argument) saw essay writing as an ordered presentation of an argument well supported by evidence. Interpretation was superordinate in this conception, with organisation and data supporting it. This is also the conception that History teachers would like their students to have.

Students who held the second conception viewed the essay as a viewpoint, or as the ordered presentation of a distinctive point of view on a problem or issue, supported by

## CHAPTER 1

attention to organisation. Interpretation was still superordinate to organisation, but there was a relative lack of reference to data as evidence.

Students who held the third conception viewed the essay as an arrangement, or as an ordered presentation embracing facts and ideas, and were only concerned about including as much data as possible without attention to the quality of usage in making an argument or developing a standpoint. Data and organisation were viewed as parallel rather than subordinate to each other. Moreover, the role of interpretation was ignored.

The study also compared the marks that the 14 students obtained for their coursework in History, and found the following.

- Of the 5 students who held the third conception (arrangement), 4 obtained 60 percent or below.
- Of the 4 students who held the second conception (viewpoint), all obtained marks of between 60 and 64 percent.
- Only 2 students gained higher than 65 percent, and both held the first conception (argument).

Hounsell's study revealed that the students had different ways of seeing the structure of their learning tasks. This was reflected in whether they saw essay writing as argument, viewpoint or arrangement, and these ways of seeing were also closely related to how they saw the structure of the three important elements of learning History, namely, data, organisation and interpretation. The students' essays reflected their conception of essay writing. At the same time, their learning of History also reflected how they discerned the structural relationship between data, organisation and interpretation. This, in turn, determined their approach to writing essays in their History coursework. This approach affected not only the marks that they achieved for this particular essay, but also their overall academic performance in the History course.

From the foregoing two examples, it is clear that if we wish to help students to develop powerful ways of acting, we must first help them to develop powerful ways of seeing. As the way that a student responds to a learning situation depends on how he or she sees the situation, or the *relevance structure* of the learning situation, teachers should pay attention to building a relevance structure between the students and the object of learning.

As a result of learning, a student may experience the same situation in a more advanced or more complex way, and the relevance structure of the situation as seen by the student may also change accordingly.

## The external horizon of the object of learning

Knowing an object is not confined to what we can see or can touch of the object. For example, if we are in a forest and we see a pair of moving antlers, we will not think that it is a pair of antlers miraculously flying through the air on its own. As we have prior knowledge of deer, our experience tells us that although we can only see the antlers, they are attached to a deer running through the trees. Similarly, when we hear a car horn behind us, without looking back we know that there is a car approaching us from behind. In phenomenological terms, this is known as ‘appresentation’. ‘Appresentation’ refers to the fact that although phenomena are, as a rule, only partially exposed to us, we do not experience the parts as themselves, but experience the whole of which the parts are parts. In other words, we also experience the external horizon in which the parts are situated (Marton & Booth, 1997, p. 100). An object of learning acquires meaning through its external horizon.

### Example 1.9

Dahlgren and Olsson (1985) interviewed a group of Swedish pre-school children (around six years old) about why they had to learn to read and write. They found that some in the group failed to understand why they had to learn these skills. Two years later, when the group of children had already been to school for a year, the research team conducted a follow-up interview with the children. They found that those who said that they did not understand why they had to learn to read and write two years before had fallen behind in their learning progress. When children cannot link the learning of reading and writing (parts) with their world (the whole) and discern the relationship between them, learning becomes meaningless and cannot take place effectively.

Of course, the parts that we experience and the whole object are often incomplete or unclear. Learning is likened to finding the pieces to complete a jigsaw puzzle. As Marton and Booth (1997) describe, “*the whole needs to be made more distinct, and the parts need to be found and then fitted into place, like a jigsaw puzzle that sits on the table half-finished inviting the passerby to discover more of the picture*” (p. 180).

As we continue to explore the world, we learn and gain knowledge about it, and this is also a part of our constituting the world. When we learn about something specific, we learn this in the context of the world around us, and this learning experience is also affected by the people around us. We develop a shared language and a shared culture. Through learning, the world that we know becomes closer to the world that is known by other people. The experienced world, which is constituted by people, also influences our understanding of it.

The result of learning is necessarily changing our experience of something in this world. The reason we change our ways of seeing something in the world is brought about through our relationship with the world, and not constructed by ourselves, rather it is jointly constituted between us and the world (Marton & Booth, 1997, p. 138-139). *'Learning is mostly a matter of reconstituting the already constituted world'* (Marton & Booth, 1997, p. 139).

### The object of learning

The object of learning is a special term in Variation Theory. It is not the same as 'learning objectives'. Learning objectives points to the end of the process of learning, the learning outcomes, and are pre-determined. On the contrary, the object of learning points to the beginning rather than the end of the process of learning. It seems to have a life of its own because it is dynamic and can change during the course of the process of learning. The object of learning is not the same as the notes, texts or teaching materials that teachers use while teaching. I will just give a brief introduction to the object of learning here, but will elaborate further in chapter 2.

#### *The two aspects of the object of learning*

Current reforms seem to treat the learning of knowledge and the cultivation of higher order thinking capability as mutually exclusive to each other, so that the approach is either back to basics with a focus on the mastery of subject knowledge or reform to cultivate higher-order thinking capabilities to prepare students to face the world of the future. However, novice and expert research points out that the capability to engage in an inquiry process to solve problems can only be built on a deep understanding of the subject knowledge. The learning of knowledge and the cultivation of higher-order thinking capability thus cannot be taught in isolation, and in fact they are closely related to each other (Bransford, Brown & Cocking, 2000, p. 237-238). Variation Theory resolves this conflict by pointing out that an object of learning has two aspects: the specific aspect, which refers to the subject matter, knowledge or skill that we wish students to learn (short-term goal), and the general aspect, which refers to the capabilities that can be developed through the learning of the specific aspect (long-term goal).

When selecting an object of learning, teachers should not consider a teaching topic or concept, or even its position relative to the structure of the discipline (such as Mathematics), in isolation. Teachers must also consider the relationship between the learners and the object of learning to find out the reasons for

learning that concept. The value of learning an object lies in whether the learning experience can help students to gain a better understanding of the world in which they live. For instance, other than regarding the learning of ‘percentages’ in primary schools as a matter of course, we should further ask ourselves how can the learning of percentages help learners to understand their living environment and actual life. An application of percentages in daily life is being able to understand discounts and thus becoming a smart consumer. It is important to find out the prior knowledge required of students before they learn percentages and what possible knowledge can be developed from learning percentages. Teachers should not simply cover the curriculum according to the teaching syllabus and curriculum guide without asking whether a topic is worth teaching, how it relates to the goals of education, the kinds of capabilities we wish students to develop, the kinds of difficulties students will encounter when learning the topic and the kinds of prior knowledge students should have before they can learn the new concepts or master the new skills. We should also examine how the teaching of the topic relates to topics that students will learn in the future.

*The internal horizon of the object of learning*

The internal horizon of the object of learning refers to the critical features or aspects and parts, and their relationships to each other and to the whole.

*The part-whole relationship*

There must be a whole to which the parts belong before the parts can make sense to us. We cannot learn mere details without knowing what they are details of. When the whole does not exist, learning will not be successful.

Example 1.10

A topic that is frequently discussed is the learning orientation of Chinese and other Asian students. People always think that Asian students focus very much on reciting, and that reciting is related to surface learning. It is believed that students using this method regurgitate details without understanding, which will not lead to satisfactory learning outcomes. However, it is also noticed that many Asian students’ academic performance compares favourably with, or even surpasses, that of their European and American counterparts. This paradox has puzzled many educational researchers, many of whom have studied and explored the topic extensively (e.g., Biggs, 1979; Biggs, 1990; Kember & Gow, 1991; Kember, 1996; Watkins & Biggs, 1996). Marton, Dall’Allba and Tse (1992) stress that we must distinguish two qualitatively different ways of seeing memorisation: 1) memorisation with the intention of understanding and 2) mechanical memorisation. Asian students who hold the first view will develop a deep understanding

of the knowledge through reciting. According to Variation Theory, when students try to understand the deep implication of a passage through reciting, the passage remains constant for them. When students read it for the first time, they may not be able to understand the whole and parts of the passage well. However, each time the students read the passage again, different parts will come into focus. The focused parts will become clearer and influence the students' understanding of the whole passage. In this way, different parts of the passage will become clearer through repeated reading, and the students' understanding of the whole passage will become clearer and deeper. This kind of repetition is different from mechanical memorisation characterised by rote learning.

### *Critical features of the object of learning*

Everything has a multitude of features. Take a person as an example. The understanding of that person by his friends, family, colleagues and boss will all be different. This is because these people know him in different circumstances and focus on his different characteristics and features, which give rise to a different understanding of him. Without the appropriate experience, his friends will not have the same understanding of him as his family does, and his family will not see him in the same way as his boss. The different ways of seeing the person by different people are not wrong. Rather, they are incomplete ways of seeing him. If we want others to see an object in exactly the same way as we do, then they must also be able to focus on the same features that we do. To see an object in a particular way, we must focus on certain features that are critical to a certain way of seeing, known as 'critical features'.

#### Example 1.11

The lotus flower has many features. Our ways of seeing a lotus are directly related to which features of the lotus we focus on. For instance, if we pay attention to the structure of the ovary, the number of petals and how the stigma and stamen are arranged, then we are seeing the lotus from the perspective of a botanist and may view it as a member of the Nelumbonaceae family. If we see lotus leaves and seeds as ingredients for making soup that can improve our health, then we are seeing it from the perspective of diet therapy. A famous Chinese scholar Zhou Dunyi in the Song dynasty wrote a piece called 'In praise of the lotus'. He focused on the fact that the lotus emerges pure and beautiful from a mud pond but has not been contaminated, and can only be admired from a distance. He likened it to an idealistic and righteous gentleman. He was seeing it from a metaphysical perspective. These examples show that if we focus on different features of the lotus, we may see and understand it differently although it is the same lotus.

Given that the way in which an object or phenomenon is understood is determined by the critical features in focus, teachers need to know the critical features for the object of learning to be understood in the intended way. In addition to having a deep understanding of the topic, teachers must also know the position of the topic in relation to other subject matter and how these subjects are related within their discipline, the language used to explain the concepts in the discipline and the nature of the discipline. Teachers must also discover the critical features that are most likely to lead to student learning difficulties. The difficulties associated with different critical features are not the same. Those that are not easily discerned by teachers usually also present the greatest barrier to student learning. However, it will be difficult for teachers to discern the critical features that pose challenges to students if they themselves do not have problems in discerning those features. In this case, teachers will unknowingly ignore the features, which will result in a knowledge gap in the lesson that they may not notice. Usually, students who can discern difficult critical features on their own are assumed by teachers to have a better understanding of the teaching topic and are regarded as students of higher ability. Students who cannot discern the features by themselves will remain confused and will be regarded as students of low ability. Such students may not progress in their learning because they have missed some important messages, not because they are less able.

The critical features bear a relationship to each other and to the whole. To fully understand an object of learning, one must discern all of the critical features and their relationships simultaneously. A more in-depth discussion of critical features and their implications for teaching is presented in Chapter 3.

#### *The dynamic nature of the object of learning*

Although teachers will have an intended object of learning before teaching, they need to adjust the speed and depth of their teaching according to students' responses as the lesson proceeds. Consequently, the object of learning that teachers enact may be different from the one that they intended to teach. Also, whether students can learn depends on what they actually experience in the lesson and also their prior knowledge, thus, the object of learning experienced by students may not be the same as that enacted by teachers. Three kinds of object of learning can be distinguished: the intended object of learning, the enacted object of learning and the lived object of learning (Marton, Runesson & Tsui, 2004). The enacted object of learning is the outcome of teachers' classroom



practice and provides students with the space to learn something, making the learning of something 'possible'. However, what students actually learned depends on what they experienced in the lesson, or the lived object of learning. Students may have qualitatively different ways of experiencing the same situation, so this generates different experiences of the same object of learning for each student. It cannot be assumed that students will always understand an object in the same way as the teacher intended or was made possible in the lesson.

### **Learning is a function of discernment and discernment is a function of variation**

According to Marton and Booth (1997), learning is a function of *discernment*, which presupposes an experienced *variation*. The learning of an object is not possible if we cannot first discern the object from its context. To discern the object from its context and distinguish it from other objects, we must experience variation of the object (Bowden & Marton, 1998). In fact, we always pay attention to objects that are varying or different from others. We see many objects each day, and it is impossible for us to be equally aware of all objects at the same time. Sometimes, we complain that others are gazing at something without actually seeing it, but the fact is that we all tend to notice things that are different. For example, when a crane is standing among chickens, the crane will be noticed because it is taller. A single red flower in the midst of thick green foliage will catch our eye more easily. Another example is moving objects against a background of non-moving objects. When a number of people are watching the stars at night, it will be almost impossible to tell which stars they are focusing on and it is likely that they are all looking at different stars. However, when a shooting star shoots across the dark sky, everyone's attention will be attracted by it and it is very likely that they will all look at that star. This is a rule that we apply in daily life. For instance, if we hope to attract another's attention in a crowd, we wave our hands, jump up and down or even perform an unusual action. We also find this rule in nature. The colours of most flowers are brighter to make them stand out from green leaves so as to attract insects or birds. Chameleons change their colour to match their surroundings to avoid being easily seen. Keeping still against a moving background can generate the same effect. Deliberate attempts to systematically vary certain aspects and keep certain aspects constant may help people to discern new aspects of an object and construct new meanings. This hypothesis is supported by various empirical studies (Gu, 1991; Marton & Morris, 2002; Marton & Tsui, 2004).

Marton (2009) asserts that awareness of a single feature cannot exist without the awareness of differences (variation) between features: there can be no discernment without experienced difference, and there can be no experienced difference without a *simultaneous* experience of at least two things that differ. To help children to discern the colour 'red', we need to expose them to other colours that are not red. If hypothetically our world had only one colour – red – then the concept of colour would not exist and red would not be discerned: it would be taken for granted. Fortunately, in our world, we have colours other than red. We can then teach children the concept 'red' by pointing to a red ball and saying 'red' while pointing to a green ball and saying 'green'. By contrasting two colours, a dimension of variation (colour) is opened up on which red and green are two values. In this way, we can create a pattern of variation: we keep the ball unchanged while varying the colour. We can further expose children to balls of blue or yellow. However, this would not be not enough, because the children would not have separated 'red' (or other colours) from 'ball'. So, next we would have to show them other objects that are red, such as a red chair, a red table or a red piece of cloth. In this way, the objects ball, chair, table and cloth would be separated from red, and 'redness' could be generalised. If we simply point to an apple and say red, point to a leaf and say green and point to a mango and say yellow, it will be difficult for children to learn well because we would not be consciously using appropriate patterns of variation. We would not be paying attention to what should be varied and kept constant to help children to separate and discern the concept of colour from other concepts and aspects that are also present. When children can discern 'redness' (the critical feature), they must also have discerned 'colour' (the relevant critical aspect). It is impossible for someone to discern a critical feature without knowing which critical aspects that feature belongs to. Critical features and critical aspects are inseparable.

Readers may wonder why when teaching children most people do not intentionally use variation and yet children still learn. By the time children have reached about three or four years old, they can already grasp many complicated concepts. It would seem that learning takes place automatically. For example, a three year old has usually already mastered his or her mother tongue quite well. A wide range of studies argue that the most effective learning takes place when a child is immersed in a suitable environment in which the knower and knowledge are distributed (e.g., Lave, 1988). Of course this is true, but it is because the child encounters different kinds of patterns of variation in daily life. Surrounding adults will also give him or her timely feedback. Unfortunately, the situation

changes when the child begins schooling. What is learnt at school is often remote from the child's everyday experience, and very likely, the only knower in the classroom is the teacher. In this environment, teachers must make the object of learning available to students by intentionally creating patterns of variation that allow students to discern the critical features of the object of learning. Otherwise, learning cannot take place. The application of patterns of variation in the classroom is discussed more thoroughly in Chapter 4.

## Putting Variation Theory into practice – the development of Learning Study in Hong Kong

Learning Study is a model for creating opportunities for the school-based professional development of teachers. The use of Variation Theory builds a shared language of professional discourse, and the employment of a particular procedure and arrangement for collaborative work between teachers and researchers creates opportunities for professional socialisation and the creation of shared norms and standards of work. The focus on the teaching of an object of learning in a lesson provides a context for professional learning grounded in practice. It also centres teachers' learning on improved student performance related to particular content, which, as Cohen and Ball (1999) argue, is necessary for sustainable results.

The following concepts are pertinent to the conceptual framework of Learning Study.

1. Focusing on the 'object of learning'.
2. Adopting the view that knowing is a way of seeing. Thus, learning an object of learning means changing one's way of seeing or understanding the object.
3. Building on three types of Variation:

V1: Variation in students' ways of understanding the object of learning. Teachers and researchers work as a team to explore and identify the range of students' existing understanding of the object of learning so that any differences are properly recognised, addressed and utilised in teaching. We also encourage teachers to find out the extent to which the research lesson has helped their students to acquire new understanding or meanings.

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V2: Variation in the teachers' understanding and ways of dealing with the object of learning. Experienced teachers often possess pedagogical content knowledge and knowledge about their students. However, such knowledge often remains tacit, in the background and unshared (Elbaz, 1983; Shulman, 1986; Clandinin & Connelly, 1995). The Learning Study process ensures that ample opportunities are provided for teachers and researchers to discuss different ideas about teaching a particular student group or a particular topic in the preparation meetings. We also encourage team members to observe the research lessons taught by other members of the team and to engage in professional dialogue in post-lesson conferences.

V3: Using variation as a guiding principle of pedagogical design. With the knowledge gained from the first and second forms of variation, the team attempts to identify the critical features of the object of learning. It then decides on *what aspects to focus on*, *what aspects to vary simultaneously* and *what aspects to keep invariant or constant*, and to consciously design patterns of variation that can bring about the desired learning outcomes.

A Learning Study group usually comprises teachers teaching the same subject at the same level from one participating school and two or more members from the research team. Sometimes, it is also possible to form a team with teachers across schools, for example, in subjects like Music or Visual Art, where there may only be one such teacher in a school. Each member of the group contributes his or her own expertise, and all members share equal status. Each week, the group meets for about an hour to work on a research lesson. The whole cycle takes an average of about 10 to 12 meetings or weeks. A typical Learning Study goes through a number of steps. The steps do not always occur in the same sequence: some steps may occur simultaneously and some may be revisited during the iterative cycles. During the past 10 years, the methodology has been fine-tuned as the research team has learned from experience. Diagram 1.1 summarises the main steps of a Learning Study.

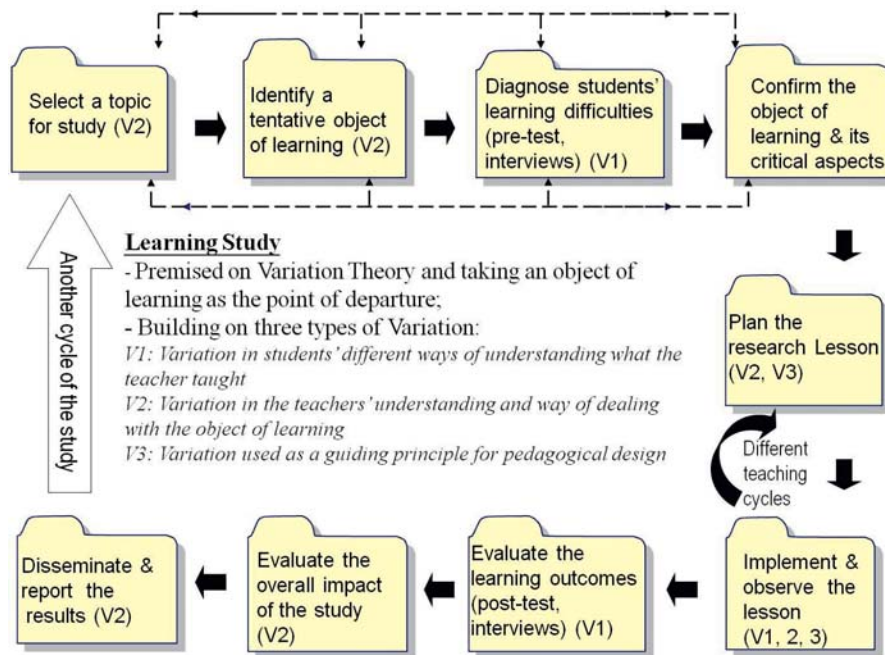


Diagram 1.1 Procedure for conducting a Learning Study

In the Catering for Individual Difference – Building on Variation (CID(v)) Project, which began in 1999, a research team led by Marton, Lo and Pong worked with two primary schools and completed 29 Learning Studies over three years. As the methodology of Learning Study matured, the team wished to find out whether similar impacts on student learning and teachers' professional development could be obtained if less intensive support were available to the school. Led by Lo and supported by a research team at the Centre for Learning Study and School Partnership (CLASP) of the Hong Kong Institute of Education (HKIEd), Learning Study was introduced to over 40 primary schools and 50 secondary schools through two Quality Education Fund supported projects (2001-2005): the Progressive and Innovative Primary Schools Project (PIPS) and the Secondary Teaching, Evaluation, and Mentoring (STEM) Project. In these projects, each project school was provided support for one Learning Study only. These Learning Studies covered the areas of Chinese Language, English Language, Mathematics, General Studies and cultural subjects such as Art, Physical Education, Music and Design and Technology. Over 100 Learning Studies were completed. In addition to being used as a process to sensitise teachers to students' different ways of understanding, the Studies helped to identify the critical aspects for effective learning of specific objects of learning.

Learning Study can also be used as a means to help schools to develop learning communities that focus on teaching and learning so that beginning teachers, experienced teachers and even expert teachers can mutually engage in professional learning. Encouraged by the success of these projects, the Education Bureau of Hong Kong provided funding for the research team at CLASP of the HKIEd to carry out a three-year project, the Variation for the Improvement of Teaching and Learning (VITAL) Project, in which 120 schools were supported to carry out a Learning Study each. The HKIEd also offers courses to teachers on the theory and practice of Learning Study, and Learning Study has been incorporated into the Institute's B.Ed. programmes. These courses, along with actual experiences of Learning Study projects, are intended to provide teachers with the knowledge and experience to continue to carry out their own Learning Studies without the support of researchers.

## Impact of Learning Studies in Hong Kong

This section examines the impact of Learning Studies on students' learning and teachers' professional development.

### Student learning outcomes

This section draws on data from the three-year longitudinal CID(v) project (2000-2003) to illustrate how Learning Studies contribute to improving student learning. By 2003, a total of 29 Learning Studies had been carried out in Mathematics, Chinese Language, General Studies, and English Language in the two project schools. Of these, 27 had a complete dataset of pre-tests and post-tests. In 24 out of the 27 Learning Studies, the research lessons had a positive effect on the performance of the whole group. In particular, in 25 out of 27 studies, the low-score group showed greater progress (at a 0.05 significance level) than the high-score group in terms of actual gain scores between the post-test and the pre-test. This shows that the differences in the understanding of specific objects of learning between the low-score and high-score groups had become smaller.

This was not particularly surprising to us, as we started our Learning Studies by identifying what caused students difficulties in learning a particular object of learning and its critical aspects. In particular, we were interested in determining the difficulties faced by students in the low-score group, and had tried our best to find ways to help them overcome these difficulties. It is therefore to be expected that this group of students should have had benefited most from the lessons.

However, we were pleasantly surprised when these findings were triangulated with the students' performance in the Hong Kong Attainment Test (HKAT), a Hong Kong wide test administered annually by the Government. In each school, the subject scores for each group of students over three consecutive years were traced. In both schools, the average scores of the groups had improved from the baseline (the year before Learning Study was carried out). What was more, in both schools the scores of the low-score groups increased steadily over the three years of the project, and the increases were statistically significant (Lo, Pong & Chik, 2005). The VITAL Project evaluation also revealed a positive impact on student learning. The key results are as follows.

- In some cases, classes with initially lower average scores in the pre-test (which the teachers also perceived to be classes of lower ability) caught up with or even surpassed the classes with initially higher average scores, which the teachers perceived to be classes of higher ability.
- In over half of the cases examined (63 out of 120), during the last cycle of research lessons the class showed the most improvement in the post-test, regardless of whether the class teacher was very experienced or less experienced.
- Of the 56 learning studies for which it was possible to carry out a statistical analysis comparing students' pre- and post-test data (the pre- and post-tests administered in the course of the learning studies were intended to be used for diagnostic purposes only and not for statistical analysis), the gap between the higher performers and the lower performers narrowed in 49 cases (Lo et al., 2008, p. 29-34).

### Teachers' professional development

In the CID(v) Project, it is difficult to attribute the improvement in the HKAT as entirely and directly related to the Learning Study lessons, as the students' participation was restricted to one lesson per term. It seems much more likely that there were other factors at play. One possibility is that the teachers were empowered through their participation in the Learning Studies, which turned them into more effective teachers. The teachers in the two project schools were indeed found to demonstrate different levels of professional development (Lo, Pong & Chik, 2005).

In the PIPS project, an independent external evaluator visited and interviewed the teachers and students in a sample of five project schools and found that students who had taken part in the Learning Studies were still able to recall and explain clearly what they had done and learned in the research lessons that had taken place several months, or even a year, before. In some schools, the students reported that their teachers had changed after the research lessons, and had become more serious about teaching and had changed their teaching strategies (Elliott, 2004).

A questionnaire was administered to all of the teachers and principals who had taken part in the VITAL Project. The results show that the teachers were very positive about the impact of the Project on their teaching.



CHAPTER 1

*Table 1.1* Survey on the Impact of the VITAL Project – Teachers  
(as of 17 April 2008)

Questionnaire – close-ended section (Scale: 5-Strongly Agree; 1-Strongly Disagree)	Either Strongly Agree or Agree		
	Cohort A (Return rate=31%; 40 respondents from 12 schools)	Cohort B (Return rate=88%; 148 respondents from 36 schools)	Cohort C (Return rate=80%; 146 respondents from 32 schools)
The teachers reflected that:			
My teaching has improved since taking part in the Learning Study.	80%	89%	94%
I have developed a deeper understanding of the subject matter.	85%	95%	95%
I am more focused on the object of learning and its critical aspects in planning a lesson.	95%	98%	100%
I have become more sensitive to students' learning difficulties.	83%	89%	93%
I will apply the Variation Theory in my lesson planning.	65%	87%	90%
I will make more use of formative assessment results as inputs to my teaching.	73%	88%	90%
Learning Studies can improve the effectiveness of collaborative lesson planning.	60%	84%	92%
I am willing to take part in collaboration, e.g., lesson planning, lesson observations.	80%	86%	90%
Learning Studies contribute to teachers' professional development.	80%	93%	97%
The concepts and procedures of Learning Study are sustainable in my school.	60%	76%	80%
I am interested in conducting further Learning Studies.	60%	68%	73%

The principals were even more positive.

VARIATION THEORY AND THE IMPROVEMENT OF TEACHING AND LEARNING

Table 1.2 Survey on the Impact of Learning Study – Principals  
(as of 17 April 2008)

Questionnaire – close-ended section (Scale: 5-Strongly Agree; 1-Strongly Disagree)	Either Strongly Agree or Agree		
	Cohort A (Return rate=26%; 10 Principals)	Cohort B (Return rate=63%; 26 Principals)	Cohort C (Return rate=60%; 24 Principals)
The Principals reflected that:			
After taking part in Learning Study, the overall teaching capability of the teachers has been enhanced.	90%	92%	96%
Learning Study brought a better atmosphere for lesson observation to my school.	90%	96%	96%
Learning Study improved the effectiveness of collaborative lesson planning in my school.	100%	92%	96%
Learning Study helped to enhance the teachers' professionalism.	90%	96%	100%
The concept and mode of practice of Learning Study will be continued in our school.	80%	81%	88%
My school is interested in continuing to participate in Learning Studies.	60%	73%	88%
I plan to use Learning Studies to promote teacher professional development and to improve teaching and learning in my school.	70%	80%	88%

The data triangulated well with our own observation during the learning studies. From the result of the questionnaire and our own encounters with the teachers and principals of these schools, we know that some schools have continued to develop Learning Studies on their own after the project ended.

The teachers also wrote many positive remarks in the open-ended response section of the questionnaire. The following views were typical.

*I believe that both my students and I benefited a lot from this Learning Study . . . Seeing my colleagues and students benefiting in many aspects, I feel that what I have done is worthwhile.*

*Learning Study gives me hope. I can overcome problems that I have not been able to solve for many years.*

Of the over 100 Learning Studies carried out, only two were unsuccessful and could not be completed. This was mainly due to several unfavourable factors coming together, including a lack of support and understanding among school leaders joining the project, unwilling teachers being assigned to participate, no consideration being given to reducing teachers' workload, and the Learning Study being led by inexperienced researchers or academics. Apart from these two cases, the less positive comments and concerns of the teachers were mainly related to resource issues, such as the need for extra time and expert support. An external evaluation of the VITAL Project came to the conclusion that Learning Study has the power when injected into the education system to effect sustainable improvement in the capabilities of teachers to bring about worthwhile curriculum and pedagogical change (Elliott & Yu, 2008).

## Conclusion

This chapter briefly introduces some important elements of Variation Theory and gives a quick description of the Learning Study as a platform for testing and applying Variation Theory. The following chapters focus on other important elements, including the object of learning, critical features and patterns of variation. Real examples in the classroom are used to explain how Variation Theory can be applied in an authentic context. Chapter 5 discusses the relationship between Variation Theory and other teaching strategies in detail. Chapter 6 demonstrates how to use Variation Theory as a theoretical framework to analyse and give feedback on lessons. Chapter 7 reviews the development of Variation Theory and paves the way for its future development, and suggests some directions for such development.



## Chapter 2

# Object of Learning

As noted in the first chapter, all learning must be directed towards something. We cannot talk about learning without referring to what is to be learnt, i.e., the ‘object of learning’. It is in this respect that Variation Theory differs from many other learning theories. In Variation Theory, the ‘object of learning’ is a special term encompassing multiple meanings, which are elaborated upon in this chapter.

### The difference between learning objectives and objects of learning

An object of learning is different from a learning objective. Learning objectives generally refer to the kinds of behavioural changes expected of students as a result of learning activities. In a sense, by stating the learning objectives, the teacher is in fact specifying the expected learning outcomes and treating the end result of learning as if it can be predetermined. This is the approach taken by many educational reforms. Policy makers believe that by specifying learning outcomes, they can prompt teachers to change their methods of teaching and thus bring about teaching reforms. For example, the Target Oriented Curriculum (TOC) reform introduced in Hong Kong in 1996, the Outcome-based Education (OBE) (Brady, 1996; Brandt, 1994; Biggs, 1999) reform currently mandated for all higher education institutions in Hong Kong by the University Grants Committee (UGC), and efforts to make use of assessments to change and promote certain teaching strategies, e.g., the ‘assessments for learning’ movement (Black et al., 2004), are focused on the end results of learning.

The original intent of using learning objectives and assessments to change teaching is to ensure that both teachers and students pay attention to the expected outcomes of learning and thus make efforts to achieve them. However, in the real educational world, two problems arise that are difficult to resolve. First, in an environment in which examination results determine whether a student is able to advance in a highly competitive school system, and a society in

which educational qualifications are key to future career success and life chances, teachers may feel under pressure to gear their teaching to assessment items, thus distorting the true purpose of education. For example, many parents in Hong Kong force their children to take piano lessons. Because the piano examination requires only that students demonstrate mastery of a few pieces of music, most piano teachers and students concentrate all of their efforts on learning just those few pieces to obtain good examination results. As a result, it is easy to find students in Hong Kong who have successfully passed Level 6 or 7 piano examinations, yet are able to play only the few pieces required in the examinations. This kind of examination-oriented learning renders it very difficult to arouse students' interest in learning the piano or exploring the subtleties and beauty of the world of music in depth. Thus, it is not surprising that many students drop the piano as soon as they have fulfilled their duty by passing the exam and that some even refrain from ever touching the piano again once they have come of age and can take control of their own life. Second, specifying the end results of learning neglects the dynamic nature of the object of learning and actually limits students' learning outcomes. Stenhouse (1975) points out that higher level educational aims are difficult to predict. In fact, the teacher is also a learner; as the Chinese saying goes, 'teaching and learning reinforce each other'. Confucius states: 'The transmission of the cultural legacy is not a one way process. It requires the teachers also to become engaged as a learner in the creative process of extending and adapting the cultural meanings presented to their students as objects of learning' (Elliott & Tsai, 2008, p. 571). As a teacher is teaching in the classroom, and interacting with students and discussing the object of learning with them, he or she gains a better and clearer understanding of the object of learning himself or herself, a point that is discussed in more detail later in the chapter. I believe that it is better to pay attention to and try to influence teaching and learning directly rather than hoping to influence the teacher's teaching and the students' learning by means of changes in assessments. Assessments should serve teaching and learning, i.e., provide feedback to students and teachers on the quality of teaching and learning, so that teaching and learning can be improved, not the other way round.

Of course, the learning objectives specified in curriculum guides serve as important references for the teacher. In general, before teachers start preparing for a curriculum unit, they will first refer to the curriculum guide and course outline to find out what learning outcomes the students are expected to achieve. For example, one learning objective specified in the Primary Two Chinese

language curriculum in Hong Kong is that students should be able to tell a story coherently. This objective specifies only the end result, not how to get there. However, most teachers rarely explore ‘what students need to learn’ if they are to be able to tell a story coherently. Instead, they focus their efforts on trying to motivate students to learn and on designing teaching strategies, such as group interactions or individual presentations, to encourage student participation. They assume that as long as the students listen carefully, they will learn. In fact, many educational reforms focus on the promotion of certain teaching arrangements, with the ‘what’ aspect of teaching generally being neglected, as if no special attention is required. The only suggestion found in the aforementioned curriculum guide on how to help students to tell a story well is that they should be encouraged to ‘listen more, tell more and practise more’. Of course, if we are teaching factual knowledge or simple skills, then it would be helpful for students to listen and practise more. If, however, we want the students to develop a deep understanding of certain concepts or want to nurture certain capabilities or attitudes, then we must first ask the question, ‘What does it take for the students to develop the capability we desire?’ For example, what does it take for a student to tell a story coherently? What should teachers teach in class? The object of learning refers to what the students need to learn to achieve the desired learning objectives. So, in a sense, it points to the starting point of the learning journey rather than to the end of the learning process. Further, the object of learning is dynamic, and so will change during the teaching and learning process, a point that is further elaborated upon in Example 2.6.

### External horizons of the object of learning

As the basic learning unit in a school is the lesson, I focus my discussion here on the learning that takes place in a lesson. Of course, we could also consider some other units, such as a course, a teaching unit or even an activity within a lesson, but, if we wish to help teachers to apply a learning theory to practice, then I believe a focus on the lesson is quite appropriate for several reasons. First, students learn through accumulation, by building upon what they have learnt in one lesson after the other. If students cannot obtain useful knowledge in each lesson, then they will be unable to accumulate useful learning in the long run, say in one month or one year. I concur with the old Chinese saying that ‘it takes a decade to grow a tree and a hundred years to nurture a man’, but would also emphasise that the qualities that contribute to the making of a mature person do not come suddenly from nothing, but are built up slowly bit by bit. For example,

if a person wants to build a brick house, then he or she cannot be concerned only with the final appearance of the house, but must take care over the quality of the bricks used in its construction. He or she must also pay attention to how the bricks are laid piece by piece to form the house. Otherwise, the house would easily collapse even after it is built! Second, considering the time resources required to develop and research a lesson, I believe a lesson to be an appropriate unit for our discussion. Such a unit also allows us to inspect all of its aspects carefully, from the choice of the object of learning to the teaching materials used and from the teaching strategies to the actual teaching enactment and student learning outcomes, in an affordable and manageable period of time.

Although this book focuses only on teaching and learning in the classroom, the applications of Variation Theory are not, in fact, limited to this setting. As noted in Chapter 1, we cannot pay attention to something but ignore its surrounding environment or external horizons. In fact, an object has no meaning in itself. Its meaning is derived from the relationship it has with the system in which it exists, i.e., its relationship with its external horizons. The meaning of an object comes from its position as a value in the dimension of variation. To take an example from mathematics, one cannot obtain the meaning of a number from the number itself, but only from its relationship with the numerical system to which it belongs. For example, the meaning of the number '4' is derived from its value in the decimal system of numbers. It is greater than 3 and less than 5. The number '10' has different meanings in the decimal and binary systems of numbers.

Example 2.1

A green plant may have many different meanings to us.

1. When we discern it from the environment that it is in, for example, we find that it is not connected to the top of the desk but is an individual object, the plant has meaning as an individual object.
2. When we compare the plant with a person and find the two to be different, a dimension of variation (living things) opens up. Plants and persons are both values in this dimension of variation. Now, the plant has meaning for us as a kind of living thing.
3. When we compare it with other plants and find different plants to have different characteristics, another dimension of variation (plants) opens up. The plant becomes a value on this dimension of variation, and its meaning lies in its status as a plant of a certain species.



## CHAPTER 2

4. We may pay attention to certain aspects of the plant, such as its colour, as we have probably seen other colours before and understand the concept of 'colour'. Now, the plant has meaning for us as a green plant.

When we consider the meaning of the term 'object of learning', we cannot ignore its external horizons, as it will have different meanings in different situations. Hence, we have to consider it in the context of the teaching and learning environment within the school classroom. The teaching and learning situation itself has its own objectives and limitations. For example, the school's objective may be to educate students to be able to gain a foothold in and contribute to the society in which they live. The society also has expectations of schools. Regardless of whether the society expects schools to produce followers who are able to adapt to societal needs or leaders with creative and enquiring minds who are innovative and able to lead and advance the society, or citizens with some other specified capabilities, or expects them to bear the responsibility of passing on wisdom and the cultural heritage to the next generation, these expectations will be translated into the aims and objectives of education and reflected in the content of school curricula. These curricula are developed after careful deliberation by a central government body, e.g., the Curriculum Development Institute in Hong Kong's case, and schools are expected to follow them. In sum, teaching in schools is not random or without purpose, and curricula are never value-neutral. Therefore, depending on the educational beliefs and philosophy of the school or its teachers, some objects of learning will be regarded as more valuable and worthwhile than others. Accordingly, although an 'object of learning' generally refers to the thing to which learning is directed, i.e., 'what is to be learnt', because students' time in the classroom is limited, teachers have to make a conscious choice when considering what to teach. Many teachers regularly complain that there are too many things to teach and too little time to do it. It makes more sense to encourage teachers to make the best use of each lesson by carefully selecting the objects of learning. I believe that it is the teachers' duty to maximise student learning of the most worthwhile object of learning in the limited time available in a lesson.

When considering the object of learning for a particular lesson, we must pay attention to its external horizon, because nothing can be separated from the environment or system in which it exists. The environment in which an object of learning exists is very important to the understanding of that object.

Example 2.2

If a man sees a pair of eyes and a shadow in the shape of a cat in a dark forest, then he might infer that a leopard or tiger is staring at him. If he sees the same pair of eyes and shadow at home, however, he would probably assume that it is merely the family cat staring at him. His experience tells him that the likelihood of seeing a leopard or tiger at home is small. Therefore, in addition to the object itself, the environment in which it is located – forest or home in this example – also plays an important role in the understanding of it.

Understanding the context of an object of learning can influence students' overall understanding of that object because the external environment affects their association with the object and whether it has any relevance to them. An object of learning does not exist on its own. Teachers must first clarify its position within the system of objects to which it belongs and its relationship with the other objects in the system. The parts of this system that are not the object of learning itself, but are related to it, belong to the object's external horizon.

Example 2.3

If a person wants to teach a child what dogs are, then he or she will probably show it many different kinds of dogs. However, Variation Theory posits that one cannot discern through 'sameness' (Marton, 2009). For example, the child in question may think that anything with four legs and a tail is a dog. So, when it sees a cat it will think that the cat too is a dog. Difference or variation is required for the child to discern the defining features of a dog. In other words, we must also show the child what is not a dog. When it is able to differentiate other animals, such as cows, horses, cats and pigs, from dogs, we can say that it has gained a deeper understanding of 'dog'. For this child, a dimension of variation (animals that have four legs and a tail) is open, and 'dog' becomes a value in the dimension of variation, and all of the other animals in this dimension constitute the external horizon of 'dog'.

Example 2.4

If a teacher wishes students to be able to express the ambience of a place by using the scene description writing technique, then he or she must first help them to situate this kind of writing style amongst the other writing styles that they have learnt. For example, it belongs to the genre of narratives (a dimension of variation). In the straight declarative writing style, events are described according to their time sequence, whereas in the flashback writing style, the last event is described first, with the rest of the events described in the usual time sequence. In the scene description writing style, in contrast, a moment in time is described in great detail. It is as if while watching a video, you press

the pause button to freeze a particular frame, allowing you to study the appearance of the actors and the surrounding atmosphere in great detail. To help students to grasp the technique of scene description, the teacher must first help them to differentiate between this writing style and the other styles within the genre of narrative writing. Accordingly, scene description is a value in the dimension of variation of narrative writing styles; the direct declarative and flashback writing styles are other values in this dimension of variation, and they belong to the external horizon of scene description.

## The two aspects of an object of learning

Apart from conveying knowledge to students, the responsibility of both school and teacher is to nurture students to become worthy human beings with all of the best qualities of the human race. There has been ongoing debate over whether it is more important to teach knowledge or teach students. Regardless of the answer, it is clear that the teaching of subject knowledge is still very important. First, it is only through the learning of subject knowledge that we can understand the past and the present. Second, subject knowledge has practical uses. It is knowledge that is essential to our survival in work or life. It constitutes the fruits of many years of hard work, of mankind attempting to understand the world in which we live (Sarason, 1999, p. 52). Of course, helping students to develop virtues, good interpersonal skills and a positive outlook on life is also very important. So, the next time you hear someone remark, ‘Teachers should teach the child and not the subject knowledge’, feel free to point out that the two are not mutually exclusive. In fact, as Sarason (1999) notes, what people probably intend when they make such a remark is not to belittle the importance of subject knowledge, but to remind us of the importance of the classroom environment, that if teachers do not understand the students’ background and ways of thinking, then their teaching is unlikely to help students to grasp the expected meaning, importance and usage of the object of learning. Variation Theory, in requiring us to pay attention to both the specific and general aspects of the object of learning, may offer a good solution to resolve this dispute.

If teachers expect students to learn the intended object of learning, then in choosing that object, they must ask themselves why their students need to learn it. What can students do with the knowledge gained? What can the learning of it do to help them in their future learning? What capabilities can students develop through the learning of this object of learning? In Chapter 1, we saw that there are two aspects of an object of learning: the specific aspect, which refers to the knowledge of a certain subject that we want students to learn (the content, and is

usually aimed at a short-term educational goal), and the general aspect, which refers to the capability or attitude that can be developed through the learning of the content in question (this aspect is usually aimed at a long-term educational goal).

Some teachers complain that because they operate under the constraints of a centralised curriculum determined by the government and must teach according to designated textbooks, there remains very little that they can do as teachers. I agree that teachers are restricted in their choice of textbooks and the content they must teach because they are bound by examination syllabi and central curricula, but I believe there is still considerable room for them to take initiatives, particularly with respect to the general aspect of the object of learning (or the indirect object of learning). What is more, the quality of learning is also, to a large extent, affected by this general aspect.

Example 2.5

‘Returning Home’, an article written by the great ancient Chinese scholar Tao Yuen Ming, used to be a compulsory component of the Chinese language curriculum for secondary schools in Hong Kong. In this article, Tao describes his life after quitting his position amongst corrupt officialdom at the age of 40 and returning to a life close to nature in the countryside. Of course, in teaching the article, teachers will discuss its content and its literary features with students. This thus constitutes the direct – or specific aspect – of the object of learning. With regard to the general aspect of the object of learning, a common approach is to help students to understand the underlying meaning of the article. To achieve such understanding, students must understand the author’s state of mind. Most Chinese language teachers find this aspect very difficult, because their students, who are only about 14 years of age, lack the relevant life experience to appreciate Tao’s feelings. How can a group of 14-year-olds, inexperienced in life, appreciate the state of mind of a man over the age of 40 who was disappointed with the government and sufficiently tired of being a government official to take early retirement in order to lead the life of a recluse? Teachers also have to answer these questions: How will it benefit the students to understand the state of mind of this author? Does it have anything to do with the students themselves? In other words, they have to pay attention to the relevance structure.

Although the specific aspect of the object of learning in this example, i.e., the content of the text, is fixed, teachers may still choose to teach different general aspects of the object of learning. The following are two possible alternative approaches.

## CHAPTER 2

1. Use this article as a basis to discuss the ancient scholar's attitude towards life. He faced a choice between Confucianism and Taoism, i.e., between 'worldly' and 'unworldly'. Of course, this option requires the teacher to have a deep understanding of both schools of thought.
2. Use this article as an entry point to discuss 'how to make choices in life' with the students. Even a 14-year-old needs to make major decisions in life, for example, whether to go into the arts or science stream in senior secondary school and whether to continue his or her studies after graduation or go straight to work. In fact, students have to make many choices in their daily lives. For example, if a teacher appoints a student to be the class monitor, then the student has to decide whether to accept the responsibility or not. Being a class monitor may damage his or her relationship with classmates. If the student does decide to accept the responsibility, then should he or she report his or her classmates to the teacher when they break the school rules? Thus, if teachers deal with 'Returning Home' from the perspective of 'making choices in life', then it is more likely to resonate with students.

Using the second option as an example, we can see that it allows teachers to analyse with the students the situation in which Tao found himself. Corruption and vulgarity in the bureaucratic culture of state officials are not unique to the era in which Tao lived. In fact, they were not only common phenomena in the different Chinese dynasties, but they can still be found around the world today. However, people still have many options. For example, they can choose whether or not to become involved in social and political activities, and even after making such a choice, they can decide to adopt different attitudes. The teacher can make use of historical figures from ancient China to illustrate his or her point. For example, in illustrating someone who chose to become involved in social reform, the teacher could refer to Poon On (an ancient scholar who is famous for being very handsome and who spent most of his time making up to the rich and famous), Tso Tso (an ancient warrior at the time of the Three Kingdoms, who tried to reunite the country to become sole ruler) or Zhu Ge Liang (a scholar and military leader at the time of the Three Kingdoms, who devoted his entire life to serving his ruler). These three personages reflect going with the flow, becoming a leader and participating actively, respectively. Amongst the ancients who chose not to become involved, we have the examples of Li Bai, a great poet of the Tang Dynasty who expressed disappointment in his ability to gain recognition through his poetry and other writing; the Seven Scholars of the Bamboo Grove, who showed their disapproval of the world by leading a carefree life; and Qu Yuan, who drowned himself to demonstrate his disappointment at his failure to persuade the emperor to make the changes necessary to prevent state affairs from going downhill. The knowledge of all these ancient figures has been covered somewhere in the

Chinese Language curriculum and should be prior knowledge of the students. Teachers can also cite well-known contemporary figures as examples.

None of the foregoing decisions represent the one taken by Tao, who chose to resign from office, go back to nature and lead a simple life. By pointing this out, teachers can associate the object of learning with its external horizons. They can show the significance of Tao's choice by comparing it with the choices made by other historical figures the students know about from other subjects, including Chinese language, history and literature. In fact, the dimension of variation (the choices made in the face of difficulties in life) is open, and the different choices made by these individuals from ancient times are values on this dimension. Eventually, teachers can emphasise to students that no matter how complicated the problems they face in life are, there are many ways of resolving them, thereby developing more powerful ways of seeing amongst students. Particularly for those who may feel that suicide offers an easy way out when confronted with a minor setback, this learning process will convey a positive message.

## Direct and indirect objects of learning

At the same time, we can have a direct and an indirect object of learning. The direct object of learning usually refers to content, so it is concerned with specific aspects, for example, 'the three phases of water'. The indirect object of learning refers to what the learner is supposed to become capable to do with the content. It can be dealing with a specific aspect or it can be dealing with a general aspect. For example, 'being able to recall the three phases of water' is an indirect object of learning which is specific. 'Being able to distinguish between the three phases of water', 'using the three phases of water as an example of a scientific explanation' are indirect objects of learning which are dealing with general aspects.

### Example 2.6<sup>1</sup>

A group of teachers in a Learning Study found that their students encountered more difficulties in learning the history of the Wei, Jin, and Northern and Southern Dynasties than that of the other Chinese dynasties. The teachers interviewed four Secondary One and three Secondary Two students and found the following views.

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<sup>1</sup> This example comes from Learning Study VL054 in the "Variation for the Improvement of Teaching and Learning" (VITAL) project carried out by Yiu Kai Bun, Kwok Wing Yin, Lo Ka Yan, Ho Ka Po, Tam Yi Mei, Kum Yim Oi, Lam Hung, Lam Lai Fong and Kung Kun Ho. The project was funded by the Education Bureau of Hong Kong.

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1. Studying Chinese history means memorising many historical facts, and this is the greatest difficulty in learning Chinese history.
2. Students are interested in learning Chinese history because there are many interesting stories.
3. Students do not know why they have to learn Chinese history.

However, beyond the memorisation of historical facts, one of the objectives of the Chinese history curriculum is to develop certain capabilities through the study of Chinese history, including ‘learning about the historian’s way of thinking’ and ‘developing a historical sense’. Therefore, a worthwhile object of learning in Chinese history is the capability to appreciate and develop a deep understanding of the implications of historical events, to see historical events in the light of the nature of historical knowledge and to find their deeper meaning. By helping students to develop a historical sense, it will also help them to remember historical facts more easily and to develop in-depth knowledge of history.

After much deliberation, the research team finally decided that the direct object of learning would be the ‘Battle of River Fei’ (a historical event). The indirect object of learning would be ‘understand the historical significance of the event, i.e., its effects on later historical events’.

Two critical features were identified as contributing to the indirect object of learning:

1. An important historical event will have a substantial influence on the succeeding development of China.
2. There are always lessons to be learnt from any historical event.

This case clearly demonstrates that the quality of the learning outcome is heavily dependent on the teacher’s choice of indirect object of learning.

### The dynamic nature of the object of learning

Through the course of teaching and interacting with their students, teachers gain a better understanding of the object of learning. Hence, the object of learning is not invariable. Based on students’ reactions and their own more in-depth understanding of the object of learning, teachers regularly make adjustments to it. For example, it is often very difficult for the teacher as an adult and successful learner to comprehend the difficulties a young student might encounter in learning to tell a story because he or she is proficient in narration and in telling a story in an organised manner. To help students to develop the capability to speak

in an organised manner, the teacher must first discover what it takes to be able to tell a story coherently.

Example 2.7<sup>2</sup>

Teachers in one Learning Study discovered that most of their Primary Two students were unable to tell a story coherently, and thus endeavoured to help them to develop the capability to do so. The teachers initially believed their students were unable to tell a story coherently because of their poor memories. That presented a problem, because what can teachers do to help students with bad memories? They decided that they must first explain the story to the students to create a lasting impression, for example, through role plays, and then require the students to read the story many times to help them to remember it. At this time, the teachers chose the following object of learning.

- Direct object of learning: the content of a story
- Indirect object of learning: the ability to recite and tell a story

However, this object of learning does not seem worthy of teaching and learning time. It might result in students being able to tell one story very well, but does nothing to improve their general capability to tell stories.

The teachers first tested each student by asking him or her to read a story, and students were encouraged to jot down notes to help them to memorise it. Each student was then asked to retell the story, and the teachers made recordings of all of the students doing so. Then, they interviewed some of the students who had not done well on the test, and asked them how they had tried to remember the story. Most of these students said they had tried to memorise it word by word or sentence by sentence. Although they said they had tried to memorise as much of the story as they could, most were able to remember only two or three sentences. The teachers also interviewed the students who had done well. These students said they had first tried to understand what the story was about, then tried to remember some important points, for example, the people involved and the time and place, and then made the rest up. These interviews led the teachers to realise that the reason some students performed better than others was because they had worked out a more effective method. They thus decided that they needed to teach the students an effective method of remembering and telling a story. As the successful students mentioned the importance of the time, place and people involved in the story,

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<sup>2</sup> This example comes from Learning Study VL028 in the “Variation for the Improvement of Teaching and Learning” (VITAL) project carried out by Ko Po Yuk, Au Yuen Yee, Lai Meng Choo, Cheng Tak Sze, Yeung Sau Tsang, Lam Man Yin, Wong Yin Mei, Chan Man Kei, Yeung Big Fun, Law Ming Wai and Tang Man Fan. The project was funded by the Education Bureau of Hong Kong.



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these became the critical features. As every story has a beginning, a middle (the development component) and an end, the teachers decided to provide students with a framework that would help them to improve their memories (see Table 1).

*Table 2.1* Framework for Remembering a Story

(Time, place, people)	Event
Beginning	
Middle/Development	
End	

Both the direct and indirect object of learning changed at this point, as follows.

- Direct object of learning: a framework for remembering a story
- Indirect object of learning: the ability to use this framework to help to remember and tell a story

However, when the teacher taught this research lesson in the first cycle, she discovered problems with the framework. There was a possibility that the time, place and people could change at different stages of the story, and yet the teacher had made these elements invariable in the framework, which caused confusion for some students. Accordingly, another teacher in the Learning Study group amended the framework (see Table 2) to deal with this problem in the next cycle of teaching.

*Table 2.2* Revised Story Framework

	Time	Place	People	Event
Beginning				
Middle (Development)				
End				

Post-lesson interviews showed that modifying the framework helped the students to learn much better. Table 3 compares the pre- and post-test results between the first and third cycles.

Table 2.3 Percentage of Students Telling the Story in a Coherent Manner

	First cycle of teaching	Third cycle of teaching
Pre-test	17%	11%
Post-test	61%	75%
Gain	+44%	+64%

This example shows that if teachers can gain a more in-depth understanding of how students learn, then their own understanding of the object of learning will also become more thorough and, accordingly, the more likely they are to be able to choose the critical features that can help students to grasp that object. The object of learning will also change accordingly, and this change will lead to more effective, worthwhile and in-depth learning. In other words, the object of learning is dynamic during the course of planning and teaching.

Students cannot naturally discern the critical features of an object of learning. It is therefore the duty of the teacher to provide them with opportunities to be able to do so. As a result of his or her interaction with students, the teacher may come to understand the object of learning better, and so may make modifications to it to render it more worthwhile. Of course, teachers must begin with an intended object of learning, but good teachers will always aim to maximise students' learning of the most worthwhile object of learning within the time constraints of the lesson. Accordingly, good teachers will not obstinately stick to the original intended object of learning and the teaching plan, but will make adjustments in light of their deepened understanding of the students and more thorough appreciation of the object of learning. In this way, teachers are also learning and making improvements continuously. As the object of learning may be adjusted and altered in the course of lesson planning and enactment, and thus may come to differ from the original intended object of learning, here we differentiate the two by calling the object of learning that is actually enacted in the classroom the 'enacted object of learning' (Marton, Runesson & Tsui, 2004, p. 23).

At present, Object Based Education (OBE) is being pushed onto Hong Kong universities by both the University Grants Committee (UGC) and the government, understandably enough because the government wants to hold teachers accountable for their teaching to ensure the desired results in students. However, what I am advocating in this chapter is not the same as OBE. Of course, I agree that if the intended object of learning is the same as the enacted

object of learning, and if teachers can study the object of learning in-depth, identify all of its critical features and make use of variation as a pedagogical tool to help students discern those features, then it is possible that there will be a significant effect on student learning. However, we have to admit that we can never predict exactly what the learning outcome should be, as we must take into account both the dynamic nature of the object of learning and the unpredictable nature of the classroom, the result being that the enacted object of learning will usually differ from the intended object of learning. Above all, it is how the students themselves experience the object of learning that really matters. We cannot force students to learn, but we can provide the best opportunities for them to learn. Thus, we expect teachers to make constant modifications according to students' reactions to render the object of learning more worthwhile.

Of course, different students may experience the enacted object of learning in different ways due to their different backgrounds and prior knowledge. We call students' experience of the object of learning the 'lived object of learning' (Marton, Runesson & Tsui, 2004, p. 23). It is this lived object of learning that is key to whether students have truly gained the knowledge in question. If the lived object of learning does not correspond with the critical features, then the students have not gained the intended knowledge.

Example 2.8<sup>3</sup>

In one of the Primary Two Chinese language texts, there is a chapter called the 'Wishing Well', which describes the adventure of a frog who lives in a well. The frog becomes irritated by the many people who throw coins into the well to make a wish. So, one day, the frog jumps out of the well, drops in a coin and makes the wish that people will stop dropping coins into his well. The story has no ending. A group of teachers engaged in a Learning Study decided that asking students to finish off the story by writing an ending would help them to discern that there is no fixed way of writing a story and that the same story can have different endings. Their overall intention was to encourage students to exercise creativity in their writing. Hence, in this case, the direct object of learning was the 'Wishing Well' chapter, whereas the indirect object of learning was the ability to be bold and creative in writing. In the first cycle of teaching, as a motivation strategy, the teacher brought in a birthday cake she had made and used 'making birthday wishes' as

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<sup>3</sup> This example comes from a learning study within the Progressive and Innovative Primary Schools (PIPS) project funded by the Quality Education Fund of the Hong Kong SAR.

the introduction. She then discussed other ways of making wishes with the students, after which she took out a real paper offering and demonstrated how to post paper offerings onto a Wishing Tree (there is a Wishing Tree situated close to the school). She also asked the students to write their wishes on heart-shaped pieces of paper and to post them on a paper Wishing Tree, which she had prepared and attached to the notice board. Finally, the teacher explained the text and, because class time had run out, assigned the writing of the story's ending as homework. After the lesson, the researcher interviewed three students:

*Researcher: What did you learn in the lesson just now?*

*Students A, B and C (simultaneously): To make a wish ... different ways to make wishes.*

*Researcher: Why did the teacher teach you different ways to make wishes?*

*Students A, B and C (shaking their heads and thinking for a while): I don't know.*

We can see that although the teacher intended to encourage the students to be bold and creative in writing an ending to the story the 'Wishing Well', the enacted object of learning was rather different. Because the teacher used different ways of making wishes as examples, students' attention was drawn to these different ways of making wishes. As a result, the object of learning as experienced by the students, that is, the lived object of learning, was the 'different ways of making wishes'.

In this example, although the students learned something – the different ways of making wishes – what they learned was not a worthwhile object of learning. Some would even argue that it was an undesirable one because it may have taught the students to become superstitious. In sum, teachers must pay attention to the dynamic nature of the object of learning and do their best to discover the enacted and lived object of learning.

## Internal horizons of the object of learning

At least two types of discernment are required to recognise an object A. First, one has to discern A from its external horizons and environment. Second, one must discern A's internal horizons. An object's internal horizons are related to the nature of the object itself. There are two aspects of internal horizons: structure and meaning. The structural aspect refers to the relationship of parts to parts, parts to the whole and the superordinate/subordinate relationships between the different aspects (Marton & Booth, 1997, p. 87-88). To learn about an object, one must be able to discern these two aspects (structure and meaning) simultaneously. In fact, it is not even possible to discern one without the other.

## Parts and whole of the object of learning

The parts and whole refer mainly to the structure of an object. For example, if we look at a man as a 'whole', then his eyes, ears, mouth, nose, hands, legs, etc. are parts of the whole. If a man saw a pair of eyes in dark woods and recognised them as the eyes of a deer, then this would mean that he had already discerned the structure of a deer, its eyes relative to its other parts, such as its mouth and nose, and its whole (the face of a deer and the profile of its body). We can ask, however, whether this man realised that this was a pair of deer eyes first (its meaning) and then discerned the profile and other parts of the deer (its structure) or whether he discerned the profile and other parts of the deer first and then realised that what he was seeing was a pair of deer eyes? If you think about it carefully, then you will probably agree that the two occur simultaneously (Marton & Booth, 1997, p. 86-87). The following are some examples of parts and whole.

### Example 2.9<sup>4</sup>

Take 581215192226 as an example. Different people will have different ways of seeing its structure, and so will derive different meanings, as follows.

1. 581215192226 may be seen as a whole number;
2. as 12 numbers, 5, 8, 1, 2, 1, 5, 1, 9, 2, 2, 2 and 6, each of equal importance; or
3. as the following series of numbers: 5, 8, 12, 15, 19, 22 and 26. In this case, each subsequent number is created by alternating the addition of 3 and 4. Thus, the numbers 5, 3 and 4 are more important because 5 is the first number in the series, and each succeeding number is generated by adding 3 or 4 to the preceding number.

This example shows that the meaning we attach to the number(s) depends on how we see its/their structure. At the same time, however, how we see the structure of the number(s) depends on the meaning that we attached to it/them. For example, why would we see the structure of the numbers as 5, 8, 12 and 15 and not 5, 8, 1, 21 and 5? It must be because we have already perceived a certain regularity amongst the numbers. Therefore, structure and meaning are discerned simultaneously.

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<sup>4</sup> This example is taken from Katona, G. (1940), *Organizing and Memorizing* (New York: Columbia University Press), which is reported in Marton, F., & Booth, S. (1997), *Learning and Awareness*. Mahwah, NJ: Lawrence Erlbaum, p. 88.

Example 2.10<sup>5</sup>

There is a sentence in the chapter entitled ‘A Polite Little Guest’ in a Primary Two Chinese language textbook that says: ‘Do not interrupt while others are talking’. In this example, the teacher first taught the students how the Chinese character for ‘insert’ (插) evolved from its hieroglyph, i.e., the word looks like a knife being inserted into a piece of meat. She then asked the students to guess the meaning of the word ‘interrupt’, which is made up of two Chinese characters, 插 (meaning ‘insert’) and 嘴 (meaning ‘mouth’). The teacher then explained that interruption could be thought of as inserting your words into others’ conversation and that words came out of the mouth. Therefore, when the two characters are paired to form a word, they take the meaning ‘interrupt’. Following this explanation, the teacher asked students to identify the sentence that contains the word ‘插嘴’ (interrupt) in the text. The students came up with the sentence ‘do not interrupt while others are talking’. The teacher then explained the meaning of the whole sentence and its relation to the theme ‘A polite little guest’. In this case, the word ‘插’ (insert) is part of the whole word ‘插嘴’ (interrupt). The meaning of the part changes when it is seen as part of a whole, and it also contributes to the meaning of the whole. The word ‘插嘴’ (interrupt) is also a part of the sentence (which can be regarded as a whole), a part that contributes to the meaning of the sentence. The word ‘插嘴’ is initially value-neutral, however. Being part of the sentence changed its meaning, that is, gave it the meaning of being considered an impolite act. The sentence ‘do not interrupt while others are talking’ is itself also a part of the text (a whole). The different sentences (parts of the whole) contribute meaning to the text/theme. Parts can be meaningful only in relation to the whole, and the overall meaning of the whole (that is, what is polite) is determined by its parts.

Example 2.11<sup>6</sup>

Several English-language teachers intended to teach students how to guess the meaning of new words by using contextual clues and certain indicative words/phrases, e.g., ‘otherwise’, ‘but’, and ‘on the other hand’, as these words/phrases indicate opposite meanings. Accordingly, if students know the meaning of the sentence before an indicative word, they can then guess the meaning of the following sentence and vice versa, the point being that it is not necessary to know the meaning of every new word to

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<sup>5</sup> This example comes from Chik, P.P.M., & Lo, M.L. (2004), “Simultaneity and the enacted object of learning”, which appears in F. Marton & A. B. M. Tsui (Eds.), *Classroom Discourse and the Space of Learning*. Mahwah, NJ: Lawrence Erlbaum Associates, pp. 89-110.

<sup>6</sup> This example comes from Learning Study VL036 in the “Variation for the Improvement of Teaching and Learning” (VITAL) project carried out by Alice Chow Wai Kwan, Joanne Ng, Megan Chung, Eleanor Tai, Kelvin Lam and Vivien Lui. The project was funded by the Education Bureau of Hong Kong.

understand the general meaning of an article. The teachers' rationale for taking this approach was their attribution of their students' lack of interest in reading to their limited vocabulary, which meant that they often had to stop reading to look up words in the dictionary, thereby making reading a boring exercise. In this case, the direct object of learning was 'indicative words', and the indirect object of learning was 'the capability to guess the meaning of new words from their context with the help of indicative words'. The long-term goal was to enhance the reading capabilities of students and increase their interest in reading. In this example, the article is the whole, and the sentences and words in the article are its parts. When the students initially read the article, they could not grasp the meaning of the whole because they did not understand its parts. However, once a student became aware of the relationship between a new word (a part) and other parts of the article (the sentence before, indicative word and the sentence following), he or she obtained a different understanding of the new word (e.g., gained an initial grasp of the meaning of the new word) and, accordingly, a different understanding of the whole article.

## Relationship between an aspect and the whole and one aspect and another

Another way to look at the structure of the object of learning is to look at the relationship between the aspect and the whole and that between aspects. This applies to abstract concepts. Take a brown Alsatian as an example: colour, animal and pedigree are its aspects. We must first have discerned the different values of 'animal' in the dimension of variation – animal – with dog being one value. Then, we must also have discerned Alsatian as a value in the dimension of variation – pedigree. The two aspects, dog and pedigree, have a relationship: pedigree is subordinate to dog, which is superordinate. Further, we must also have discerned the dimension of variation (colour), with brown being a value in this dimension. However, colour and pedigree are not related in a superordinate/subordinate relationship. To discern a brown Alsatian, we have to discern the three values (critical features) on the three dimensions of variation (critical aspects) simultaneously, and discerning this dog requires these three features to be discerned simultaneously.

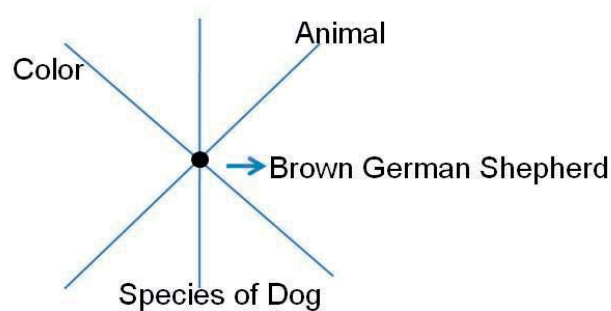


Diagram 2.1 The meeting point of the three dimensions

Example 2.12

Säljö (1982) conducted a study on how a group of university students attempted to comprehend an article. The researcher requested a group of university students to read an article about learning, and then asked them how they understood it. The results showed that although the students had read the same article, they derived different meanings, which could be categorised into two completely different ways of understanding. Some students understood the article as being a list of different forms of learning presented in a sequential manner, and they saw no connections between these forms. Another group of students understood the article as having a theme (that is, forms of learning) that was illustrated with different sub-themes (the different forms of learning). This second group of students understood the article as presenting ideas in a hierarchical structure, and saw obvious connections between the main theme and the sub-themes.

Säljö discovered that the students who understood the article in the form of ‘a hierarchical structure’ demonstrated an organised and meaningful understanding of it compared with those who understood it in the form of ‘a sequential structure’. In other words, the former group had a better grasp of the article’s theme. The findings of the study indicated that those students who saw the hierarchical structure of the article were able to gain a better understanding of its in-depth meaning, whilst those who saw it as having a sequential structure grasped only a superficial meaning (Marton & Säljö, 1976, p. 4-11; Säljö, 1975; Säljö, 1982).

Example 2.13

Referring back to Example 2.7, why would teaching students a storytelling framework have such a profound effect on their learning? The teacher initially discovered that the students who demonstrated poor storytelling performance were trying to remember every word and every sentence of the story, which suggested that they did not



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understand its overall structure. Since meaning and structure must be discerned together, and these students were unable to discern the structure of the story, its meaning remained unclear, which explains why they found it difficult to tell the story: the story probably appeared to them as a bunch of meaningless words!

The students who exhibited better performance, in contrast, were found to have discerned the structure of the story, although that structure may have been incomplete. They discerned that there were certain elements in the story, such as time, place and people, although they missed out its sequence: beginning, middle (development) and end. Once the teacher had taught the students the structure of a story, they were then able to discern that a story has a beginning, middle or development part and an end, and that each of these stages may take place at different times and places and have different people involved. Also, different events may take place in different parts of the story. Once students understood the structure of the story, and were able to identify the elements in that structure, they were then also able to simultaneously grasp the story's meaning. Once they understood its structure and meaning, they naturally found it easier to tell.

This example illustrates that discernment of the structure and meaning of the object of learning occurs simultaneously. If students cannot discern the structure of a story, then they cannot understand its meaning. If they can discern the meaning of the story and can repeat it in an organised manner, then they must also have discerned its structure. In this case, the beginning, middle (development) and end are values on the dimension of variation of 'the stages of a story', and this dimension is a critical aspect of storytelling. The beginning of the story itself can be seen as a dimension of variation or an aspect, with time, place, people and events being values on that dimension. Time, place, people and events are also variables, and so are also dimensions of variation or aspects. The difference between a critical feature and a critical aspect is that the latter refers to a dimension of variation and the former is a special value on that dimension of variation.

### The importance of simultaneous discernment

To understand an object, we must discern its critical features simultaneously.

#### Example 2.14

The primary general studies curriculum has several sections dealing with astronomical phenomena. Some primary students find the idea that we can see only one face of the

moon difficult to comprehend. The explanation provided by the teacher in this example was that the time required for the moon's own rotation and its revolution around the Earth is the same; as a result, those of us on Earth are able to see only one side of the moon, and we all see the same side. For students to understand this phenomenon, two critical features must be discerned simultaneously: 1) the moon rotates on its own axis, and it takes one month for it to rotate once; 2) the moon revolves around the Earth, and it also takes one month for it to revolve around the Earth once. Many students are able to discern these two critical features independently, but if they cannot discern them simultaneously, then they will be unable to understand the phenomenon. For example, some students might focus on the rotation of the moon and think that after half a month it will have rotated 180 degrees, and therefore will have its back to the Earth! Their intuition tells them that if the moon rotates on its axis, then there is bound to be a time when its back is facing the Earth. These students have this view because they have not discerned that while the moon is rotating, it is also revolving around the Earth. Of course, if the moon did not revolve and remained in its original location, then we would certainly see its other side. However, after half a month, the moon has already reached the other side of the Earth, and therefore its other side will not be facing the Earth, but rather outer space, as shown in Diagram 2.2.

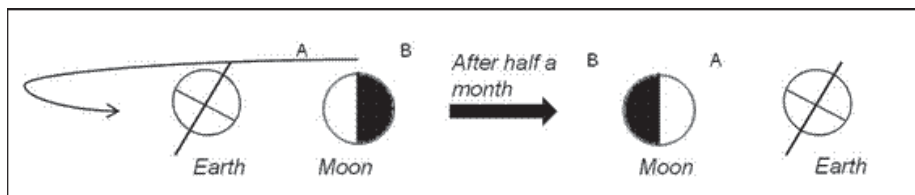


Diagram 2.2 Simulation of the moon's revolution from the right to the left side of the Earth

## Summary

The quality of a lesson can be judged only by its effect on student learning, and whether the learning is worthwhile depends on the object of learning selected by the teacher. The choice of the object of learning affects the quality of students' learning. Whether the teacher can identify the critical features and draw them out directly affects whether students are given the opportunity to learn. Here, it is important that we say 'whether the students are given the opportunity to learn', not 'whether they can learn'. We make this distinction because although the teacher can increase students' opportunities to learn, whether the students actually learn depends, amongst other factors, on how they experience the object of learning during the lesson. However, if the teacher does not create the

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necessary conditions for students to be able to discern the critical features of that object, then students will not be able to learn from the lesson.

The reader may have the impression that the critical features can be identified in advance simply by analysing the content, but this is not the case. Critical features are critical because the learners participating in the study have problems with them. Thus, the critical features are always empirically determined, even though some can frequently be identified through analysis of the content because they are often the defining features of the phenomenon in question. Critical features will be dealt with in greater detail in Chapter 3.

The chart in Diagram 2.3 summarises the various terms discussed in this chapter and the relationships amongst them.

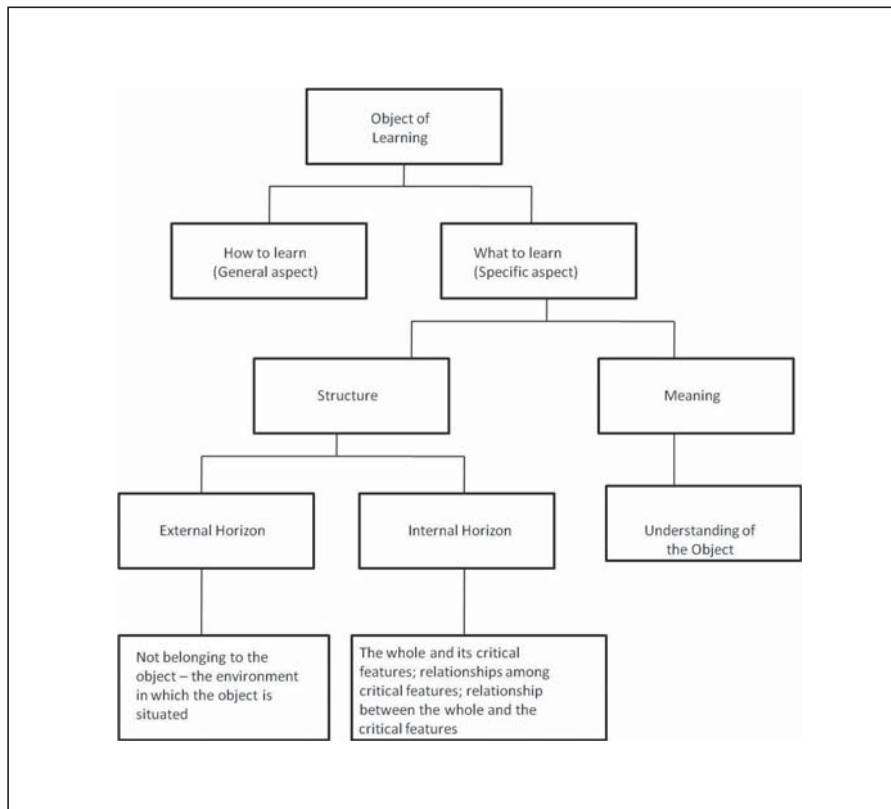


Diagram 2.3 The relationship between the object of learning and its attributes



## Chapter 3

# Critical Features and Critical Aspects

### Introduction

As mentioned in the previous two chapters, an object has many features. When we focus on certain features we see the object in a particular way. However, when we focus on other features we will see the same object differently.

#### Example 3.1

Human hands possess many features, such as muscles and bones, palm prints, fingerprints, contours, textures. Depending on which features we discern and focus on, we will acquire a different understanding of hands. Conversely, to understand hands in a particular way, we must focus on certain specific or critical features. For example, from the perspective of criminology, to understand the hand as a tool for crime detection and the identification of persons, fingerprints are the critical feature, whereas other features such as the space and gestures that hands can produce are irrelevant and may even be distracting information. For artists seeking to understand hands as an object of art, the contour and texture of hands and the sense of space and strength conveyed by gestures are the critical features. To understand hands from a particular point of view, only the features that correspond to this view are critical, although hands possess many different features.

In this chapter, the critical features of an object of learning and how these can be identified are discussed in more detail.

### The difference between critical features and critical aspects

After reading the first two chapters, the reader may have formed the impression that the terms ‘critical features’ and ‘critical aspects’ are being used interchangeably. However, they are not equivalent. Critical aspect refers to a dimension of variation, whereas critical feature is a value of that dimension of variation. For instance, when I describe a dog as a big, brown Alsatian, I am referring to its critical features: big, brown and Alsatian. When we have discerned

its critical features, it means that we must at the same time also have discerned some of its critical aspects, such as size, colour and pedigree. This is because unless we understand the concept of size, we cannot talk about big or small. When we can differentiate between big and small, a dimension of variation (size) opens up. Similarly, it is not possible to discern 'brown' without discerning the dimension of variation of colour, nor Alsatian without at the same time discerning the dimension of variation of pedigree. In this book, when I mention the critical features of an object of learning, the reader should also be mindful of the relevant critical aspects, although they may not be stated explicitly because critical features and critical aspects are indivisible. When students are able to discern the critical features, they must also have discerned the relevant critical aspects. For example, every Chinese character possesses three aspects – morphological, phonological and semantic – and the actual form, sound and meaning of each character are the critical features of that character.

## The importance of identifying critical features

Before deciding how to teach an intended object of learning, teachers must first identify the critical features of that object of learning. There are two important reasons for determining the critical features.

### 1. To facilitate teachers' understanding of the object of learning

The results of phenomenographic studies tell us that teachers and students may see the same object of learning differently. Teachers' ways of seeing things are usually influenced by the 'natural attitude' (Marton & Booth, 1997, p. 148). Nevertheless, our understanding of an object is due to our simultaneously focusing on certain features. In other words, if we expect others to have the same understanding of the object as we do, we must help others to discern these same features (the critical features for this way of seeing) and focus on them. Yet although we may have already discerned these critical features and grasped the relationships among them as a whole, resulting in a state of 'fusion' in which the features and the whole are experienced as an undivided entity, we may not be able to identify certain individual critical features unless our natural attitude is suspended and we attempt to analyse the object of learning carefully.

Example 3.2<sup>7</sup>

In 1983, the J. Paul Getty Museum in California acquired a kouros, a perfectly preserved marble sculpture dating from the sixth century, for US\$10 million. A kouros is a sculpture of a nude male youth standing with his left leg forward and his arms at his sides. There are only about two hundred kouros in existence, and most have been badly damaged or are found in fragments in grave sites or archaeological digs. However, this one was almost perfectly preserved. It stood close to seven feet tall. The museum spent three years conducting a thorough investigation using a variety of forensic methods to test the authenticity of the sculpture. Finally, they decided to buy it. When the sculpture went on display for the first time, some of the world's foremost experts on Greek sculpture felt that it did not look right. They sensed that it was a fake, but could not say why. Finally, it was proved that the instinctive sense of these experts was correct. The experts had developed the ability to focus on all the critical features of ancient Greek sculptures all at the same time to form a quick impression. In other words, they had already discerned the critical features of kouros, the relationships among them and their relationship with the whole, which had 'fused' to give them their instinctive sense of these objects. When asked to explain their instinctive sense, they first had to separate the critical features that had already been fused, which they initially found difficult. These features were not at once obvious to them until they stopped to analyse their own understanding of the kouros and took the whole apart again analytically.

We may have similar experiences that we simply know about something but cannot say why. It takes some time before we can unpick the rationale behind our thinking. For example, when a person who cannot ride a bicycle asks a cyclist how to ride a bicycle, the most probable answer that he or she will receive is that 'practice makes perfect'. Of course, some students may be able to ride a bicycle after a lot of practice. However, if they are helped to discern the critical features of riding a bicycle, for example that the bicycle should have forward momentum, and the cyclist must push hard on the pedals at the beginning to create that forward momentum; or that the bicycle should be maintained in a balanced position, so that if it tilts to the left then the rider should lean to the right, then it is more likely that they will learn to ride a bicycle successfully and quickly.

Another example is the learning of fractions in mathematics. When we say that a fraction is one third ( $1/3$ ) or one tenth ( $1/10$ ), we mean  $1/3$  of 1 or  $1/10$  of 1.

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<sup>7</sup> This example comes from Gladwell, M. (2005). *Blink: the power of thinking without thinking*. USA: Little, Brown and Company, Hachette Book Group.

However, we do not usually specify the unit (or the whole) as 1, but mostly take it for granted. Nevertheless, this critical feature is a source of learning difficulty for many students. In Example 2.7 in Chapter 2, which is about teaching storytelling to primary students, many teachers shared the idea that ‘practice makes perfect’. However, if teachers themselves cannot discern the critical features for tell a story fluently, then it will be difficult for students to learn this skill. Teachers must override their natural attitude and recognise that it is quite natural for students to see the object of learning in a different way to the way that they themselves see it. The only way that teachers can help students learn to see the object of learning in the same way that they do is to first analyse and identify the critical features that they themselves focus on to arrive at the meaning that they have acquired of the object of learning. They must then make use of variation to guide students to discern each critical feature and the relationships among the features and between the features and the whole to bring about fusion. For instance, when teaching storytelling to children, teaching should not stop at ‘we are going to teach children to tell a story fluently’, but must also answer questions such as ‘what must children learn to be able to tell a story fluently?’

## 2. To help teachers deal with students’ individual differences

According to Variation Theory, by having learned ‘something’, the learner must have changed his or her way of seeing that ‘something’, which may lead to a more thorough understanding or a wider perspective of the ‘something’, or even a totally new way of seeing it. This is because the learner now focuses on features or aspects of the ‘something’ that he or she ignored in the past. The learner may not have been aware of the existence of these aspects or may simply have taken them for granted and left them in the background. The responsibility of teachers is to provide opportunities for students to discern previously neglected critical features or aspects.

When students are unable to learn what is intended, in most cases the reason is not their lack of ability, but the fact that they have missed some of the critical features of the object of learning. There are several reasons why this happens. For example, students may not have paid attention during the lessons, or their intuitive way of seeing may be obstructing the intended new way of seeing. Another important reason is that teachers may not have provided learning experiences that give students the opportunity to discern the necessary critical features and aspects.



## CHAPTER 3

To tackle the problem of student diversity in learning, teachers must identify and actively help students to discern the critical features of the object of learning. From among the many critical features of an object, teachers must also identify those that are causing students learning difficulties. Some critical features are easier to identify than others. Some critical features are particularly difficult for teachers to identify because the teachers themselves do not find these features difficult to discern, and take them for granted. They do not highlight these features in their teaching because they may not realise that it is necessary to do so, or may even be unaware of them. A learning gap is then created. Students who happen to be able to discern these features will come to a better understanding of the topic and will be considered more able by the teachers. Those who do not discern these features are left puzzled, as they have missed pieces of information that are vital to their understanding of the intended object of learning.

### Example 3.3<sup>8</sup>

A drama teacher who wanted to teach students to use body language to express emotions encountered difficulties. Although the teacher had already demonstrated the actions many times, some students still could not perform them. At first, the teacher thought that the students might be shy or of low ability. When the teacher noticed that some students were actually trying very hard to imitate his actions but failed, he examined the students' imitative actions carefully. He found that the students only paid attention to his overall actions and had failed to discern the critical features. Once the teacher had identified this problem, he analysed the critical features of each action with the students. For instance, the critical features of expressing fear include 1) a finger being clamped over the mouth or biting the fingers; 2) grinding the teeth (to express trembling); 3) moving the hands up and down (to express trembling); 4) widening the eyes. The teacher then asked the students to try the action for each critical feature and then to perform all of the actions simultaneously. He found the learning outcome encouraging, with all of the students grasping the concept of body language to a certain extent. Whereas formerly the teacher had merely told the students that they had not done well, which made the students feel frustrated and helpless, he could now identify which critical features the students had failed to grasp and give specific feedback to help them to improve. As a result, all of the students were able to grasp how to express emotions using body language.

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<sup>8</sup> This example comes from Learning Study VL060 in the Variation for the Improvement of Teaching and Learning (VITAL) Project carried out by Lo-Fu Yin Wah, Tam Cheung-on Thomas, Lo Ka Yan, Chin Shun Tak and Wong Lai Ping. The project was funded by the Education Bureau of Hong Kong.

In this example, the teacher was at first not aware that he was asking students to perform actions that he himself had mastered and taken for granted. As the students had not been led to see that the action of expressing fear was actually a combination of several actions, they found it very difficult to meet the teacher's expectations. Once the teacher had identified the reason for the students' learning difficulties, he knew to deal separately with each of the critical features, with the result that all of the students, regardless of how they had performed before, learned successfully. If the teacher wished to raise the quality of the learning further in this case, he could analyse with the students the different critical aspects that constitute fearful expression, and how these critical aspects come together to constitute the expression of fear. For example, what happens to our hands when we are frightened? We may cover our mouth with our hands, we may bite our fingers or our hands may tremble. This opens up a dimension of variation – the way of moving our hands when we are frightened – and students could be encouraged to think about other examples of moving the hands to express fear (i.e., other values in this dimension of variation). In the same way, the teacher could help students open up yet more dimensions of variation (or critical aspects) of expressing fear, such as the behaviour of our eyes or the way we move our mouth. The teacher could also discuss how these different gestures come together and become our body language. In this way, all of the students, both high achieving and low achieving, are more likely to be able to learn.

## Identifying the critical features of an object of learning

Teachers and students have different experiences of an object of learning, so naturally have different ways of seeing it. Teachers usually have difficulty understanding students' learning difficulties because they themselves do not encounter difficulties with the object of learning. As noted, sometimes students' difficulties are caused by teachers taking certain critical features for granted and leaving them in the background rather than highlighting them in class. If the students' perception of the object of learning can be identified and compared with the way of seeing that the teacher wants the students to develop, then it should be possible to identify which critical features the students have failed to grasp so that these can be taught specifically and effectively. There are many different methods of finding out the critical features of an object of learning, including a literature review, sharing past experience of teaching this topic with other teachers, interviewing students, administering a carefully designed

diagnostic pre-test and post-test and analysing the results of the students' responses, and observing lessons taught by another teacher and listening carefully to students during the lesson to find out how they see the object of learning. These methods are explained in more detail in the following sections.

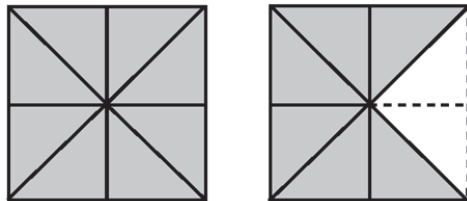
### 1. Literature review and sharing among teachers

Teachers should have a deep understanding of the basic concepts and knowledge structure of the discipline that they teach, including the relationships among the various concepts (e.g., hierarchical or sequential), the specific language used to express concepts in the discipline, the nature of the discipline and the specific methods employed to teach it. If such knowledge is lacking, then teachers will not know which units of study are most fundamental, and will not be able to determine the most appropriate sequence of study (e.g., which concepts are super-ordinate and which are subordinate) or to choose the most worthwhile topic to teach, let alone being able to identify students' learning difficulties. This reflects the notion that teaching is a professional activity. Teachers need not work in isolation; collaborating, sharing and discussing with peers can inspire teachers and help them to identify the critical features of the object of learning more effectively. According to Cochran-Smith and Lytle (2001), teachers are better able to adapt to the changing culture of school reforms and achieve high-quality teaching and learning when a wide range of teaching options is made possible through peer talks, analysis and interpretation. Through an in-depth study of the object of learning, the sharing of teaching experience among teachers, discussions and literature reviews, most of the critical features of an object of learning can be found.

#### Example 3.4

The following teaching content is given in a Primary Four mathematics textbook.

Look at the following diagrams: what is the fraction represented by the shaded part?



*Diagram 3.1* Diagram from a mathematics textbook for Primary Four students

Students who take the unit as being two squares will give the answer  $14/16$ , because they see the two squares as being divided into 16 parts, each part being  $1/16$  of the whole, and there are altogether 14 such parts. In contrast, students who take the unit as being one square will give the answer  $14/8$ , as they see each square as being divided into eight parts, each part being  $1/8$  of a square, and there are 14 of such parts. Both answers are, in fact, acceptable if the unit is clearly specified. However, if the teacher or even the writer of this textbook had in mind the question  $8/8 + 6/8$  and is using the diagram as an illustration of this, then the only acceptable answer would be  $14/8$ , as it has been taken for granted that one square is the unit. Students who see the unit as two squares and hence give the answer as  $14/16$  are very quickly given the feedback that their logic is wrong and that they are 'less able' at mathematics. An experienced mathematics teacher, after being involved in learning studies, discovered from reading the literature that 'unit' and 'unitising' are critical features of learning fractions (e.g., Lamon, 1999). In the research lesson, she dealt with these critical features and found that students made significant progress in learning fractions. She shared her findings as follows.

*Teachers have to find out students' prior knowledge. If they [the students] do not have a solid foundation, then they cannot construct new knowledge . . . I also found that the prescribed curriculum sometimes misses out the critical aspects and features. For example, in the teaching of fractions, the curriculum guide makes no reference to the concept of 'units and unitising' . . . After we completed the research lesson, the students had a better grasp of the concept of 'units'. When I later taught multiplication and division of fractions in P5, I was able to save a lot of time. (Taken from a teacher interview in a Learning Study case in the Catering for Individual Difference – Building on Variation(CID(v)) project funded by the Curriculum Development Institute of Hong Kong).*

#### Example 3.5<sup>9</sup>

A group of English teachers found that their students had difficulties asking questions using 'wh' words, such as what, who, whose, where, when and whom. Through discussion with the researchers, the teachers recognised that apart from choosing the appropriate 'wh' words, students must also understand the following points to form a grammatically correct question.

1. Whether the verb 'to do' or 'to be' should be used.
2. The appropriate use of pronouns.
3. The correct subject verb agreement.

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<sup>9</sup> This example comes from Learning Study VL011 in the "Variation for the Improvement of Teaching and Learning" (VITAL) project carried out by Derek Sankey, Joanne Ng, Phyeon Ma, Linda Mak, Manda Ng, Naomi Suen and Anita Li. The project was funded by the Education Bureau of Hong Kong.

## 4. The appropriate use of tense.

In the past, when a student wrote the following sentence ‘Where is Mary takes her piano lessons?’, the teachers would simply mark it wrong with a big ‘X’. Both teachers and students were frustrated, as only a few students were able to answer the question correctly. The teachers then realised that they should analyse what the students had learned and praise the students for being able to use the ‘wh’ word ‘where’ and the pronoun ‘her’ correctly. At the same time, they should also analyse what the students had not learned, that is, using the verb ‘to do’ (does) instead of the ‘verb to be’ (is), and following ‘does’ with ‘take’ rather than ‘takes’. These findings helped the teachers to give specific feedback to students and to plan their future teaching to deal with the critical features that the students had initially failed to discern.

## 1. Finding out from students’ ways of seeing

Critical features are critical precisely because learners have problems with them. The critical features of an object of learning must thus always be empirically determined, even if most of them can be found by analysing the content, as they are often defining features of the phenomenon in question. Teachers have to ask learners ‘what their experiences are like, watch what they do, observe what they learn and what makes them learn, analyse what learning is for them’ (Marton & Booth, 1997, p. 16). Teachers can make use of several methods to find out the relevant information, including a pre-lesson student interview focusing on the content to be learnt, a carefully designed diagnostic pre-test to analyse student learning difficulties, providing opportunities for students to express their thoughts during the lesson and listening to their opinions carefully.

*(1) Pre-lesson student interviews*

Students carry to the classroom their own preconceptions, or intuitive understanding, of the things to be taught even before teachers have made a formal start on teaching them. These preconceptions or beliefs may be incomplete or incorrect, and may become barriers to students’ learning and seeing the object of learning in a new way. The first step in helping students to learn is to find out the different ways in which students understand the thing to be taught so that teachers can target students’ learning difficulties. Probable learning difficulties can be identified by interviewing students who are going to learn or who have already learnt the topic.

Example 3.6<sup>10</sup>

To find out the learning difficulties of students learning about the image formation of plane mirrors, a teacher interviewed a Secondary Four student. As the student has already learnt this topic in the previous year, the teacher hoped to find out the kinds of difficulties that this student had encountered when learning this topic. At first, the student was able to answer all of the questions correctly. She was able to point out that an image would be formed behind the mirror if a pen was put in front of the mirror, and that the object distance and the image distance were the same. The teacher then asked, ‘if you move to another position, will the position of the image change?’ and the student answered, ‘No, because the pen does not move’.

Up to this point, the student seemed to have learnt very well. However, the teacher’s subsequent questions revealed a gap in the student’s understanding.

*Teacher: What did you find most difficult when learning the topic ‘Optics’?*

*Student: It is problematic to link the ray diagram with real situations.*

*Teacher: In everyday life, what is related to this ray diagram?*

*Student: For example, I find it weird that my image is behind the mirror when drawing the ray diagram.*

*Teacher: In your opinion, where should the image be?*

*Student: I think it should be on the surface of the mirror. In reality, our image is on the surface of the mirror!*

*Teacher: If I put the pencil here and put the mirror in the original position, where is the image? Here? (The teacher put another pencil close to the surface of the mirror to represent the position of the image.)*

*Student: Yes, as you are looking at the mirror, you will find the image on the surface of the mirror.*

*Teacher: Oh, yes, why did we say that it goes to the back of the mirror?*

*Student: When the ray diagram is drawn, the image is formed at the back.*

*Teacher: Do you believe that?*

*Student: It is hard to say whether I believe or not. My teachers told me this, scientists also say this . . . so it should be like this.*

In this example, although the student was able to point out the correct position of the image formed by the plane mirror, her answer was based on what her teacher had told her. She did not understand the concept and actually did not

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<sup>10</sup> This example comes from Learning Study VL042 in the “Variation for the Improvement of Teaching and Learning” (VITAL) project carried out by Ng Pun Hon, Walter Lam, Cheung Cheuk Wai and Wong Jack. The project was funded by the Education Bureau of Hong Kong.

believe in it. She was simply faithfully reproducing the required answer so that she would get high marks and pass the examination. If the teacher only marked the student's assignments or examination paper, he would not have been aware that the student's learning difficulties persisted. A critical feature that the student had failed to discern was that the image formed behind the mirror was actually a *virtual image*. As light rays from the object are reflected by the mirror and the angle of incident is equal to the angle of reflection, the light ray will appear to diverge after leaving the mirror. When our eyes see the reflected rays, the brain assumes that light travels in a straight line, and so tells us that the divergent rays comes from a point that is behind the mirror. From the confusion expressed by the student, the teacher realised that 'the image formed behind a plane mirror is a *virtual image*' is a critical feature that needs to be highlighted in teaching so that students can discern it. Of course, the student's teacher might already have mentioned this when he taught the topic. Teaching or mentioning a concept does not guarantee that students will be able to learn it. However, a teacher can make use of patterns of variation to help students discern the critical feature that 'the image formed behind a plane mirror is a virtual image'. For instance, students could be asked to compare the images of the same pencil by using a convex lens and a plane mirror. The image formed by the convex lens will be visible on a screen whereas the image formed by the plane mirror will not. Another method is to make use of a ray box. Students could be asked to observe light rays in two situations. Light rays travelling through a convex lens can be focused to a point, whereas light rays cannot travel through a plane mirror and focus to a point, but are reflected back and leave the mirror as divergent rays, which, when extrapolated, will converge to a point behind the mirror.

Some learning difficulties are due to students' prior experience and misconceptions, and may not be easily predicted by teachers.

Example 3.7<sup>11</sup>

An English teacher found that her students could not understand the usage of simple past tense. In a pre-test, students were asked to write a letter to a friend. In the post-lesson interview, a students was asked, 'If you write a letter to a friend, what tense should you use?' The student answered, 'was (past tense)'.

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<sup>11</sup> This example comes from Learning Study VL097 in the "Variation for the Improvement of Teaching and Learning" (VITAL) project carried out by Ann He, Lancy Tam, Jolene Pedde, Valan Chan and Sam Ho. The project was funded by the Education Bureau of Hong Kong.

- Teacher:* Why would you use 'was'?
- Student:* Because it is a letter.
- Teacher:* What tense is 'was'?
- Student:* Simple past tense.
- Teacher:* Does it have anything to do with the letter?
- Student:* The letter has been posted. [The recipient reading the letter] happens after a long time. So, simple past tense should be used.
- Teacher:* Oh! That happens after a long time. So, simple past tense should be used. [The teacher checked the post-test of the student. She found that he had used simple present tense and so she asked a follow-up question.] However, I have a question. You said simple past tense should be used in writing a letter. Why didn't you use it this time [in the letter just written]?
- Student:* Because it is written at this moment and is not going to be sent to others, so present tense should be used. It is going to be given to the teacher now.
- Teacher:* If I asked you to write down what happened on Sunday, what tense would you use?
- Student:* Simple present tense.
- Teacher:* Simple present tense?
- Student:* Oh, no. Present continuous tense (because the teacher will read it while I am writing the letter).

This example shows that the student made the choice of tense according to the time when the recipient would read the letter. Clearly, it is necessary for students to realise that the choice of tense should be made according to the time when the actions or events occur, and this is a critical feature. The way of thinking of this student is strange, but he has his own logic. The problem is that his answer would be correct in certain situations (e.g., writing a letter to someone about something that happened in the past), which will reinforce his belief. However, in other situations, he will be told that he is wrong. If this student is not given appropriate feedback to help him clarify his misconception, he will lose confidence in learning English, and may give up and become a 'less-able' student. In this example, if the teacher wants to help the student to learn, she must first understand the student's logic and how this logic affects the student's learning and take the right steps to tackle the problem. This example shows that the learning difficulties that students encounter in learning are usually the best sources for teachers to determine the critical features of the object of learning.

*(2) A carefully designed pre-test and in-depth analysis of students' answers*

By interviewing students, it is possible to find out how some students see things. To check whether other students share this way of seeing or the same learning



difficulties, a carefully designed diagnostic pre-test and post-test can be conducted and students' answers analysed thoroughly. It should be stressed here that the questions in the pre-test and post-test should be analytical and focus on the critical features of the object of learning. For example, to test students' storytelling ability, every student should be asked to tell a story, which should be recorded or videotaped for further analysis. To test whether students understand the function of a first paragraph and how to write it, every student should be asked to write the first paragraph of a passage for which the title and content have been given, and their work should be carefully analysed. Open-ended questions could be included to determine other ways of seeing.

Example 3.8<sup>12</sup>

In a Secondary 2 English lesson, the teacher decided to teach the usage of relative pronouns. To determine students' learning difficulties with using relative pronouns, they were asked to join two sentences by using a relative pronoun:

- The man forgot his umbrella.
- I worked with him on this case.

The students' mistakes could be divided into two groups:

1. The man forgot his umbrella whom I worked with him on this case.

These students were able to use the relative pronoun 'whom' correctly, but had left the pronoun 'him' in the sentence. The students had failed to identify that 'whom' should be used to replace 'him'. Moreover, the relative pronoun was placed in the wrong position: it should be placed immediately after the antecedent, in this case 'man'. The sentence originally meant that 'I worked with this person on this case', but it becomes 'I worked with his umbrella!' The sentence should be rewritten as 'The man with whom I worked on this case forgot his umbrella'.

2. I worked with the man on this case who forgot his umbrella.

These students used the relative pronoun 'who' correctly, but placed it wrongly. The sentence originally meant that 'this person forgot his umbrella', but becomes 'this case forgot his umbrella'. The sentence should be rewritten as 'I worked with the man who forgot his umbrella on this case.'

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<sup>12</sup> This example is from a learning study case from Shatin Tsung Tsin Secondary School led by Zhang, Yuefeng Ellen in 2009.

Furthermore, the teacher also found that the main clause in the first example was different from that in the second example (In Example 1, the main clause is ‘The man forgot his umbrella.’ In Example 2, the main clause is ‘I worked with the man on this case.’) The teacher thus asked another question: ‘what is the difference between the two sentences: ‘I worked with the man who forgot his umbrella on this case.’ and ‘The man with whom I worked on this case forgot his umbrella?’’ The students thought that the two sentences were the same, and thus had the same meaning. From this, the teacher discovered that apart from the position of the relative pronoun and what it replaces, there is another learning difficulty that needs to be overcome: the meaning and function of the main clause and the relative clause and the relationship between them. This is one of the critical features of relative pronouns.

#### Example 3.9<sup>13</sup>

In a S.4 Chemistry lesson, the teacher intended to teach the factors affecting the rate of chemical reactions. He interviewed some students about the topic. Some students thought that the volume of the reactants was one of the factors, which is not correct. To find out if this misconception was common, the teacher designed a pre-test that contained the following question.

*Consider the chemical reaction between zinc and 10 c.c. of 1M hydrochloric acid. If 20 c.c. of 1M hydrochloric acid is used instead, then how will the rate of reaction be affected?*

The teacher asked students from S4A and S4B to sit the pre-test. The results showed that 52% of the S4A students and 89% of the S4B students thought that the reaction rate would increase because the volume of acid used had doubled. On discovering that so many students had this misconception, the teacher decided to include ‘if the concentration of the reactants is unchanged, then the rate of chemical reaction is not affected by the volume of the reactants’ as a teaching focus. When learning ‘X’, it is important to teach what ‘X’ is, but it is equally important to teach what is ‘not X’.

### (3) Lesson Observation

Sometimes, critical features cannot be uncovered in pre-lesson interviews, but only emerge when the students interact with the object of learning during the lesson.

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<sup>13</sup> This example comes from Learning Study VL005 in the “Variation for the Improvement of Teaching and Learning” (VITAL) project carried out by Lo Mun Ling, Hung Hoi Ying, Lee Chi Shing, Wong Yiu Cheung and Yung Wing Hin. The project was funded by the Education Bureau of Hong Kong.

Example 3.10<sup>14</sup>

A teacher teaching condensation in ‘the three states of water’ had identified two critical features: water vapour condenses when it meets a cold surface (i.e., temperature is a factor) and there is water vapour in the air that is invisible. In the lesson, the students were asked to observe two cans of soft drink. One had been left in the classroom at room temperature, and the other was taken out of a refrigerator. After a while, the students noticed that water droplets had formed on the surface of the cold can, whereas the surface of the can at room temperature remained dry. The teacher discussed the factors that had caused the formation of water droplets on the can with the students. All of the students said that it was due to the temperature change, and that water droplets had formed because the can was cold. This is probably because the teacher had used the following pattern of variation:

Table 3.1

Kept Invariant	Varied	What is to be discerned
Soft drink can	Temperature of can: room temperature vs. cold	Water droplets were only found on the cold can.

Experiencing the variation in temperature and finding that the emergence of the water droplets on the cold can only helped the students to discern that water droplets are formed only on a cold surface. The teacher was very happy about the learning outcome, and went on to ask, ‘Where do the water droplets come from?’ As the students had learned about evaporation in the previous lesson, the teacher was expecting the students to answer that they came from the air, indicating that the objective of the lesson had been achieved. Instead, the teacher was surprised by the students’ answers.

*The water droplets come from the refrigerator.*

*The water inside the can leaked out! My water bottle is the same. When Mum took it out of the refrigerator in the morning, it was cold. I put it in my school bag and it leaked.*

Although the teacher did not expect these misconceptions from the students, fortunately she was tactful and provided opportunities for the students to express their ideas. She listened to the students’ responses carefully and gave them appropriate feedback immediately.

<sup>14</sup> This example is from a Learning Study case from Shap Pat Heung Rural Committee Kung Yik She Primary School carried out by Lo Mun-ling and Lai Meng Choo in 2003.

To deal with the first misconception, the teacher wiped the cold can with a piece of dried cloth, yet water droplets still formed on the surface of the can after a short while. The teacher repeated the procedure several times. The students then agreed that the water droplets did not come from the refrigerator, but must have been formed after the can had been taken out of the refrigerator.

To deal with the second misconception, the teacher poured away all of the soft drink inside the can and wiped the surface of the can. Again, water droplets began to form on the surface after a while. The students then realised that the water droplets were not leaking from the can.

#### *(4) Post-lesson Interview and Post-test*

The relationship between teaching and learning is not a causal one. Teaching can at most make learning possible and determines how this possibility is constituted. It is thus important to study not only how to teach and produce lesson plans and teaching materials, but also to understand what opportunities have been opened up for students to learn and what they have actually learnt. If ‘learning’ has really taken place in a lesson, then this can only be understood from what students have actually learnt. The learning outcome is also different for every student. How students understand the object of learning depends on the features of the situation or phenomenon that they have identified and discerned. To improve their teaching, teachers must try to learn from their actions, reflect and gain feedback on their teaching in the spirit of action research. Although teachers may correctly identify all of the critical features of an object of learning and successfully elicit them in the lesson, this only reflects the teacher’s effort in bringing out the ‘enacted object of learning’; there is no guarantee that the students have learnt in the way intended. Students’ learning is affected by their prior knowledge, previous experience and their experience during the lesson. Further, in our experience, it is unusual for all of the critical features to be uncovered in one study.

##### Example 3.11

To find out whether the students in Example 3.10 had grasped the concept of condensation, the researcher conducted a post-lesson interview with three students of different academic achievements – high, middle, low – to ascertain how students of different levels had understood the object of learning.

All of the students agreed that water condenses when the temperature decreases and water droplets are then formed. When asked where the water droplets came from, all of

the students agreed that they came from the air. However, when the researcher asked if they really believed that there is water vapour in the air, one student said, 'I don't believe there is water vapour in the air. If there was water in the air, then we would all have been drowned in air!'

*Researcher: Did the teacher demonstrate in the previous lesson that water evaporates when it is heated?*

*Student: Yes, water becomes air when it is exposed to heat.*

*Researcher: What do you mean by 'becomes air'? Do you mean the oxygen we breathe and the carbon dioxide we exhale?*

*Student: It will become oxygen, but not carbon dioxide. For example, hydrogen, which is very light and it can float . . . You see . . . there is no water on some planets, so there is no air. There is water on Earth, so there is air . . .*

In addition to learning at school, students are constantly learning through many other channels, such as books and television programmes, and form different ideas about an object of learning before they actually encounter it in class. When that which the teacher teaches seems to contradict their own 'theory', and the teacher is not aware of the students' doubts, misconceptions and learning difficulties, students will try to resolve the problem on their own using their prior knowledge and logic. The aforementioned interview highlights that a very important critical feature – what actually happens to water when it evaporates – was not covered. In teaching this topic, teachers need to deal with the following questions.

- What is the difference between water in the gaseous state and the liquid state?
- Air is a mixture of several gases; water vapour is only one of them.
- Why can a change in temperature cause water to change its state?

It is impossible for students to understand and grasp the concept of evaporation if these critical features are not dealt with in the lesson. Teachers can make use of the information obtained in post-lesson interviews to design the next lesson such that they can help students to resolve their learning difficulties and contradictions with their prior knowledge.

## Conclusion

To fully understand students' learning difficulties, teachers must adopt an inquiry approach and consider themselves as learners. If every teacher takes students'

ways of seeing the object of learning seriously and adopts an action research approach to identifying the critical features of the object of learning, then students will be afforded better opportunities to learn, and for some students, learning that was once impossible may become possible.

## Chapter 4

# Using patterns of variation

### Introduction

*'No conditions of learning ever cause learning. They only make it possible for learners to learn certain things'* (Marton, Runesson & Tsui, 2004, p. 22-23). The teaching and learning relationship is not one of cause and effect, but of what is made possible in the lesson (through the enacted object of learning jointly constituted by the teacher and the students) and what possibilities are actually made use of by the students themselves (the lived object of learning experienced by the students). To discern the critical features of novel situations, or to discern previously taken for granted features of familiar situations, learners must *experience for themselves* certain patterns of variation and invariance of these features. This is a *necessary condition* of learning. Although teachers cannot make their students learn, they can make learning possible by paying attention to this necessary condition of learning.

As Bransford, Brown and Cocking (2000) point out,

*A common misconception regarding 'constructivist' theories of knowing (that existing knowledge is used to build new knowledge) is that teachers should never tell students anything directly but, instead, should always allow them to construct knowledge for themselves. This perspective confuses a theory of pedagogy (teaching) with a theory of knowing . . . teachers still need to pay attention to students' interpretations and provide guidance when necessary (p. 11).*

Thus, teaching should be a conscious structuring act. Students have to learn to be discerning, and do not necessarily discern naturally what they need to discern. They must learn to discern every quality (feature), whether innate or not (Marton, 2009). It is the responsibility of teachers to create learning conditions that make the required discernment possible.

Several studies have demonstrated the use of patterns of variation to improve student learning outcomes (Runesson, 2005; Marton & Tsui, 2004; Marton & Morris, 2002). Pang and Marton (2003) show that students of teachers who

consciously used patterns of variation learnt better than students of teachers who did not. This chapter explains how teachers can make use of patterns of variation to create opportunities for students to discern the critical features identified. However, teaching is an integrative act and not simply the application of patterns of variation, and thus whether the intended effects of patterns of variation are brought about also depends on the choice and use of appropriate teaching strategies and teaching approaches.

## Variation and learning

Currently, there is too much emphasis on using examples to show similarities. It is held that once students can discern the similarities between examples, they will be able to infer the relevant rules and concepts. The second implication of Donovan, Bransford and Pellegrino (1999) for the enterprise of teaching and teacher education (see Chapter 1) is that ‘teachers must teach some subject matter in depth, providing many examples in which the same concept is at work and providing a firm foundation of factual knowledge’ (p. 11). However, according to Variation Theory, relying solely on similarities is not sufficient. Marton (2009) asserts that awareness of a single feature cannot exist without an awareness of the differences (variation) among features. There can be no discernment without experienced difference, and there can be no experienced difference without a *simultaneous* experience of at least two things that differ.

### Example 4.1

The concept of ‘hot’ cannot exist without the concept of ‘cold’. If everything in this world were at the same temperature, then we would not be able to discern hotness; similarly, it is only through experiencing the difference between hot and cold that the concept of coldness can be discerned. Hot and cold constitute a dimension of variation (degree of hotness, or temperature). Just as the awareness of hotness cannot exist without the simultaneous awareness of coldness, there cannot be an awareness of either coldness or hotness without the simultaneous awareness of temperature. That is, the dimension of variation (temperature) must be experienced at the same time as its values (cold and hot). Temperature is a critical aspect (dimension of variation) of an object (e.g., water, air), and being hot is a critical feature (a value along the dimension of variation) of the object. For finer differentiation, different temperatures are values along this dimension of variation.

So discernment, simultaneity and variation (or difference) go together. This means that we cannot discern a particular quality based on the sameness of this



quality in different instances. If the world consisted only of males, we would never be able to discern the concept ‘maleness’, and it would be unnecessary to do so. We can only discover ‘maleness’ by juxtaposing it with another quality (i.e., femaleness). However, this does not mean that we cannot learn from sameness to make generalisations, but we can only see sameness *once we are aware of the quality in question*, not before.

#### Example 4.2

A mother wishes to teach a very young child the concept ‘clean’. If she points to some clean clothing and says ‘clean’, then shows a clean handkerchief and other clean objects and says ‘clean’, will the child learn the concept ‘clean’? It would be very difficult because the child may pay attention to other common features among the objects, for example, that they are all made of cloth or that all of them are white. In this case, it is essential for the mother to point out ‘what is not clean’ also, such as showing a dirty handkerchief and saying ‘not clean’ (provided that the child understands the meaning of ‘not’ or the relevant body language like shaking the head, waving the hands or other relevant facial expressions). The mother should also choose handkerchiefs with the same colour, pattern and shape so that the only difference between the two handkerchiefs is that one is clean and the other one is dirty. In this way, the child will be able to understand what the mother means. The mother can then show the child other examples of clean objects so that the meaning of ‘clean’ will be reinforced by similar examples of ‘clean’ things.

Without experiencing difference, it is impossible to discern similarities. Thus, in addition to showing similar examples, teachers must also show non-examples. For example, when teaching students what a triangle is, the teacher should also show students what a triangle is not by comparing it with, say, a rectangle, a pentagon, other polygons, two parallel lines, two intersecting lines and a pyramid. By so doing, students will discern the critical features of triangles by contrasting triangles with other non-examples.

## Kinds of awareness brought about by patterns of variation

### Contrast

Marton (2009) describes the awareness brought about by experiencing the difference (variation) between two values as *contrast*.

Example 4.3

Have you ever tried to play a game in which you have to spot the differences between two similar pictures? If the rules of the game are changed and the two pictures are shown one by one, then the level of difficulty of the game will be much higher because we do not know to which features we should pay attention when the first picture is shown. Unless we have an exceptionally good memory and can remember every detail of the pictures, it will be very difficult to spot the similarities and differences between the two. Conversely, if the two pictures are shown simultaneously for us to compare and contrast, then it will be much easier to spot the differences.

We can discern the critical features of an object more easily if we are able to contrast it with another object. An oft-cited quote from the famous psychologist Kurt Lewin (1890-1947) is pertinent here: ‘You cannot understand a system until you try to change it’. Only with changes in events does one begin to acquire the information necessary to abstract generic properties or define the features of such events. Experienced teachers often make use of contrast to assist students’ learning. Bruner (2006) reports some good examples of using contrast.

*We have leaned heavily on the use of contrast, highly controlled contrast, to help children achieve detachment from the all too familiar metric of social life: the contrasts of man versus higher primates, contemporary technological man versus ‘primitive’ man, and man versus child (p. 126).*

Example 4.4

Many Chinese characters look similar, such as 巳、己、已; 戌、戌、戌, with each character differing from the others in a minor and subtle way. Unless such subtleties are consciously pointed out by the teacher, they may not be easily discerned by students. If a teacher teaches the character ‘己’ on its own, then students may easily write the character wrongly because they are not able to discern the critical features of the character ‘己’. When they later meet the two characters ‘巳’ and ‘己’, they may wrongly assume that all three characters are the same. To enable students to discern the differences among these characters, it would be better for the three characters to be shown simultaneously and the critical difference among them pointed out explicitly. In this way, students will experience the variation of the critical feature and will be more likely to be able to discern it. The same applies to the teaching of the Chinese characters 戌、戌、 and 戌.

As with visible and tangible objects, contrast can also be brought about when students experience variation between their prior knowledge and the new way of seeing the same thing as intended by their teacher. However, when the teacher presents a novel way or a more complete concept in the lesson, this does not

necessarily mean that students will be able to contrast this new way of seeing with their old way of seeing, which may be incorrect or incomplete. In fact, this rarely happens, and the majority of students are quite ready to regurgitate facts that their teachers have told them without comparing these with their own ways of seeing. Without being aware of such differences, when their memory of what the teacher has told them fades, students will revert to their original intuitive way of seeing. This is because the two ways of seeing the same thing have not been brought to the students' focal awareness simultaneously and have not been placed in the foreground, and so the pattern of variation is not effective in bringing about contrast. Certainly, there will be some students who will contrast their prior knowledge with what the teacher has taught and will be able to learn successfully. This explains why in the same class there are always some students who are able to learn while others cannot. However, teachers should not let learning happen by chance. They should consciously create an opportunity to introduce contrast to bring students' original way of seeing and the new way of seeing to the fore so that students will focus on the two simultaneously.

Example 4.5<sup>1</sup>

Many Secondary 2 students lack an understanding of pH value. Many students think that the pH value of a dilute acid will increase if the solution is diluted. However, they do not know that the pH value will increase by one increment only if the solution is diluted ten times, the reason being that pH value and concentration are not directly proportional ( $\text{pH} = -\log[\text{H}^+]$ ). However, the concept of 'log' is beyond the secondary 2 Mathematics curriculum, and so this formula is not taught. The following is a dialogue between a teacher and her students.

*Teacher:* There is about  $50 \text{ cm}^3$  of dilute hydrochloric acid. What do you think its pH value will be?

*Students:* About 1 or 2.

The teacher dipped a glass rod into the dilute hydrochloric acid and then touched a piece of pH paper with the glass rod. The pH paper turned red, showing a pH value of 2.

*Teacher:* Correct! If I now add  $10 \text{ cm}^3$  of water to the dilute hydrochloric acid, what will the pH value be?

*Student A:* I am not quite sure, about 3 or 4.

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<sup>1</sup> This example comes from Learning Study VL103 in the "Variation for the Improvement of Teaching and Learning" (VITAL) project carried out by Lo Mun Ling, Chan Wing Yan, Wong Yuen Shan, Ho Yuen Ting and Yim Bing Man. The project was funded by the Education Bureau of Hong Kong.

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*Teacher: Are you sure that the pH value will increase?*

*Students: Yes!*

The teacher added 10 cm<sup>3</sup> of water to the dilute hydrochloric acid in the beaker and then tested the pH of the solution as before. The colour of the pH paper did not change, which showed that the pH value was still 2. The students were surprised.

*Teacher: If I now add another 10 cm<sup>3</sup> of water again, do you think the pH value will change?*

*Students: It will definitely increase!*

The teacher added 10 cm<sup>3</sup> of water to the 60 cm<sup>3</sup> of dilute hydrochloric acid in the beaker, and again tested the pH of the solution. The colour of the pH paper was the same, which showed that the pH value was still 2. The teacher then added 30 cm<sup>3</sup> of water into the dilute hydrochloric acid. By this time, the dilute hydrochloric acid had been diluted to half its original concentration, but the pH value was still 2. The students were even more surprised.

In this example, if the teacher had directly told the students that the pH value of an acid would increase by one when the acid was diluted ten times, then the students would have memorised this fact but would probably have forgotten it soon afterward. Instead, the teacher made use of variation to help the students contrast their intuitive way of seeing with what actually happened. When the teacher asked the students to guess the pH value, the students' intuitive way of understanding pH was brought to the forefront of their awareness, and when the actual value was found, the two values were simultaneously in their awareness, which allowed the students to discern their own misconceptions.

In this example, to avoid students forming the misconception that the pH value will not change regardless of how much the acid is diluted, it is necessary for the teacher to bring out the pattern of variation in Table 1 by showing students the change in pH value when the acid is diluted more than ten times.

*Table 4.1* Pattern of variation to help students discern the relationship between pH and dilution

Invariant	Varied	Critical feature to be discerned
Amount of acid in the solution	The volume of water added (less than ten times and more than ten times)	The pH value will not change if the acid is diluted less than ten times.  The pH value will increase by one every time the acid is diluted ten times.

Example 4.6<sup>2</sup>

Some English teachers found that their students were not motivated to read in English because they encountered too many unknown words in the reading passages. Having to stop reading and check the meaning of these unfamiliar words in the dictionary killed the students' interest in reading. One teacher decided to teach the students how to guess the meaning of unfamiliar words by picking out contextual clues with the help of transitional words (e.g., otherwise, but, therefore, so, that). The teacher first showed students a passage with a few unfamiliar words and asked if they could understand the gist of the passage. As predicted, the students gave up when they came across new words. The teacher then asked the students what they should do when they met unfamiliar words. Most students said that they would check the meaning in the dictionary or ask for help from teachers or parents. At this point, the teacher told the students that he would teach them how to get the gist of the passage without seeking help from the dictionary or others, which would motivate them to read more. The students showed a strong interest. The teacher taught the research lesson. At the end of the lesson, the teacher showed the students the same passage and asked them about the gist of the passage. All of the students answered the questions correctly. The teacher asked them why they could not understand the passage at the beginning but could do so at the end of the lesson. The students explained that they guessed the meaning of unfamiliar words by context and transitional words. In this example, the teacher made use of variation to bring out contrast to allow the students to discern that they could not understand the passage at first because they did not make use of the context and transitional words to guess the meaning of new words. After they had learnt this strategy, they could understand the passage without checking the dictionary or seeking help. The students not only learned this strategy; they were also motivated to apply it in their reading. In the lesson, the

<sup>2</sup> This example comes from Learning Study VL036 in the "Variation for the Improvement of Teaching and Learning" (VITAL) project carried out by Alice Chow Wai Kwan, Joanne Ng, Megan Chung, Eleanor Tai, Kelvin Lam and Vivien Lui. The project was funded by the Education Bureau of Hong Kong.

reading passage was kept invariant while the strategies used to find the meaning of new words were varied. The students were thus able to experience the difference in their understanding of the passage brought about by the two strategies. The pattern of variation was as follows.

Table 4.2 Pattern of variation enacted in the English lesson

Invariant	Varied	Critical feature to be discerned
The reading passage	The reading strategies: The students' strategy. Guessing the meaning of new words by context and transitional words.	One can understand the passage better if one uses the strategy of guessing the meaning of new words with the help of context and transitional words.

This is an example of embedding the teaching of meta-knowledge (refer to Chapter 1) into the lesson. The teachers utilised this pattern of variation to help the students to discern the benefit of using the strategy of guessing the meaning of new words using contextual clues, and that this is a more powerful strategy.

## Separation

When the learner suddenly becomes aware of a value by contrasting it with another value (e.g., male vs. female, large vs. small, red vs. green), we can say metaphorically that the value is *separated* from the object, and a dimension of variation is opened up (e.g., gender, size, colour). The learner previously treated this object as an undivided whole, but after becoming aware of the value (feature) and its dimension of variation (aspect), is capable of focusing on the value independently, naming it or even changing it. The value becomes visible by opening up the dimension of variation in which it is a value. In this way, the value is separated from the object of which it is a feature. The implication is that we can never understand how others understand something without knowing what it is compared with, or in what dimension of variation it is situated.

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### Example 4.7

The number '10' has different meanings when it features in a decimal system and when it features in a binary system. When in a decimal system, it is a number greater than 9 and less than 11. In a binary system, it is between the numbers 1 and 11, and expresses the same quantity as 2 in a decimal system.

'One cannot learn mere details without having an idea of what they are details of. Learning is mostly a matter of reconstituting the already constituted world' (Marton & Booth, 1997, p. 139). The implication for teaching is that the learning cycle should start with the learner's encounter with the undivided whole, with the question that they are supposed to learn to address. Thus, it is useful for a teacher to first help students to separate the object of learning from its context. Such an encounter does not make it possible for the students to discern the critical features, but creates a 'relevance structure' that provides them with an experience of the undivided whole from which the critical features can subsequently be discerned.

### Example 4.8<sup>3</sup>

In a language lesson in a primary school, a teacher aimed to teach students to enrich the content of a passage by writing descriptions of the mental state of the characters. Before teaching the critical features of the object of learning, the teacher decided to help students to discern the object of learning as a whole and why learning it is worthwhile. The teacher adopted the following teaching strategy. He showed two passages to students.

First passage:

*'A student found a hundred-dollar note on the floor. He looked around and found that nobody was there, so he picked up the note and kept it'.*

Second passage:

*'A student found a hundred-dollar note on the floor. His desire to buy stationery immediately came to his mind, so he picked up the note. However, he was worried that what he had done had been seen by someone, so he put the note down on the floor again. He struggled, but it was too tempting... Eventually, he looked around and found that nobody was there, so he picked up the note and kept it'.*

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<sup>3</sup> This example is from a Learning Study case from Tai Koo Primary School led by Ko Po-yuk in 2008.

The main difference between the two paragraphs is that the second describes the mental state of the student whereas the first does not. Experiencing the variation in the two paragraphs enabled the students to contrast the effects brought about by the use of mental descriptions. Having established the usefulness of this writing technique, the teacher then proceeded to teach other relevant particulars, such as what mental description is, what mental description is not and its critical features.

In this example, 'writing by using mental descriptions' was first separated from 'writing'. A dimension of variation of 'technique of writing' was opened, and 'writing by using mental descriptions' and 'writing without using mental descriptions' become two values on this dimension of variation. In other words, 'writing by using mental descriptions' was identified as one of the techniques of writing.

After separating the object from its context in the initial encounter, the learner will probably treat this object as an undivided whole, whereby the critical features are fused with the object and cannot be discerned separately. To discern the critical features, these critical features must be separated from the whole. Thus, it is necessary for the learner to experience variation in a critical feature, so that they can become aware of this feature and its dimension of variation (aspect), before the learner is capable of focusing on the value independently.

#### Example 4.9

A young child first encountering a brown chair may take it as an undivided whole, for example, 'brownness' and 'chair' are fused and cannot be discerned separately. In order for the child to be able to separate 'brownness' from 'chair', it must have the experience of different brown objects. To be aware of the concept 'brown', the child must first become aware of at least two different colours, such as brown and red, for example, by seeing a brown chair and a red chair. An awareness of 'brown' and 'red' will open up a dimension of variation (colour), with brown and red as values. When the child later encounters other colours, these colours will become values on this dimension of variation. The value in the dimension of variation (e.g., brown, red) is subordinate to the dimension of variation (e.g., colour). It is impossible for us to discern the critical features of a phenomenon or an object without discerning the critical aspects (the dimension of variation in which they are values), and vice versa. Discernment of the critical aspects and critical features of the object of learning is always simultaneous. For example, when a child is aware that an object has a colour (e.g., yellow, which is a critical feature) that is different from the colour of other objects (although he or she may not know that it is called yellow), the child has also discerned one of the critical aspects of the object: its



colour. When the child discerns that the object carries a colour (the critical aspect), this implies that he or she has discerned one of the critical features: yellow.

## Generalisation

Let us assume that the object of learning is to discern (recognise, tell apart) a triangle. The teacher may show students many triangles on paper or on the blackboard, point to each one of them and say, 'triangle', hoping that the learner will discern the defining features of a triangle. In this way, the teacher will be keeping the focused *feature*, 'triangle' invariant and varying other out of focus aspects (e.g., size, kind of triangle, colour). However, according to Variation Theory, this is not the best approach. Rather, the teacher should do the opposite and vary the focused *aspect* of geometric form and keep the out of focus aspects invariant. This means that at least one other value in the same dimension of variation (geometric form) must be brought in to enable learners to experience difference, because meaning derives from difference; not from sameness.

After the teacher has separated (or made visible) the triangle-nature of the figure on paper (through comparison with the other figures on the paper), she will next need to separate the triangle-nature of the figure from other aspects that are not critical aspects (or defining features) of a triangle, such as size and colour, because so far, the students have only encountered one triangle of one size and one colour, which may happen to be a right-angled triangle. It is thus necessary to introduce variation in these as yet out of focus aspects.

To do this, the teacher must keep the focused value (triangle) invariant while systematically varying each of the previously out of focus aspects one by one. This is what we call **generalisation**. The focused value is generalised while the previously out of focus values are separated.

Let us assume that the triangle that is initially encountered is a right-angled triangle. If we have not varied the kind of triangle, we have not separated 'right-angled triangle' from 'triangle'. By showing students two triangles, one of which is right-angled triangle and the other is an equivalent triangle (all of the angles are 60 degrees), a dimension of variation (different kinds of triangle) opens up, and right-angled triangle is separated from triangle, as it now has a separate identity and is a separate value on the dimension of variation (different kinds of triangle). Note that although the pattern of variation is the same, it is a generalisation from the point of view of 'triangle' (which is superordinate to right-angled triangle and equivalent triangle) as the object of learning, because it

separates out features that are not defining features of triangles. For example, being a right-angled triangle is not a defining feature of a triangle; ‘kind of triangle’ is an aspect that can have many values. However, the same pattern of variation leads to separation from the point of view of ‘right-angled triangle’ (subordinate to triangle) as the object of learning, giving ‘right-angled triangle’ an identity that separates it from triangle. Thus, in deciding whether the pattern of variation leads to separation or generalisation, we must make clear what the object of learning is.

Example 4.10<sup>4</sup>

A P.4 General Studies teacher found that a common misconception among his students was that they believed that a prism is the source of a rainbow. They had the idea that when sunlight strikes a prism, a rainbow is emitted, just as when one presses the switch of a torch, a beam of light is emitted. The teacher believed that such misconception may have arisen because the students had never experienced variation in the tool (a prism) used to split white light into the colour spectrum, as the teacher used this same tool to split sunlight to form a rainbow every time. The teacher devised a pattern of variation in which white light was kept invariant, while the tool used to split white light was varied, such as a prism, small water droplets (formed by spraying water from a bottle), an oil layer on the surface of water, and the shiny surface of a CD. When students experienced that a rainbow was always formed despite these different tools being used, a dimension of variation (the tools used to split sunlight) was opened up. The tools used were all values on this dimension of variation. Here, the invariable principle is that white light consists of composite colours and can be split into them. By varying the tools used to split white light into its composite colours, the ‘toolness’ of the prism is separated from the prism because the same function can be performed by different tools. The prism is not critical to the process, just as being a right-angled triangle is not critical for being a triangle. Thus, with respect to ‘tools used to split white light’ as an object of learning, the pattern of variation brings about generalisation, as it separates out features that are not critical, for example, the tool being a prism. Separation also occurs with the prism as an object of learning, as it is separated from ‘tools used to split white light’, and gives it an identity on this dimension of variation along with other values, such as small water droplets and an oil layer.

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<sup>4</sup> This example is from a Learning Study case of the Catering for Individual Difference – Building on Variation (CID(v))Project funded by the Curriculum Development Institute of the Hong Kong SAR. The learning study was led by Lo Mun Ling in 2000.

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Critical features can be discerned if they vary while non-critical features remain invariant. If two aspects vary together, then they will fuse, and the two features cannot then be easily differentiated. Hence, when learners need to discern more than two or more critical features, the most powerful strategy is to allow them to discern them one at a time before they encounter simultaneous variation of these features.

### Example 4.11

To teach students the personal pronouns in English, a teacher first showed the students a sentence:

*John is reading a book, he is happy.*

He then replaced 'John' with 'My brother' and 'My father', resulting in the following two sentences:

*My brother is reading a book, he is happy.*

*My father is reading a book, he is happy.*

In this way, by varying the noun that 'he' stands for, a dimension of variation (What he stands for) is opened up and nouns such as 'brother' and 'father' are values on this dimension of variation. In other words, the students could discern that 'he' can stand for nouns such as John, my brother and my father. At this point, the students may not have been aware that 'he' stands for male only.

The teacher then showed the students another sentence:

*Mary is reading a book, she is happy.*

She replaced 'Mary' with 'My sister' and 'My mother', resulting in the following two sentences:

*My sister is reading a book, she is happy.*

*My mother is reading a book, she is happy.*

In this way, the students could contrast the use of 'he' and 'she' and notice that 'he' cannot stand for nouns such as Mary, my sister and my mother. With respect to 'he' as an object of learning, this is generalisation, as it helps to separate a critical feature that is not a defining feature of 'he'. 'He' can only stand for 'males' and not 'females'. In the same way, with respect to 'she' as an object of learning, this is also generalisation, as it

helps to separate a critical feature that is not a defining feature of 'she'; 'she' can only stand for 'females' and not 'males'. With respect to the nouns 'Mary', 'my sister' and 'my mother', this is separation as these nouns become values in the dimension of variation 'what she can stand for'. When students pay attention to the variation in the personal pronouns used (he, she) while other components are kept constant, a dimension of variation (personal pronouns) is opened up. 'He' and 'she' are values on this dimension of variation. Opening up a dimension of variation (personal pronouns) facilitates students' learning in the future, as when they come across other personal pronouns such as 'we', 'they', 'you' and 'it' they will be able to organise them along this dimension of variation and discern the association between these values and other previously learnt values such as 'he' and 'she'.

## Fusion

An understanding of a phenomenon or an object sometimes depends on the simultaneous awareness of several critical aspects and how these aspects relate to each other and to the phenomenon or object as a whole. A pattern of variation that involves simultaneous variation of the dimensions of variation that correspond to the critical aspects makes it possible for *fusion* to take place.

### Example 4.12

In an Economics lesson, a teacher can make use of variation to help students to discern that the price will increase if there is greater demand, provided that the supply is kept constant, and that the price will drop if there is greater supply, provided that the demand is kept constant. Helping students to experience the effect on price when both supply and demand vary simultaneously brings about fusion, and students will become aware that the price of a given commodity is determined by the relative magnitude of changes in both the supply and demand of that commodity.

### Example 4.13<sup>5</sup>

A teacher intended to teach the comparison of fractions in a Mathematics lesson. First, she kept the denominator invariant while varying the numerator, and asked students to compare the fractions  $1/6$ ,  $2/6$ ,  $3/6$ ,  $4/6$ ,  $5/6$ . The students were able to discern that the larger the numerator, the larger the fraction, provided that the denominator is kept constant, and vice versa. Next, she kept the numerator invariant and varied the

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<sup>5</sup> This example is the interview script from a Learning Study case (VL090) of the Variation for the Improvement of Teaching and Learning (VITAL) project funded by the Hong Kong Education Bureau. The project was carried out by Wong Tak Wah, Yeung Sun Yan, Cho Kwai King, Wong Kit Man, Mak-Lee Siu Man, Ng Mui Kun, Yung-Chan Wai Shuen, Lam Tsz Cheung, Sin-Yuen Ching Wah and Law Man Ting.

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denominator and asked students to compare the fractions  $1/2$ ,  $1/3$ ,  $1/4$ ,  $1/5$ ,  $1/6$ . The students were able to discern that the larger the denominator, the smaller the fraction, provided that the numerator is kept constant, and vice versa.

Is this sufficient for students to be able to compare fractions? After the lesson, some of the students were interviewed. They were asked to compare two fractions:  $1/4$  and  $1/8$ . Many of the students answered correctly. Similarly, most of them gave correct answers when asked to compare  $3/8$  and  $5/8$ . However, when the students were asked to compare  $3/4$  and  $5/8$ , two types of answers were given. The first type was that  $3/4$  is larger than  $5/8$  because 4 is smaller than 8 and the smaller the denominator, the larger the fraction. The second type of answer was that  $3/4$  is smaller than  $5/8$  because 3 is smaller than 5 and the smaller the numerator, the smaller the fraction. Students who gave the first answer only paid attention to the varied denominator and neglected the condition that the numerator should be kept constant when comparing fractions. Conversely, the students who gave the second answer only focused on the varied numerator and neglected the condition that the denominator should be invariant when comparing fractions. Hence, comparing  $3/4$  and  $5/8$  may bring about fusion, as students experience the simultaneous variation of both the numerator and the denominator, which will hopefully help them to become aware that they should pay attention to both.

As mentioned in Chapter 1, learning proceeds from an undifferentiated and poorly integrated understanding of the whole to increased differentiation and integration of the whole and its parts. Through learning, the whole is rendered more distinct, and the parts can be found and then fitted into place, making the part-part relationships and part-whole relationships clearer (Marton & Booth, 1997, p. viii). Students will learn better if the teacher is able to consciously structure the teaching in such a way as to bring out the structure of the content with clear part-part relationships and part-whole relationships. The following two examples show patterns of variation that can be used to help students to discern part-whole relationships.

### Example 4.14

In a reading lesson, Teacher B read aloud the first paragraph of a text of several paragraphs that the students had not seen before. She then purposely asked questions about the first paragraph that the students were unable to answer due to insufficient information. She read aloud the second paragraph of the same text and asked students whether their understanding of the first paragraph had changed. The teacher then read aloud the third paragraph and asked the students whether their understanding of the

first paragraph had changed. She repeated this until she had finished reading all five paragraphs of the text, each time asking the students if their understanding of the first paragraph had changed. In Teacher B's lesson, the first paragraph was kept constant throughout, yet the text (the whole) in which the first paragraph was situated (as a part) varied from being a text with a single paragraph to a text with five paragraphs. As the whole of which the paragraph was a part varied, the students' understanding of the first paragraph also varied. The pattern of variation thus created helped the students to become aware that to understand a paragraph, they must pay attention to the contextual clues that they may be able to find in other paragraphs.

*Table 4.3* Pattern of variation used in the reading lesson

Invariant	Varied	Discernment
The first paragraph of the text	The text (the whole) of which the first paragraph is a part (from a one-paragraph to a five-paragraph text).	Our understanding of a paragraph is affected by other paragraphs in the same text.

Clearly, one way to highlight part-whole relationships is to keep a component part constant and vary the whole by progressively including other component parts to make up the whole. For example, in this case, the first paragraph remained while the whole varied from being composed of the first paragraph, the first and second paragraph, and so on until all five paragraphs were included. This pattern of variation is reported by Chik and Lo (2004), who illustrate with two cases how the pattern can be brought about by arranging the lesson content in what they refer to as a hierarchical structure (p. 96), and that this is effective in helping students to discern part-whole relationships.

Example 4.15<sup>6</sup>

A Chinese teacher aimed to teach students to guess the meaning of unfamiliar words by context to raise their interest in reading and their reading ability. She used the following teaching materials in the lesson.

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<sup>6</sup> This example comes from Learning Study VL081 in the "Variation for the Improvement of Teaching and Learning" (VITAL) project carried out by Ho Man Sing, Lai Meng Choo, Tsoi Kim Tung, Ha Lai Wah, Wong Kam Wing, Tam Wing Kwan, Chan Wai Wah, Wong Ching Man, Chan Shun Man, Ng Ming Sze, Lee Yuk Wah, Chan An Fung and Miu Lai Fan. The project was funded by the Education Bureau of Hong Kong.

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‘moving suddenly from the quiet home to the **noisy** street, the clamour made my baby sister cry’ (...從寧靜的家裡，突然走到喧囂的大街上，街道上的聲音使妹妹哇哇大哭起來。).

The teacher asked the meaning of ‘**喧囂** (noisy)’, but nobody in the class knew the answer. The teacher then asked students to pay attention to the radicals of the two Chinese characters and guess what the two words related to. As both characters contain the radical ‘口’, which means ‘mouth’, the students were able to guess that these two characters must be related to the mouth, so that it may have something to do with either ‘eating’, ‘speaking’ or ‘making sound’. Next, the teacher asked the students to pay attention to the sentence that followed: ‘The clamour on the street made my baby sister cry’, and asked the students if their understanding of the word ‘**喧囂** (noisy)’ had changed after reading this sentence. The students were then able to deduce that the word must be related to ‘sound’ and not ‘eating’ or ‘speaking’. The teacher then invited students to read the preceding sentence ‘moving suddenly from the silent home to the **noisy** street,’ and asked them how this sentence helped their understanding. The students said that it was probable that ‘**喧囂**(noisy)’ is the antonym of ‘quiet’ in the previous sentence due to the hint given by the word suddenly. At this point, the students were able to guess the approximate meaning of the word ‘**喧囂** (noisy)’ by context.

In this example, the students initially had a very obscure understanding of the sentence, or the whole. However, when their understanding of the new word ‘noisy’ (**喧囂**) (which is a part of the whole) became clearer, their understanding of the whole also improved.

Table 4.4 Pattern of Variation

Invariant	Varied	Critical feature to be discerned
The new word (a part of the whole). The text (the whole).	What the teacher highlighted in the text.	Better understanding of other parts of the text other than unknown vocabulary brings about a better understanding of that vocabulary and the text. The parts and the whole are related and give each other meaning.

The important point is that in Variation Theory, ‘variation’ does not refer to the variation of teaching strategies; rather, the kind of variation to which it refers is always directed towards the critical aspects of the object of learning. When certain aspects or features of the object of learning are kept constant while other aspects or features are varied, a pattern of variation is produced. In other words, a pattern of variation summarises what is varied and what is kept constant in the critical features of the object of learning.

## Variation must be experienced by the learner

A pattern of variation is a useful tool for structuring teaching to make the learning of the object of learning possible. However, the pattern of variation and invariance that is actually experienced by students and what they focus on determines the actual pattern of variation experienced and what can be discerned. Thus, whether the expected learning outcome can be achieved hinges on whether the pattern of variation can be experienced and discerned by the students.

### Example 4.16<sup>7</sup>

In an English lesson, the teacher aimed to teach students that the meaning of a sentence is affected by the position of the relative pronouns. The teacher made use of the following examples and expected that the students would be able to discern this relationship through contrast.

- a. *The man **who has big eyes** has a lovely girl friend.*
- b. *The man has a lovely girl friend **who has big eyes**.*

The teacher generated the following pattern of variation.

Table 4.5 Pattern of variation used in the relative pronouns lesson

Invariant	Varied	Critical feature to be discerned
The main clause ‘The man has a lovely girl friend’.	The position of the relative clause ‘who has big eyes’.	The meaning of a sentence is affected by the position of the relative pronouns.
The relative clause ‘who has big eyes’.		

<sup>7</sup> This example is from a learning study led by Dr Ellen Zhang.



For the students to learn, they must be able to experience the variation in the positions of the relative clauses (which the teacher can control) and the variation in the meanings of the sentences simultaneously (over which the teacher has no control because it is a learning outcome that depends on the students). However, an awareness that the meanings of the sentences are different may not be automatic. In fact, they probably are not aware of the difference because if they knew that the different positions result in different meanings, then they do not have to learn, as they knew it already. In this case, the teacher could help by explaining the meaning of the sentences, or by decomposing each of the sentences into two simple sentences.

*Sentence a: 'The man **who has big eyes** has a lovely girlfriend' is the same as 'The man has big eyes. The man has a lovely girlfriend'.*

*Sentence b: 'The man has a lovely girlfriend **who has big eyes**' is the same as 'The man has a lovely girlfriend. The girlfriend has big eyes'.*

The teacher can then ask the students 'Who has big eyes?' to help them discern the change in meaning of the sentence as the position of the relative clause changes.

## Conclusion

Discernment requires experience of variation. Appropriate patterns of variation can help to bring about the different kinds of awareness that are necessary for learning. To summarise, contrast helps the learner to discern a particular phenomenon, concept, or aspect and separate it from its context and other phenomena, concepts or aspects. Thus, when the learner can contrast a triangle with a square, the dimension of variation 'geometric figures' (which is superordinate to triangle) will be opened up, with the triangle as a value along this dimension of variation. Triangle is subordinate to 'geometric figures'. Contrasting triangles with what are 'not triangles' (e.g., squares, pentagons, hexagons) allows the critical aspects of triangles, such as the number of sides, to be separated out. Students can then learn from sameness by looking at different kinds of triangles (e.g., right-angled triangles, isosceles triangles, equivalent triangles), and aspects that vary within triangles can be discerned. This will help students to generalise about triangles, as they will be able to separate out aspects such as size of angles and length of sides as not being defining features, but rather dimensions of variation of triangles.

A pattern of variation indicates what is varied and what is kept invariant with respect to the critical aspects or features of the object of learning. If only one

critical aspect is varied while others are kept constant, then the critical aspect that varies can be discerned through contrast. When two aspects vary simultaneously while all the other features remain invariant, this results in simultaneous variation of these two aspects. Such patterns can help students discern the relationship between two dimensions of variation, which is also an example of fusion. Even if the variation pattern is the same, different learning outcomes may result depending on the particular discerning experiences of individual students and what is being focused on. In general, when the focus is on what is superordinate, the awareness is of generalisation. When the focus is on what is subordinate, it is separation. If the focus is on the simultaneous variation of two or more aspects, it is possible for fusion to take place. Using patterns of variation to highlight part-whole relationships is also an example of fusion.

Marton (2009) recommends a teaching sequence of ‘fusion (the undivided whole) — contrast (leading to separation of dimensions of variation, so that critical aspects and features will be separated out from the whole) — generalisation (differentiating the critical aspects from those that are not) — fusion (seeing all the critical aspects in relation to each other and to the whole).’ The initial ‘fusion’ refers to learners’ initial encounter with the undivided whole, their understanding of the problem and the question that they are supposed to learn to address. This encounter does not make it possible for them to discern the critical features, but creates a ‘relevance structure’, an experience of the undivided whole from which the critical features are subsequently discerned.

This chapter discusses how to use patterns of variation to bring out different kinds of awareness. Readers will probably have noticed that the teaching strategies and approaches used by the teachers to introduce variation are not included in the examples of patterns of variation described. This is because the same pattern of variation may be enacted using different teaching strategies. The preferred teaching strategies and approaches that best enact Variation Theory in the classroom are further discussed in Chapter 5.

## Chapter 5

# Using Variation Theory as a guiding principle in teaching

### Introduction

Chapter 4 explains how teachers can make use of patterns of variation to help students to discern an object of learning and its critical features. However, the use of patterns of variation cannot be independent of teaching strategies, but rather must be closely linked with teaching strategies to be effective in helping students to learn. Whether a pattern of variation is effective depends to a great extent on whether suitable teaching strategies are employed so that students experience the pattern as intended. In other words, in addition to paying attention to the ‘what aspect’ (the critical features that must be discerned simultaneously), teachers must also pay attention to the ‘how aspect’; that is, how can the ‘what’ aspect be brought to the focal awareness of students?

No single teaching approach or strategy will be effective for teaching all objects of learning and their critical features. Thus, before considering which teaching approach, method or strategy to use, we must first consider what we intend to teach, or the object of learning. This sounds like a truism, yet whether at the policy-making level or the lesson preparation and teaching level, most people are still focusing only on teaching approaches and strategies. For example, when the activity approach was introduced to primary schools in Hong Kong, teachers felt compelled to teach through activities in every lesson. Consequently, the first consideration for some teachers in planning a lesson was to choose an activity rather than asking what kinds of capabilities they wished to develop or nurture in the students, and what kinds of content would best bring that about. Other teaching strategies promoted recently include collaborative learning, co-operative learning, small class teaching and project learning. However, promoting teaching strategies that are detached from considerations of learning content is like putting the cart before the horse, and will most likely affect the quality of student learning.

After a thorough consideration of whether the object of learning is worthwhile, whether it is relevant to the students, its external horizon and internal horizon, its critical aspects, the relationships among its parts and between the parts and the whole, and the kinds of patterns of variation that can be used to help students discern the critical features, we can continue by asking the following questions.

- Which teaching approach is best for achieving the intended student learning outcomes?
- Which teaching method or strategy will best help students to develop a relevance structure so that they can find meaning in what they are learning and be able to fully participate in the learning activity?
- How can students be best helped to develop the identified capabilities, skills or attitudes through the learning of the content?
- What kinds of learning activities will best bring out the intended pattern of variation?
- What kinds of classroom interactions will help teachers to obtain the necessary feedback from students about their understanding of the object of learning?
- What kinds of assessment methods will provide feedback to teachers and students about the effectiveness of the learning that has taken place or is taking place?

This chapter first discusses the relationship between Variation Theory and teaching strategies, and then introduces actual cases to illustrate how the effectiveness of using patterns of variation to bring about the learning of knowledge, skills and attitudes can be enhanced by the appropriate use of teaching strategies.

## Variation Theory and commonly agreed teaching principles

Teaching principles derived from Variation Theory are compatible with many principles of teaching on which the educational community has reached a consensus. Chapter 1 mentioned the large-scale project 'How People Learn' that reported three implications for the enterprise of teaching and teacher preparation (Donovan, Bransford & Pellegrino, 1999).

1. Teachers must draw out and work with the existing understanding that their students bring with them.
2. Teachers must teach certain subject matter in depth, providing many examples in which the same concept is at work and providing a firm foundation of factual knowledge.
3. The teaching of metacognitive skills should be integrated into the curriculum in a variety of subject areas (p. 10-17).

These teaching principles are first compared with those derived from Variation Theory, and the way in which Variation Theory can help teachers to make commonly promoted teaching strategies more effective is then illustrated using actual examples.

### **1. Teachers must draw out and work with the existing understanding that their students bring with them**

Variation Theory is compatible with this first principle. Variation Theory originates from phenomenography, which focuses on people's experience of a particular phenomenon. Whether students have learned a phenomenon or object is understood to mean whether students have changed their ways of seeing or understanding that object or phenomenon. Teaching must thus begin with finding out students' prior understanding of the object of learning. The reason is simple: we must know how students understand the object if we are to change their ways of seeing that object. In fact, not only should we pay attention to the variation in students' understanding of the object of learning at the beginning of the learning process; it is also important to continuously assess how students' ways of seeing are changing during the learning process. If teachers do not know what students are thinking during the teaching process, then they cannot give useful feedback to students or provide further suitable learning experiences to steer their ways of thinking and seeing towards what is intended. Variation Theory postulates that different people understand the same object in different ways. If we can understand other people's ways of seeing, we can on one hand challenge our natural attitude of assuming that everyone sees things in the same way that we do, and thus become more tolerant and inclusive of others' views, and on the other hand widen our own ways of seeing things. If a member of a social group can acquire understanding of how other members view a phenomenon based on their experience, then a collective mind (Marton, 1981)

will be formed that encompasses different experiences of different phenomena, which is more inclusive and richer than a single mind.

Clearly, Variation Theory necessarily points to teaching strategies that are student-centred, where students and teachers interact actively to jointly constitute the object of learning. Teachers must encourage students to express their views and their understanding of the object of learning so that the following aims can be achieved.

Teachers can obtain feedback on whether their teaching is effective and so can immediately adjust their lesson plan in response.

Teachers can utilise students' differing views and understanding of the object of learning as a resource so that other students can experience variation in understanding of the same object and be exposed to more powerful ways of seeing.

## **2. Teachers must teach subject matter in depth, providing many examples in which the same concept is at work and providing a firm foundation of factual knowledge**

Variation Theory also emphasises deep learning. Knowing an object means being able to discern it from its external horizon and knowing both its meaning aspect and structural aspect. Teachers' responsibility is not only restricted to teaching certain subject matter, but also helping students to discern the position of that subject matter in the whole subject structure, its relation to knowledge that students have already learnt and will learn in the future, and the meaning that learning that subject matter has for them (its relevance structure). Thus, Variation Theory makes a strong demand for a 'foundation of factual knowledge'.

To a certain extent, Variation Theory is also compatible with the principle that teachers should provide many examples in which the same concept is at work. However, how to select and apply different examples is more stringent and explicit in Variation Theory. Variation Theory clearly points out that it is impossible for students to discern the critical features if teachers only provide them with *similar* examples. Rather, teachers must also provide students with counter examples to enable them to contrast and discern the critical features. As was pointed out in Chapter 4, contrast is necessary for the discernment and separation of critical features. Contrast should precede generalisation, as similar

examples will not help students to discern critical features, although once the critical features can be discerned, then generalisation can help to separate the features that are not critical features (please refer to Chapter 4 for details). However, teachers often ignore this point.

### 3. The teaching of metacognitive skills should be integrated into the curriculum in a variety of subject areas

Marton (2009) argues that we must learn to discern every quality (feature), whether it is innate or not. Awareness of a single feature cannot exist without an awareness of the differences (variation) between features. Knowledge thus cannot be directly transmitted; instead students must experience the appropriate pattern of variation that will lead them to discern the critical features. Learning how to discern is a kind of metacognitive skill.

If teachers use Variation Theory as a guiding principle of pedagogical design, and after each lesson help their students to reflect on their own learning process, then students are likely to be able to discern how they come to acquire knowledge. If teachers make use of patterns of variation in every lesson (invariant), although the object of learning and its critical features may vary, then students are likely to discern how to use an effective pattern of variation to learn. For instance, they can try to find the critical features of an object by contrasting examples and counter-examples of the object.

#### Example 5.1<sup>1</sup>

One of the requirements for the Chinese oral examination in Hong Kong secondary schools is that students should be able to express their opinions fluently on any given topic for one minute. In a secondary school in Hong Kong, a group of teachers found that despite having instructed students many times on this topic and given them practice in giving one-minute talks, the students did not perform well. The teachers developed a Learning Study aimed to help students to improve their performance in the one-minute talk. Through student interviews, they found out that many students did not have a clear structure for their talk, and it became apparent that this was a critical feature that students must discern to perform well. The teachers decided to teach students the three steps of a one-minute talk: 1) make the purpose of the talk clear at the beginning; 2) use indicators such as 'first', 'then' and 'finally' in the development stage to help the audience

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<sup>1</sup> This example comes from a learning study carried out by a group of teachers of the HKMA K.S. Lo College in 2004. The learning study was led by Ko Po Yuk.

to follow their points of argument; and 3) include a conclusion and ending sentence before closing. After planning what to teach, the teachers designed patterns of variation to help the students discern the importance of each stage through contrast. When teaching each stage (beginning, development and conclusion), the teacher showed two videos of two students talking about exactly the same content. The only difference between the two presentations was that the first student did not state the purpose of the talk at the beginning whereas the second did, for example, by saying 'I would like to share with you my opinions on . . .' By comparing their own understanding of the two talks in the two videos, the students were able to discern the importance of stating the purpose of the talk at the beginning. The teachers dealt with the other two stages in a similar way. After the research lesson, the teachers found that the students made significant progress in their oral practice. After one year, the teachers were invited to share their experience of conducting Learning Study in a public dissemination seminar opened to all teachers in Hong Kong. The teachers brought along a student who had taken part in one of the research lessons to share her learning experience. The student told the audience that the research lesson left a deep impression on her. She highlighted that the teacher had taught the elements to their class in previous lessons, but that she had forgotten them shortly afterward. In the research lesson, the teacher used a video to contrast the effect of having and not having the three elements of a one-minute speech, and she was able to experience the effect on herself between a speech with and without each of the three elements. Without this contrast, she admitted that it would not have had such a deep impression on her. The student also stated that she had been practicing using what she had learnt when making speeches ever since. Although the student was not able to use the language of Variation Theory to explain her learning, she was aware that being able to compare and contrast had allowed her to discern and appreciate the importance of the critical elements, which benefited her learning.

## How Variation Theory enhances the effectiveness of certain common teaching strategies

As mentioned, teaching strategies are closely related to the 'how' aspect of learning and the 'general aspect' of an object of learning. The general aspect of an object of learning refers to the capabilities that teachers wish to nurture in students through the teaching of specific aspects (e.g., content/subject knowledge) of the object of learning. For example, we may wish to nurture students an interest in scientific inquiry through the teaching of 'Colours of Light'. Here, 'Colours of Light' is the specific aspect and 'an interest in the process of scientific inquiry' is the general aspect of the object of learning. It



follows that during teaching, teachers should not only follow the textbook to explain phenomena and ideas or simply perform demonstrations, but should design learning experiences for the students that will allow them to ask questions and design and conduct experiments on their own to answer their own questions so that they can experience the joy of scientific inquiry. Similarly, when teachers wish to help students to develop more powerful ways of seeing, they must give students opportunities to express their own views and listen to other students' views. The general aspect of the object of learning can only be achieved through the use of appropriate teaching strategies that will bring about relevant learning experiences. The choice of teaching strategy should not be arbitrary, but should be determined by the object of learning. Although innovative and lively teaching strategies that engage students are desirable, appropriate guidance and debriefing by teachers are also necessary. It is the responsibility of a teacher to teach students the most worthwhile object of learning in the limited time available in a lesson. With guidance from teachers, students should be able to learn more and learn deeper. If teachers only adopt the role of classroom manager and do not facilitate students' learning, then their presence in the classroom will be of no account. In this case, teachers are not fulfilling their duty as teachers, because they are dispensable.

Variation Theory is compatible with the majority of teaching strategies currently promoted. However, when designing and using these strategies, it is important to consider whether students will be provided with opportunities that will allow them to experience variation of the critical features. If such opportunities are not provided, then students will not have the opportunity to learn because the necessary conditions of learning will not be in place. The way in which Variation Theory can help teachers to use certain common teaching strategies more effectively is presented in the next section, illustrated with actual classroom examples.

## **Relationship between Variation Theory and subject-specific teaching strategies**

There are often specific teaching strategies promoted by different subject disciplines. For instance, communicative approach and task-based learning is emphasised in English teaching in Hong Kong, whereas in Science teaching, problem solving, an inquiry approach and experimental methods are often the promoted strategies. Variation Theory can help teachers to use these strategies more effectively.

Example 5.2<sup>2</sup>

In a Learning Study on the rate of chemical reaction at Secondary Four level, two teachers were involved in teaching research lessons. Before the lessons, students were interviewed about their understanding of the ‘rate of chemical reaction’. It was discovered that the students believed that increasing the volume of a reactant would increase the rate of the reaction, which is a misconception. In addition to dealing with the critical feature: ‘the rate of a reaction is affected by the concentration of a reactant’ in the research lesson, the teachers also dealt with another critical feature, that is, ‘the volume of a reactant does **not** affect the rate of a chemical reaction’.

The research team decided to use the following experiment in the lesson:

*Add calcium carbonate to dilute hydrochloric acid to produce calcium chloride, carbon dioxide and water as represented by the following chemical equation.*



The teachers then designed two patterns of variation to deal with the two critical features:

1. *If the volume is unchanged, then the concentration of the reactant will affect the rate of reaction.*
2. *If the concentration is unchanged, then the volume of the reactant will not affect the rate of reaction.*

Table 5.1 Two intended patterns of variation

Invariant	Varied	Critical features to be discerned
Mass of CaCO <sub>3</sub> ; Volume of acid	Concentration of acid	Concentration affects the initial rate
Mass of CaCO <sub>3</sub> ; Concentration of acid;	Volume of acid	Volume has no effect on the initial rate

In addition to using these patterns of variation, great attention was also paid to the ‘how’ aspect or act of learning. As this was a science lesson, teaching strategies that were considered to be exemplary in science teaching were employed, namely, an experimental

<sup>2</sup> This example comes from Learning Study VL005 in the “Variation for the Improvement of Teaching and Learning” (VITAL) project carried out by Lo Mun Ling, Hung Hoi Ying, Lee Chi Shing, Wong Yiu Cheung and Yung Wing Hin. The project was funded by the Education Bureau of Hong Kong. The author also wishes to acknowledge the contributions of Helen Hung and the teachers at the project school.

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approach that gave students hands-on experience, with the whole lesson being carried out using an inquiry approach.

In both classes, the students conducted the experiments themselves. Different groups of students were assigned different combinations of calcium carbonate and acid in a pattern carefully designed by the teacher to enable generalisations to be drawn from the results. The following table shows the combinations of the six groups of students in the lesson.

*Table 5.2* Combinations of the six groups of students in the experiment

Group	Mass of CaCO <sub>3</sub> (Invariant)	Concentration of acid (Invariant)	Volume of acid (Varied)
1	1 g	0.5 M	5 cm <sup>3</sup>
2	1 g	0.5 M	10 cm <sup>3</sup>
3	1 g	0.5 M	15 cm <sup>3</sup>
Group	Mass of CaCO <sub>3</sub> (Invariant)	Concentration of acid (Varied)	Volume of acid (Invariant)
4	1 g	0.5 M	5 cm <sup>3</sup>
5	1 g	1 M	5 cm <sup>3</sup>
6	1 g	1.5 M	5 cm <sup>3</sup>

The teaching plan, experiment and patterns of variation adopted in the two research lessons were the same. Students in both classes were fully engaged in the experiment during the lesson. In the post-experiment discussion, the teachers used the experimental results of the various groups to analyse the data. For example, the teachers both used data from groups 1, 2 and 3 to discuss with the students the effect of volume on the initial rate of reaction when the concentration of the reactants remained unchanged. The teachers then used data from groups 4, 5 and 6 to discuss with students the effect of concentration on the initial rate of reaction when the volume of the reactants remained unchanged. An analysis of the performance of the students in one of the items in the pre- and post-test illustrates whether the students were able to learn effectively. This particular item aimed to test how well the students had understood the effect of volume and concentration on the reaction rate. The item is reproduced as follows.

Q1. 10g of zinc is added to 20 cm <sup>3</sup> of 1 M HCl and hydrogen is produced. Which of the situations below will affect the initial rate of reaction?	
A	Using 10 cm <sup>3</sup> of 2 M HCl to replace 20 cm <sup>3</sup> of 1 M HCl
B	Using 20 cm <sup>3</sup> of 3 M HCl to replace 20 cm <sup>3</sup> of 1 M HCl
C	Using 30 cm <sup>3</sup> of 1 M HCl to replace 20 cm <sup>3</sup> of 1 M HCl
D	Adding water to the reactant
E	Using more concentrated HCl

There was a large difference between the learning outcomes of the two classes after the two research lessons. The students in class 4A performed better (80% correct, with an increase of 10% compared with the pre-test) in answering questions on the effect of concentration on the reaction rate (sub-questions B and E). However, they regressed (only 42% correct with a decrease of 6% compared with the pre-test) in answering the question on the effect of volume on the reaction rate (sub-question C). The decrease of 6% after the research lesson showed that the students had not understood this point well. It was thus natural that the students did not show great improvements in answering the questions on the effect on the reaction rate of changing both concentration and volume simultaneously (sub-questions A and D).

Table 5.3 Percentage of Correct Answers for Class 4A

4A	Correct answer for sub-questions A and D	Correct answer for sub-questions B and E	Correct answer for sub-question C
Pre-test	6%	70%	<b>48%</b>
Post-test	24% (+18%)	80% (+10%)	<b>42% (-6%)</b>

In contrast, the students in class 4B showed improvements in all five sub-questions (Table 5.4), showing that they had acquired a deeper understanding of the effect of the two factors (concentration and volume) after the research lesson. This is particularly reflected in the improvement in the answers given for sub-question C compared with class 4A, which showed a regression for this sub-question. The correct percentage given by class 4B rose from 11% to 80% after the research lesson, an increase of 69%. This result indicates that the students in 4B had a deeper understanding of the effect of volume on the reaction rate. As the percentage of students who gave correct answers for

sub-questions B and E was already high in the pre-test, the increase in the correct percentage for sub-questions B and E was not as high as that for sub-question C, although the correct percentage was still high (83%, with an increase of 19%). However, the number of students who got the answers correct for sub-questions A and D was still low (only 15% correct with an increase of 2%), showing that the students still were having difficulties considering the two factors when they were varied simultaneously, probably because the teacher had not moved towards ‘fusion’ (considering the simultaneous variation of the two factors on the rate of reaction) in the lesson. Further improvement is needed in this respect.

*Table 5.4* Percentage of Correct Answers for Class 4B

4B	Correct answers for sub-questions A and D	Correct answers for sub-questions B and E	Correct answer for sub-question C
Pre-test	13%	64%	<b>11%</b>
Post-test	15% (+2%)	83% (+19%)	<b>80% (+69%)</b>

To many students, the second critical feature (if the concentration is kept constant, then the volume of the reactant will not have any effect on the rate of reaction) is counter intuition, therefore, it is quite difficult to change their belief. Obviously, in the first teaching cycle (4A), the students were not able to fully grasp this critical feature. However, students in the second teaching cycle showed significant improvement. What actually happened in the two cycles? To find out, we must analyse the teaching enactment in the two lessons in greater detail.

#### *The enacted object of learning in the first cycle*

In the first cycle, the teacher followed the lesson plan closely. He was a very experienced teacher with a good knowledge of chemistry, and his instructions and explanations were clear. During the lesson, he gave students many opportunities to participate in the experiment and in the discussions, and helped them to make generalisations about the rule instead of directly giving them the answers. The lesson had been designed using the approaches and strategies promoted by science educators to give students opportunities to carry out experiments using an inquiry approach. As it takes time to carry out an experiment, the teacher adopted a common strategy used in teaching chemistry whereby each group was assigned to conduct the experiment using acid of a designated

concentration and volume and the students were required to plot the rate curve for only one set of data. The results of each group were then pooled in the debriefing session. Each group was asked to plot the rate curve on a transparency. The transparencies from all groups using the same concentration but different volumes of acid (groups 1, 2 and 3) were overlaid on the projector to find the effect of volume on the reaction rate. The gradients of all of the rate curves overlapped, showing that the initial rates were the same. The transparencies from the groups working with the same volume but different concentrations of acid (groups 4, 5 and 6) were then overlaid to find out the effect of concentration on the reaction rate. None of the gradients of the rate curves overlapped, showing that the initial rates were different. Why were the students then unable to achieve the expected learning outcomes? If Variation Theory is a viable theory, then it should be able to explain this phenomenon.

Variation Theory tells us that if we want students to focus on a particular critical feature, they must experience the variation of that critical feature. Thus, if we wish students to discover the relationship between the volume of acid and the initial reaction rate, then they must be able to experience the simultaneous variation of the volume of acid used and the initial reaction rate. Although the students in the first lesson were engaged in the experiment and plotted the rate curve, they were unable to experience the simultaneous variation of the volume of acid and the initial reaction rate. In the research lesson, each group had to conduct only one experiment and plot the data for that experiment. They only used acid in a fixed concentration and volume, so it was impossible for them to experience the simultaneous variation of the two aspects. Only when the teacher gathered the data from all of the groups in the debriefing session were students given the opportunity to experience the intended pattern of variation. Perhaps this is where the problem lay. In the debriefing, the teacher only spent a few seconds pointing out that they were comparing acid of the same concentration but different volumes. If the students happened to be distracted at that moment, or had not listened carefully to the teacher, then they would have missed the critical moment of learning the critical feature. This critical moment occupied not more than one minute of the entire lesson, which lasted for 80 minutes.

In the second cycle, the planned activities remained unchanged. However, in view of the problem identified in the first research lesson, the teacher of the second cycle made a minor change in the lesson to ensure that the students were able to experience the intended simultaneous variation by themselves. Before the group work, the students were given a clear task to seek an answer to the question about whether the volume of a reactant affects the rate of a reaction. They had to decide which groups' data they should select for comparison to find the answer. After the students had finished the experiment,

they had to actively look for the groups with the appropriate data that would help them to answer the question. As the students had to figure out which groups to select for comparison (that is, groups using acid in the same concentration but different volumes) there would be a greater chance for them to experience the simultaneous variation of the volume of acid and the initial reaction rate. The post-test results showed that although only 11% of students got the relevant answer correct in the first class (4A), 80% of students in the second class got it correct, an increase of 69%.

*Table 5.5* Comparison of percentage of correct answers on ‘the effect of volume on the reaction rate’ in the two classes in the pre- and post-test

Correct percentage	4A	4B
Pre-test	48%	11%
Post-test	42%	80%
Increase	-6%	+69%

From this example, it is clear that it is important for teachers to intentionally target teaching activities that promote the learning of critical features. Asking appropriate and guided inquiry questions is an example of how this can be achieved. In terms of the choice of classroom activities, the most important criterion is not whether students can be fully engaged and are participating happily in the activities, but whether they engage in an activity that provides them with opportunities to experience an appropriate pattern of variation so that the intended critical features can be discerned. Variation Theory provides us with a scientific method to analyse and explain the relationship between students’ learning outcomes and the effective use of teaching strategies. It can also be used as a guiding principle for the design of learning activities.

## Variation Theory and learning motivation

The majority of studies on learning motivation focus on the social aspect of learning. Diverse teaching approaches, strategies and activities are commonly advocated to increase interactions among students to enable them to learn happily. Here, a different view of motivation is adopted that focuses on the relationship between students and the object of learning, and the importance of creating a relevance structure for the learning to be seen as meaningful to the learner. According to Marton and Booth (1997), ‘Each situation, whether we consider it a learning situation or a situation in which one is applying something learned, has a certain **relevance structure**: the person’s experience of what the

situation calls for, what it demands' (p. 143). Thus, whether students see the link between the object of learning and their daily life experience will affect their understanding of and response to the object of learning.

Example 5.3

Consider two situations.

1. *Jack is late for school. When he enters the classroom, the teacher asks, 'What is the time please?'*
2. *Jack is coming home from school. He is stopped by a stranger who asks him, 'What is the time please?'*

In the first situation, Jack may think that the teacher is blaming him for being late to school and is thus making a sarcastic remark. His immediate reaction may be to apologise for his lateness and explain the reasons for being late. In the second situation, Jack may notice that the stranger is not wearing a watch and so may tell him the time. Faced with the same question, Jack responds in different ways because he associates the same question with different relevance structures.

Before learning any object, students will usually make an assessment of what learning this object means for them. If students think that the object is completely meaningless to them, then naturally they will not have any motivation to learn it. Whether teachers can create a relevance structure to motivate students to learn thus greatly affects the learning effectiveness.

Example 5.4<sup>3</sup>

In a Secondary Two Science Learning Study on neutralisation, the teachers found that to fully understand the neutralisation curve, the effect on the pH value of diluting acids and alkali is a critical feature. Two teachers made use of different motivation strategies to deal with the topic. The teaching was conducted over two lessons. The first teacher asked the students at the beginning of the lesson to guess the effect on the pH value of diluting an acid or an alkali with water. All of the students thought that the pH value would change. The students were then asked to explore the change in pH value when water was added to an acid or an alkali experimentally. Most of the students were surprised to find that the pH value of the acid and the alkali did not change when diluted with water, even up to several times its original volume. The teacher then performed a demonstration to contrast the two cases. In the first case, he diluted 1 cm<sup>3</sup> of acid with 1

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<sup>3</sup> The data for this example comes from Learning Study VL103 in the "Variation for the Improvement of Teaching and Learning" (VITAL) project carried out by Lo Mun Ling, Chan Wing Yan, Wong Yuen Shan, Ho Yuen Ting and Yim Bing Man. The project was funded by the Education Bureau of Hong Kong.



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cm<sup>3</sup> of water each time and measured the pH each time until 10 cm<sup>3</sup> had been added. No change in pH was found when measured with pH paper. In the second case, he diluted 1 cm<sup>3</sup> of acid with 10 cm<sup>3</sup> of water each time and measured the pH each time until 100 cm<sup>3</sup> had been added. It was found that the pH value increased by one unit after each dilution when measured with pH paper. He did the same for the alkali and obtained similar results. At the end of the lesson, the teacher helped the students to arrive at the conclusion that the pH value of an acid or alkali will change by one unit each time it is diluted 10 times. In the second lesson, the teacher invited students to explore the effect on the pH value of adding an acid to an alkali (or an alkali to an acid) and to plot the titration curve with pH value as the Y-axis and the volume of acid/alkali added as the X-axis. Finally, the teacher explained neutralisation to the students and used what had been taught in the last lesson – the effect of diluting an acid and an alkali on the pH value of a solution – to explain the change in pH value during neutralisation, that is, that during the neutralisation of an acid by an alkali, the pH value remains nearly unchanged at the beginning (e.g., pH = 2) until very close to the end point, but then rises dramatically (e.g., pH = 10). After that, the pH value remains constant no matter how much alkali is added.

Table 5.6 Pattern of variation enacted in the first lesson

Invariant	Varied	Critical features to be discerned
1cm <sup>3</sup> of an acid (or an alkali) ;	Amount of water (1 cm <sup>3</sup> each time) added	The pH value of the acid (or the alkali) does not change during dilution
1 cm <sup>3</sup> of an acid (or an alkali)	Amount of water (10 cm <sup>3</sup> each time) added	The pH value of the acid (or the alkali) changes by 1 unit each time

By putting the two activities together, the following pattern of variation was enacted:

Table 5.7 Alternative pattern of variation enacted in the first lesson

Invariant	Varied	Critical feature to be discerned
1 cm <sup>3</sup> of an acid (or an alkali)	Degree of dilution: 1 time each 10 times each	The pH value only changes by 1 unit each time it is diluted 10 times.

The second teacher made use of a different motivation strategy. He played a two-minute video at the beginning of the first lesson about the harmful effects of water pollution on

humans that was attributed to the industrial emission of sewage. The teacher then asked the students to play the role of a factory owner whose factory discharged diluted hydrochloric acid as an industrial waste. He asked them to consider what methods they would use to deal with this waste to reduce its harmful effect on the environment. The students proposed various solutions. Some of them thought that the acid should be diluted before being discharged. Some of them thought that alkali should be added to the acid to neutralise it before being discharged. The teacher then commented that certainly, if water could be used to dilute the acid, then the cost might be lower than using an alkali. The teacher suggested that the students carry out an experiment to see if this method would work. The teacher gave students 10 cm<sup>3</sup> of 1M dilute hydrochloric acid and asked them to try to increase the pH value of the acid from 1 to 7 by diluting with water so that the industrial waste could be discharged safely. Through the experiment, the students found that to increase the pH value from 1 to 2, they had to add 100 cm<sup>3</sup> of water to the 10 cm<sup>3</sup> of 1M dilute hydrochloric acid, and that an amount of water that was 10 times the volume of the acid was further needed to increase the pH value of the acid by 1 more unit, and so on. To increase the pH value of the 10 cm<sup>3</sup> of 1M dilute hydrochloric acid from 1 to 7 would thus require about 10,000,000 cm<sup>3</sup> of water. The cost would be very high, and the students concluded that this method was not workable. In the second lesson, the teacher invited the students to explore whether it would be workable to use an alkali to neutralise the acid, and asked students to plot the titration curve. Finally, the teacher explained neutralisation to the students. Like the first teacher, the second teacher also used what was taught in the first lesson – the effect of dilution on the pH value of an acid and an alkali – to explain the change in pH value during neutralisation as indicated on the titration curve with pH as the Y-axis and the volume of acid/alkali added as the X-axis.

In the lessons taught by the two teachers, the same patterns of variation were enacted. However, the relevance structure created in the two classes was quite different. In the two lessons taught by the first teacher, the students' intuitive understanding, which happened to be a misconception, was intentionally utilised by the teacher. Students were asked to carry out an experiment, the result of which challenged their belief. Some academically oriented students in the class may have been intrigued by the results of the experiment, which would have motivated them to learn and continue to carry out the scientific inquiry required of them by their teacher. However, there is no guarantee that all of the students would have found such pure academic inquiry meaningful, as they may not have been able to see any immediate application of this knowledge to their daily life or the environment. This concern was addressed in the lessons taught by the second teacher. The aim of the scientific inquiry was clear: to solve an environmental pollution

problem affecting the well-being of people. Some of the students in the class may still have felt that the problem was not related to them as they may not have been interested in working in industry. For such students, teachers may have to find other ways to link the object of learning to the students' life experience to help them to develop a relevance structure that will give meaning to the object of learning and the motivation to learn it.

Students' interest in learning a topic depends on whether they find it related and relevant. This in turn affects their academic performance. Making use of patterns of variation can help turn certain critical features from 'impossible' to learn to 'possible' to learn, but it does not guarantee that all students will learn. Creating a relevance structure for students moves teachers one step forward in helping students to learn.

Motivation strategies are important. However, they must target the creation of a relevance structure for students. Activities related to motivation strategies should not distract students' attention from the object of learning, as this will waste precious class time and negatively affect students' learning.

#### Example 5.5

In Example 2.8 in Chapter 2, a teacher wished to make use of the research lesson to encourage students to write creatively. Unfortunately, the motivation strategy she used distracted students from the intended object of learning. As the students were engaged in activities that enabled them to experience variation in making wishes, this was what they learnt, yet such experience was neither the intended nor the most valued object of learning. When another teacher taught this topic, she used the activity of writing about making wishes on one's birthday to introduce the topic as a motivation strategy. She then moved directly to explain the accompanying text and asked the students to write the ending to the story in groups. She also allowed time for each group to share their work. In this way, the following pattern of variation was enacted.

*Table 5.8* Enacted pattern of variation

Invariant	Varied	Critical feature to be discerned
The story	The ending of the story written by students	The same story can have different endings

After the lesson, the researcher interviewed three students.

- Researcher:* *What did you learn in the lesson?*  
*Student A:* *There can be different endings to the same story.*  
*Researcher:* *Do you like listening to these different endings?*  
*All Students:* *Yes.*  
*Researcher:* *Why?*  
*A Student:* *Because we can create different story endings on our own.*

It is a good idea to use teaching strategies that promote students' interest in learning and engage them in activities. However, when selecting an activity to be used in a lesson, we should not only ask ourselves, 'Are students interested and engaged in the activity?' We also need to ask more stringent questions, such as 'Will the activity ignite students' curiosity and interest in the object of learning or its critical features?' It is important that teachers carefully design activities to motivate students to learn, but the focus of such activities should always be on the critical features of the object of learning. The pattern of variation that is being enacted through each activity should be carefully analysed to make sure that the activity is serving to help students to discern the relevant critical features of the object of learning.

## Variation Theory and the cultivation of attitude

Variation Theory is not only applicable to the learning of knowledge and skills. It also applies to the cultivation of attitude, as the following two examples illustrate.

### Example 5.6<sup>4</sup>

Cantonese Opera is an art especially appreciated by Hong Kong people, and in 2009 Cantonese opera was designated an Intangible Cultural Heritage by UNESCO (UNESCO, 2009). On stage, the artists make use of graceful movements of the eyes, fingers, hands, torso and legs to make what is virtual seem like reality in the minds of the audience. The main purpose of teaching Cantonese Opera in schools is to help students to appreciate and treasure this art. In a Cantonese Opera Learning Study, teachers used a number of video clips of Cantonese Opera episodes to introduce the following critical features of Cantonese Opera.

- There are standard ways of acting out certain actions (e.g., opening a door, riding on a boat).

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<sup>4</sup> This is from a Learning Study carried out by a primary school in Tai Po in 2009. The Learning Study was led by Yuen Tsz Leung.

- Actors must convey complex ideas to the audience (e.g., space, furniture, changes in time) through detailed and exaggerated finger movements and body gestures rather than relying on scenery and stage equipment.

Above all, the teachers hoped that by acquiring a deeper understanding of why and how Cantonese opera actors act out certain actions in specific ways, students would appreciate the elegant movements of the actors and pay attention to the art form produced by the whole body and the details that the actors wished to convey.

Only the concluding episode of the lesson is discussed here, in which the teachers attempted to help students appreciate the elegance and grace of the movements of Cantonese Opera actors.

***Description of the last episode of the lesson in the first teaching cycle***

*Teacher: Get into groups of three and discuss how you board a boat. The pier is here. Later, I'll ask you to act out boarding a boat and riding the boat from here to there.*

The students carried out the activity. Then one group of students was asked to perform in front of the class.

*Teacher: Pay attention to their every move. What's the difference between them?*

*Student 1: One student is pretending to hold an oar.*

*Teacher: So, this group has attended to details, like using an oar to row the boat. Now I'll show you a video; watch how these people board a boat.*

The teacher showed the video of part of a Cantonese Opera, in which a boatman rowed a boat to the shore, three men boarded the boat, and they all went off together. There was no actual boat, and thus the actors had to make the audience feel that they were indeed boarding and riding in a boat.

*Teacher: Now you saw them board a boat. After they got on the boat, their bodies moved up and down. Why?*

*Student 2: Because there were waves.*

*Teacher: How did they move?*

*Students: They moved slowly.*

*Teacher: In fact, every movement, however slight, is important. In Cantonese Opera [because there is no furniture or equipment], the actors depend only on their movements to show whether they are indoors or outdoors and the distance they have travelled, and their movements are slow. Did you think of all the movements involved in rowing a boat just now [when you were*

*rowing]? No, because we did not think in enough detail. But in Cantonese Opera, the movements are very detailed, **and the actions are very graceful.***

In this lesson, the teacher focused the students' attention on the details of the movement, merely mentioning that 'the actions are very graceful'.

***Description of the last episode of the lesson in the second teaching cycle***

In the second cycle of teaching, the teacher taught in a very similar way. However, guided by Variation Theory, minor changes were introduced in response to feedback from the student learning outcomes in the first cycle. The teacher first invited three students to act out boarding and riding a boat. After the performance, the students were asked to comment on whether the performance was good. The teacher then showed the same video of the boatman and the three gentlemen riding in a boat. After showing the video, as in the first lesson, the teacher discussed with the students how the actors showed that they were riding in a boat. The teacher then continued:

*Teacher: Which part is elegant and graceful?*

*Student 1: One of the actors picked up his clothes before getting on to the boat.*

The teacher then asked the class to attempt the same performance in groups of three, but noted that there were some criteria that they had to bear in mind. First, they must show through detailed movements that they were riding in a boat; second, they must show a change of space; third, they must show through their actions the presence of the boat; and finally, their action must be graceful and detailed. They were given three minutes to think about how to carry out the performance and were then asked to perform. Afterwards, the same three students who had performed at the beginning of the class were invited to perform in front of the class again. The teacher asked the class to comment on their performance, based on the four criteria that they had been given.

*Student 2: It was good that they showed that they were moving from the pier and boarding the boat, and acted as if the boat was rocking.*

*Teacher: What's the difference [between the first performance and this one]?*

*Student 3: They used some of the movements we saw in the video.*

*Teacher: Which movements are similar to those in the video?*

*Student 4: It felt very real to me, very good.*

*Teacher: Was there any change in space? Any graceful parts? **How could you make the movements more graceful or elegant?***

*Student 5: Go lighter, not so heavy.*

*Teacher: Yes, their movements are a bit rough. **How can we make it more graceful?***

Students volunteered answers, and the teacher referred to the video again in the discussion.

***Description of the final episode of the lesson in the third teaching cycle***

In the third lesson, the teaching was very similar to that in the second lesson. The video was shown first, and then the class practiced the rowing act together with one group being elected to perform in front of the others. The only difference was that the whole class was asked to mark the performance using the four criteria mentioned in lesson 2. The video episode was then discussed in detail as in lessons 1 and 2 and the same group was asked to perform again. The whole class was then asked to comment on the acting, and again to give marks for the performance on each of the criteria.

In all three lessons, the teachers taught using very similar activities and the same video clip, with only very minor differences. To find out how the students had learned, an open question was used to ask students to compare the way that the actors acted with what we would normally do in daily life.

In the post-test, some of the students in the first class pointed out that the actors paid attention to the details of their action to turn the virtual into the real in the audience's mind. However, none of them mentioned that the movements of the Cantonese Opera actors were graceful and elegant either in the pre-test or the post-test. The following table shows that 62% more students in the second class mentioned or conveyed the idea that the movements of Cantonese Opera actors are graceful and elegant in the post-test. In the third class, the increase was even greater, from 3% to 82%, some 79% more than in the pre-test.

*Table 5.9* Comparison of the pre- and post-test results of the three classes

	1 <sup>st</sup> cycle lesson	2 <sup>nd</sup> cycle lesson	3 <sup>rd</sup> cycle lesson
Pre-test (% of students)	0%	5%	3%
Post-test (% of students)	0%	67%	82%
% gain (% of students)	0%	+62%	+79%

The indirect object of learning has to be learned through the direct object of learning. In this case, the direct object of learning was the content, the movements of the Cantonese Opera actors in a scene about 'riding in a boat'. The movements of the actors and the very detailed enactment formed the internal horizon, including actions such as the actor

boarding the boat and the boat moving up and down due to the weight of the actor, the actor's body then moving up and down due to the rocking of the boat and the boat finally coming to an equilibrium, but rocking again as the second actor boarded the boat. This last action took into account the movement of the boat and the position of the first person, that is, the person standing at the head of the boat went up while the person standing at the tail went down. Noting the different acts (parts) and seeing their relationship with each other (part-part) gives meaning to the whole (riding on a boat) so that each of the parts becomes meaningful.

From the results of the students' post-test and also their performance during the lessons, it was clear that the students in all three classes had learned the direct object of learning quite well. However, learning the direct object of learning does not imply that the students would also have learned the indirect object of learning, and in this particular case, the students in the first lesson had not. The indirect object of learning was 'appreciate the graceful and elegant movement of the actors'. How can the difference in student learning outcomes in the three classes be explained?

'To become aware of something, we must separate it from something else, and there are necessary conditions for this separation to take place. To separate the elegance of movements from the movements themselves, we must experience the same movements with varying degrees of elegance, or at least be aware of the two values: graceful and not graceful' (Lo & Marton, 2012). The teachers were aware of this necessary condition, and so had planned for this in their research lesson. The idea was to invite a group of students to act out boarding a boat before they watched the video, so that the awkward movement of the students would provide a contrast to the graceful, elegant and artistic movement of the Cantonese Opera actors. It was intended that this activity would enable the students to discern what was intended.

Unfortunately, in the first lesson, the teacher never referred back to the students' acting at the beginning of the lesson to intentionally highlight the contrast and provide an opportunity for the students to experience the variation in movement simultaneously. The dimension of variation of the degree of gracefulness was not explored. Instead, the teacher focused solely on the graceful acting of the three actors in the video. As all three actors performed in an elegant and graceful manner and there were only very subtle differences between them, it was not easy for the students to discern that the acting was elegant and graceful.

The teacher of the first lesson did try to draw the students' attention to the expected learning outcome by explicitly saying 'the actions are very graceful'. However, judging



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from the student learning outcomes, this strategy was not successful. This demonstrates that telling students what to discern is not effective; students must **experience** the necessary variation **themselves** to be able to discern the intended object of learning.

The pattern of variation enacted in the first lesson is shown in Table 10, and probably helped the students to discern that there are standard ways of showing boarding and riding in a boat, because the actors all acted this out in very similar ways. However, the intended indirect object of learning was not achieved.

*Table 5.10* Pattern of Variation Enacted

Invariant	Varied	Critical feature to be discerned
The action of boarding and riding on a boat	Actors	There are standard ways of boarding and riding a boat in Cantonese Opera

In the second lesson, the teacher taught in a very similar way. The difference was that she asked the same group of students to act out riding in a boat again after watching the video, and immediately asked the class to contrast the movements of the actors with those of the students. In this way, she focused their attention on the difference between graceful movements (as in the video, and to a certain extent, in the second student performance) with those that were not graceful (as in the first student performance). By asking questions like ‘How can we make the movements more graceful or elegant?’, the teacher explicitly drew the students’ attention to the appropriate variation, thus opening up a dimension of variation on gracefulness of movement. As a result, more students were able to appreciate the graceful movements of the Cantonese Opera actors, as intended.

In the third lesson, not only did the teacher ask the students to compare the acting of the group of students who came out to demonstrate with that of the Cantonese Opera actors, she also asked them to grade the performance of the students based on four criteria, one of which was whether the movement was graceful and elegant. She then asked the students how they could improve the movement to make it more graceful, again bringing this critical feature to the fore by exposing the students to the appropriate variation (Table 5.11). A higher percentage of students were able to acquire the intended indirect object of learning in the second and third class than in the first class.

Table 5.11 Enacted pattern of variation

Invariant	Varied	Critical feature to be discerned
The action of boarding and riding on a boat	The quality of the performance – awkward (students) vs. elegant and graceful (Cantonese Opera actors)	The actions in Cantonese opera are elegant and graceful

Once students can differentiate between graceful and awkward movements through contrast, in fact a dimension of variation is open (degree of gracefulness of action) with two values: clumsy and awkward movement. The teacher can further draw the students' attention to the fine distinctions between the movements of each of the four actors in the video, as each of them performed with different degrees of grace and elegance. In this way, more values can be added to this dimension of variation: The clumsy and awkward moment of the students would be at one end of this dimension of variation, then the act of the three gentlemen, and the very sophisticated and artistic movement of the boatmen would be at the other end (see Table 5.12).

Table 5.12 Pattern of variation for discerning the finer distinctions

Invariant	Varied	Critical feature to be discerned
The action of boarding and riding in a boat	Cantonese Opera actors showing different degrees of mastery of the art	Subtle differences in the action affect the degree of elegance and grace of Cantonese Opera

Example 5.7<sup>5</sup>

In a TV programme entitled 'A class divided', Jane Elliott, a primary teacher in a small, all-white town successfully changed her students' attitude on discrimination. The great and lasting impact of the lesson on the children was revealed 30 years later, when they once again gathered together to talk about the lesson. Although she might not have been aware of it, she had made use of variation tactfully in her teaching. The lesson is described and analysed as follows.

<sup>5</sup> This example comes from a video 'A class divided' by the Public Broadcasting Service (PBS). This video can be found at the following website: <http://www.pbs.org/wgbh/pages/frontline/shows/divided/>.

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On the day after Martin Luther King Jr. was murdered in April 1968, Jane told her class that blue-eyed students were smarter, nicer, neater and better than those with brown eyes, and so should be given privileges. All brown-eyed students were to put on a band for identification. Throughout the day, the blue-eyed students were given special treatment, for example, they were praised even when they did wrong, they enjoyed a longer recess and were first in the lunch line. The brown-eyed students were blamed for whatever they did and ridiculed for minor mistakes they made. With the teacher's encouragement, the blue-eyed students started to enjoy bullying the brown-eyed students and made life difficult for the brown-eyed students, who took on the look and behaviour of genuinely inferior students, performing poorly in tests and other work. On the second day, the teacher told the class that she had made a mistake, brown-eyed students were in fact more outstanding. Immediately, the bands were transferred from the brown-eyed students to the blue-eyed students, and confidence was also quickly transferred from the blue-eyed students to the brown-eyed students. The brown-eyed students showed great progress in group learning on that day. To take revenge on the blue-eyed students, the brown-eyed students turned into little devils. They redoubled their efforts to pay the blue-eyed students back for their sufferings the previous day. Friends turned into enemies. By the end of the day, many students were crying and wishing they could return to the harmonious school life they had experienced before. Finally, the teacher guided the class to reflect on whether it is right to decide on the quality of a person by his appearance. The experience of the two days had a great impact on the children, and their attitude to discrimination was greatly influenced. After 30 years, the students had all grown up and some were parents. The host of the TV programme brought them together again to the classroom to meet their teacher. They all remembered the lesson vividly, and volunteered many examples to prove that they had rejected any kind of discrimination ever since. For instance, one student mentioned that she had never discriminated against non-whites, although in the village where she lived most of her neighbours were conservative and did discriminate. This example indicates that the lesson was very effective. The success is probably attributable to the opportunities open to the students to experience two kinds of identities imposed on them, which allowed them to be able to contrast the treatment and feelings brought about by those two identities. The students were able to discern that although they were still the same person, the identity that was imposed on them brought about different treatment and feelings. If the teacher had stopped at the first teaching activity that identified the blue-eyed students as superior, then the students would not have been exposed to the appropriate variation, and would not have been able to experience the different feelings caused by the two identities personally. The success of the lesson is due to the fact that the teacher provided students with the opportunity to contrast the great

difference in the treatment they received with the different identities (varied). This allowed them to realise that their happiness was built on the suffering of others. The students resented the feeling of being discriminated against, and all the time knew that this label had nothing to do with their own nature (invariant). They came to dislike racial discrimination and extended this resentment to any kind of discrimination. This lesson shows that students' attitudes can be effectively changed if appropriate variation is applied.

Note that great care must be taken if teachers wish to adopt this lesson in their classes. Unless the teacher handles the issue in a very tactful manner and the debriefing is done very skilfully to achieve the targeted aim, the lesson may lead to several problems. For example, students' self image and confidence may be destroyed, the relationship between teacher and students and friendships between students may be damaged, and the teacher may receive complaints from parents. To teach effectively so that the teaching will have a lasting impact on the students, the teacher must have mastered other kinds of capabilities in addition to making use of appropriate patterns of variation, such as good teaching skills and tact. Teachers must be creative in choosing their teaching strategies and content so that it will help them achieve their objectives.

## Variation Theory as a scientific basis of the art of teaching

Since Comenius (1592-1670) first introduced the notion of the art of teaching (Comenius, 1985), the idea has been taken up by many educators and educationists (e.g., van Manen, 1992; Sarason, 1999). However, most research studies on the art of teaching were focused at a general level (e.g., students' motivation to learn, how their classroom experience affects their self-perception) and were not linked to specific objects of learning. This section looks at the issue from a different perspective that focuses on how teachers deal with the object of learning, contextualised in actual classroom practice. By so doing, it is hoped that readers will be stimulated to reflect on whether Variation Theory provides a scientific basis for the art of teaching.

### The relationship between the art and science of teaching

Those who argue that teaching is a science focus on the fact that much of the knowledge generated from a rigorous process of research about teaching and learning can be generalised and applied to situations and contexts beyond the

concrete teaching situations from which such knowledge is derived. In contrast, those who argue that teaching is an art focus on the fact that teaching is a social activity that involves emotions and feelings. Teaching is an impromptu and innovative activity, and the interactions between teachers and students are greatly influenced by feelings and emotions. The act of teaching has its own personality and appeal, and charismatic teachers can be very influential. The way in which this happens is often guided by the heart. One frequent testimony that reminds us that teaching is an art is when we encounter teachers who have mastered the skills and technical aspects of teaching, and are following the curriculum guidelines closely or even copying the practices of exemplary teachers, yet still fail to help students to learn effectively. Experienced teachers know that what works well in one class to bring about effective learning can turn out to be completely unworkable in another class. Thus, that which affects students' learning effectiveness is beyond what can be explained from a technical perspective, and involves the teacher's pedagogical tact, the relationship between the teacher and the students, the care exercised by the teacher towards the students, the classroom language used, how well the teacher knows the students and whether the teacher is sensitive enough to recognise the subtle changes in atmosphere and mood and students' ways of thinking, and whether the teacher is able to flexibly adjust the progress and content of the teaching according to students' responses.

Arguing for a dichotomy between teaching as art and teaching as science may not be helpful, rather, we should regard science and art as different aspects of teaching, or dimensions of variation. According to Variation Theory, every phenomenon has many features. How we understand the phenomenon depends on what features we focus on at any one time. This is also the case for teaching. Teachers are humans; not robots or computers. They naturally have their own personality and teaching styles. When we focus on a teacher's relationship with the students, the teacher's emotions, feelings and personality will naturally be in focus. The teacher's concerns and care for the students will emerge as tactful actions. When we focus on these aspects, the art of teaching is discerned. However, when teaching, there are targets and learning objectives that must be achieved. A clear teaching flow and intended object of learning should be set to guide the lesson. In designing the lesson plan, teachers usually follow commonly accepted teaching and learning principles that are derived from learning theories, such as the use of routines to manage classroom discipline; the identification through evidence-based inquiry of the critical features of an object of learning; and the use of Variation Theory as a guiding principle. The learning outcomes of

the students can, to a certain extent, be predicted and explained by the teachers' teaching acts, and a teacher's teaching effectiveness can be assessed to a degree by analysing student learning outcomes. Once we focus on these aspects and the relationship of these aspects with students' learning outcomes, the science of teaching is discerned.

The scientific basis of teaching ensures that decisions about how to teach and what are good principles of teaching are based on evidence and not on the whims of individual teachers. However, more often than not, teachers will find that it is not possible to adhere to a rigid lesson plan due to student diversity in the classroom. Further, a teacher's own personality will inevitably affect the way he or she handles different situations. Outstanding teachers are those who have good mastery of many kinds of teaching skills and strategies, are reflective not only before or after the lesson but also during the lesson, and are thoughtful in action. Such teachers will be able to take innovative action in response to students' reactions in the dynamic and complex teaching environment. While keeping in mind that the object of learning must be worthwhile, even the object of learning can be constantly improved as teachers and students gain better insights into it. Thus, both the object of learning and the ways in which it is handled in class will be subject to change according to time, place and people. When teaching is thus sublimated from its scientific basis, it takes the form of an art.

The art and science of teaching are both critical aspects of teaching (the whole). Of course, there are other aspects of teaching too, such as its social aspect. During the teaching act, all of these aspects are displayed in a state of fusion.

### **The art of designing teaching activities**

Even when the appropriate pattern of variation has been designed, there are still many different ways of bringing this pattern out through classroom activities. When a teacher has planned an appropriate teaching activity, he or she will still have to make adjustments to the lesson flow in response to students' reactions. Responding tactfully to the dynamic classroom situation to ensure that students are being challenged and brought to new heights of learning and potential is beyond the scope of a teacher as mere technician. This is well illustrated by the following example.

Example 5.8<sup>6</sup>

Consider the Primary Three Learning Study case about ‘condensation’ described in Example 3.10 in Chapter 3. In this case, the teacher hoped to teach students that water vapour in the air condenses to water droplets when cooled. The following pattern of variation was designed.

*Table 5.13* Pattern of variation designed by the teacher

Invariant	Varied	Critical feature to be discerned
Cola can	Temperature of the cola can	There are water droplets on the surface of the cola can that is lower in temperature, but no water droplets can be found on the surface of the can that was kept at room temperature, thus condensation is related to temperature.

However, some students had the idea that the water droplets came from the liquid inside the can rather than from the air, revealing that they had not discerned the critical feature that water vapour exists in the air.

Fortunately, this was a teacher who could think on her feet. In response to the students’ view that the water droplets on the surface of the can came from the liquid inside the can, the teacher immediately poured away the liquid from the cold can. Then, after making sure that the students were satisfied that there was no liquid inside the can, she showed the students that water droplets continued to form on the surface of the cold can. In this way, another pattern of variation was enacted in the lesson.

*Table 5.14* Enacted pattern of variation in the lesson

Invariant	Varied	Critical feature to be discerned
Temperature of the cola can	Cola can with or without liquid inside	Water droplets were formed on both cans, showing that the water droplets did not come from the liquid inside the can.

<sup>6</sup> This example is from a Learning Study case from Shap Pat Heung Rural Committee Kung Yik She Primary School carried out by Lo Mun-ling and Lai Meng Choo in 2003.

The teacher had brought out another critical feature, that ‘the water droplets that condense on the surface of the can do not come from the inside of the can’. This critical feature was discovered by the teacher only after the students had interacted with the object of learning in the lesson. In this case, the teacher managed to make use of the students’ different ways of understanding as a teaching resource, and immediately devised an activity to bring out a pattern of variation to deal with their misconception. The point to note here is that the activity was not pre-planned, but improvised by the teacher during the lesson, thus showing the teacher’s teaching tact.

After the lesson, the researcher interviewed three students. This time, no one said that the water droplets came from inside the can. However, they were confused about where the water droplets actually came from. Although the teacher had contrasted a can with and without liquid to help students discern that the water droplets did not come from within the can, she never related the water droplets to the air. Thus, the students had still not discerned this critical feature. In response to this problem, the research team amended the lesson plan so that the students would experience simultaneous variation of ‘condensation/no condensation’ and ‘with air/without air’ to discern that the water droplets came from the air. The following pattern of variation was designed.

*Table 5.15* Improved pattern of variation

Invariant	Varied	Critical features to be discerned
The can is cold	The cold surface is/is not in contact with the air.	Water droplets only form on the cold surface in contact with the air, thus the water droplets come from the air.

Although the desired pattern of variation had been identified, it was a challenge for the teachers to carry it out. In most Hong Kong primary schools, there is no laboratory and it is not easy to find a vacuum pump to carry out such an experiment. Moreover, even if a vacuum pump were available, the experiment was still technically very difficult to perform. From this example, it can be seen that Variation Theory is not meant to dictate how teachers should teach a topic. The actual teaching strategy must be designed by teachers, using their own experience, intelligence and creativity. In this example, the teachers used Variation Theory as a guiding principle and eventually designed a simple experiment to solve the problem.



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In the second research lesson, the teacher took out a cold Cola can and wiped the water droplets from its surface. She then wrapped the can in a layer of tissue, followed by a layer of plastic wrap and then another layer of tissue. After a while, the outermost layer of tissue became wet but the innermost layer of tissue remained dry. The teacher then asked the students to discuss and explain this result, and used the students' different explanations to arrive at the conclusion that the water must have come from the surrounding air. The enacted pattern of variation in this lesson was as follows.

Table 5.16 Enacted pattern of variation

Invariant	Varied	Critical feature to be discerned
Cold can	Whether the cold tissue is in contact with the air or not	Only the tissue in contact with the air will be wet, thus the water droplets must come from the air.



Diagram 5.1 The teacher's way to carry out the experiment in the second research lesson

The students would also be able to discern that the tissue that was in contact with the can was dry whereas the one that was not in contact with the can was wet, and so this set up would also be able to answer the question of whether the water droplets came from the liquid inside the can.

From this example, we can see that the teaching strategy adopted for the lesson was not mechanically dictated by the pattern of variation. After identifying the critical features, the teachers still needed to think of an appropriate teaching strategy to bring out the appropriate pattern. Teaching is an art. No matter how good the pattern of variation is, it cannot be experienced by students as intended if teachers are not sufficiently creative to design an appropriate and interesting teaching activity to bring it out.

Being sensitive to students' difficulties, being able to see the reasons behind a student's answer, and identifying misconceptions and being able to deal with them involves more than technical competence: it is already in the realm of teaching as an art.

A necessary condition for students to develop a particular way of understanding a phenomenon is that they are provided with opportunities to experience the phenomenon in a particular way. This involves experiencing patterns of variation that will enable them to discern the phenomenon from its external horizon, the critical features of the particular way of understanding the phenomenon, and the relationship among these critical features and between the critical features and the phenomenon as a whole. In other words, how learners discover, experience and understand a phenomenon depends on what aspects (critical features) they discern simultaneously, and how they link these aspects. Although the derivation of patterns of variation to enable a specific type of discernment is sometimes relatively straightforward, providing learning experiences that enable students to experience the intended patterns of variation can sometimes be a challenge. The following example shows that although Variation Theory can be used as a guiding principle and inspiration for teachers, being able to come up with appropriate learning activities for a complex object of learning is an art.

Example 5.9<sup>7</sup>

The electrochemical series is an important concept in Secondary Four chemistry in Hong Kong because it provides the basis for students to understand other concepts such as electrochemical cells and chemical reactions. The concept of the electrochemical series is briefly explained here.

All metals have a tendency to dissociate into ions in aqueous solutions. This tendency varies among metals, and is called the electropotential of the metal. When a metal with a higher electropotential is connected to a metal with a lower electropotential in an electrochemical cell, electrons flow from the metal with a higher electropotential to that with a lower electropotential.

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<sup>7</sup> The data for this case come from a learning study of the Secondary Teaching Evaluation and Mentoring Project (STEM) funded by the Hong Kong Quality Education Fund. The learning study was led by Lo Mun Ling. A detailed description and analysis of the case can be found in Lo, Hung and Chik (2007).

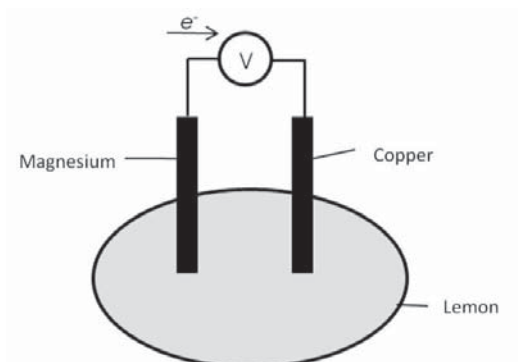


Diagram 5.2 A chemical cell made with magnesium and copper

This difference in electropotential can be measured in volts. In this way, the electropotential of different metals can be compared and ordered, and the series of metals thus formed is called the electrochemical series.

In a Learning Study case on the electrochemical series, a group of teachers agreed that the following four critical features must be discerned by students simultaneously.

- The electropotential of metals in an electrochemical cell can be compared by choosing any metal as the reference electrode and any other metal as the other electrode, and measuring the voltage produced.
- When metals are ordered according to their electropotential, an electrochemical series is produced. This series is invariant and independent of the reference metal.
- The electropotential difference between any pair of metals is constant.
- The difference in electropotential of metals is additive. That is, the voltage between metal A and metal C is the sum of the voltage between metal A and metal B and the voltage between metal B and metal C.

First, to help students discern that there is an electropotential difference between any two metals and that this difference is dependent on the metal pair, students must experience variation in electropotential differences and metal pairs simultaneously. In other words, the following pattern of variation must be enacted in the lesson.

Table 5.17 First Pattern of Variation

Invariant	Varied	Critical feature to be discerned
The structure of the electrochemical cell used in the experiment; the reference metal	The metals that are used to couple with the chosen reference metal	The voltages of the chemical cells produced by different metals coupled with the same reference metal are different.

Finding a learning activity to bring out this pattern of variation is relatively straightforward, as students can set up electrochemical cells using one fixed metal as a reference electrode and vary the other electrode. They can then measure the voltage produced, which gives an indication of the electropotential difference. In this way, students can discern that different voltages are produced when different metal pairs are coupled. In the lesson, students may be asked to do this experiment in groups. Each group will be assigned a reference metal. In the post-experiment discussion, the results of all groups can be pooled to allow the students to discover what happens when the reference metals used are also varied. Students can then compare the voltages produced by coupling different metal pairs, and compare the voltages produced by the same metal pairs from different groups. One group can also be asked to conduct the experiment without a fixed reference metal, that is, they set up different chemical cells using metal pairs of their own choice and measure the voltages. This group's data will provide further evidence and consolidation of the conclusions drawn.

It is not sufficient that the students carry out laboratory investigations; the activities must help them to develop a deep understanding of the scientific concepts at work. For students to discern the critical features of the electrochemical series, they must be able to experience variation in the reference metal and invariance in the order of the metals and the voltage between a given metal pair. Presenting this pattern of variation in the lesson was a challenge.

The teachers first considered presenting the data in the form of tables and pooling data from different groups for comparison, which is the usual practice suggested in textbooks. However, they soon realised the difficulties involved. Table 5.18 shows the result when three groups of student data were pooled and listed in table form.

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Table 5.18

Reference metal	Coupled metal	Measured voltage	Reference metal	Coupled metal	Measured voltage	Reference metal	Coupled metal	Measured voltage
silver	copper	-0.46	copper	silver	0.46	iron	silver	1.24
	lead	-0.93		iron	-0.78		copper	0.78
	iron	-1.24		sodium	-3.05		lead	0.31
	sodium	-3.51		potassium	-3.26		calcium	-2.43
	calcium	-3.67		lead	-0.47		potassium	-2.48
	potassium	-3.72		calcium	-3.21		sodium	-2.27

Although Table 5.18 shows that the reference metals vary, it does not display the metals in any specific order, because the students were not required to carry out the experiment using metals in any specific order. A pattern cannot be easily discerned from the table. The teachers will need to ask the students to arrange the data with the measured voltage in either increasing or decreasing order to give Table 5.19.

Table 5.19

Reference metal	Coupled metal	Measured voltage	Reference metal	Coupled metal	Measured voltage	Reference metal	Coupled metal	Measured voltage
silver	copper	-0.46	copper	silver	0.46	iron	silver	1.24
	lead	-0.93		lead	-0.47		copper	0.78
	iron	-1.24		iron	-0.78		lead	0.31
	sodium	-3.51		sodium	-3.05		sodium	-2.27
	calcium	-3.67		calcium	-3.21		calcium	-2.43
	potassium	-3.72		potassium	-3.26		potassium	-2.48

Some kind of order is now appearing, but it will not be immediately obvious to every student, because the reference metal is missing from each list and the three lists do not appear to be the same. The teacher will thus need to ask the students to put the reference metal into the list to create more complete lists for comparison, resulting in Table 5.20.

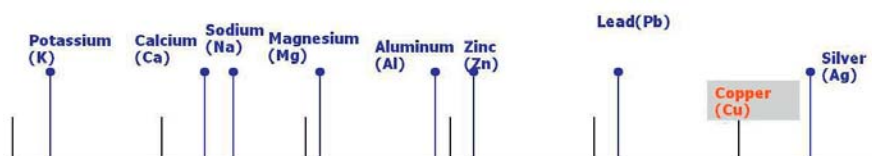
Table 5.20

Reference metal	Coupled metal	Measured voltage	Reference metal	Coupled metal	Measured voltage	Reference metal	Coupled metal	Measured voltage
silver	Silver	0	copper	silver	0.46	iron	silver	1.24
	copper	-0.46		copper	0		copper	0.78
	lead	-0.93		lead	-0.47		lead	0.31
	iron	-1.24		iron	-0.78		iron	0
	sodium	-3.51		sodium	-3.05		sodium	-2.27
	calcium	-3.67		calcium	-3.21		calcium	-2.43
	potassium	-3.72		potassium	-3.26		potassium	-2.48

It is only after these manipulations of the data directed by the teacher that the students will clearly come to see that when the metals are arranged by measured voltage, their order is the same, revealing the electrochemical series, and that this order does not change regardless of the reference metal used. Yet even at this stage, it is still not possible for the students to see that the difference in measured voltage between any pair of metals is the same irrespective of the reference metal.

To discern this critical aspect, the students must continue to compare the voltage differences between pairs of metals. For example, when silver is used as the reference metal, the voltage difference between copper and lead is  $(-0.46 - (-0.93)) = +0.47$ ; likewise, when copper is used as the reference metal, the voltage between the same pair of metals (copper and lead) is  $(0 - (-0.47)) = +0.47$ . This calculation must be repeated for each pair of metals. Discovering the additive rule is even more difficult, and would require even more direction from the teacher. The teachers decided that this would be counter to an inquiry approach, and would be no different from a transmission model of teaching, as students would merely be following instructions and performing a lot of calculations.

Variation Theory points to the necessary conditions for students to learn the electrochemical series, but does not give any hint about what kinds of learning activities or teaching strategies can be used to bring this about. After much discussion, the teachers finally arrived at an ingenious strategy. They planned to ask each group of students to use their experimental data to plot the positions of each metal on a line graph, with a fixed scale of 1 volt to 10 cm. Once they fixed the position of one metal on the line, the rest would follow as shown in Diagram 5.3.



*Diagram 5.3* A student-constructed electrochemical series using copper as the reference electrode

Each group of students would copy the line graph it obtained onto a strip of transparency film. The teacher would then display all of the transparencies from different groups on the overhead projector (Diagram 5.4).

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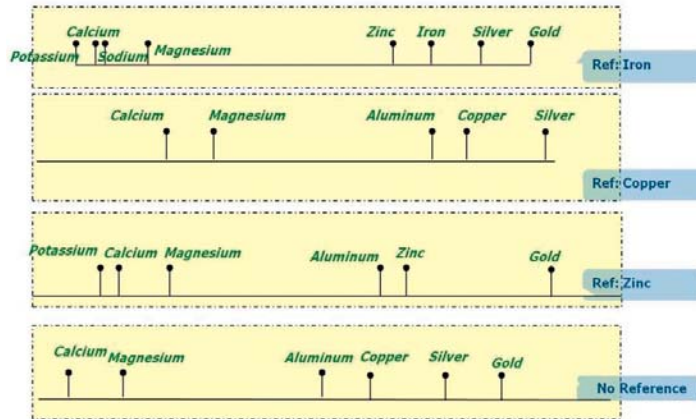


Diagram 5.4 Student-constructed line graphs using different reference electrodes displayed together for comparison

Using one of the metals as a reference point (e.g., calcium), the teacher would then line up the transparencies as illustrated in Diagram 5.5.



Diagram 5.5 Student-constructed electrochemical series lined up with reference to one metal (e.g., calcium)

In the lesson, the teaching flow would be as follows.

1. The teacher first directs students' attention to the different voltages measured between the reference metal and other metals. This opens up a dimension of variation of electropotential differences and a dimension of variation of metal pairs. The relationship between metal pairs and their electropotential differences can then be discerned by drawing attention to their simultaneous variation.
2. The teacher next draws students' attention to the different reference metals used by the student groups. This helps the students to separate the 'reference nature' of the reference electrode from the specific metal used as reference. In other words, the reference nature of the reference metals becomes a dimension of variation, and different metals become values on this dimension of variation. Using different reference metals also affects the measured voltage, because the voltage is measured against this metal as a standard.
3. Amidst all these variations (reference metals, measured voltages), the teacher then draws students' attention to the sameness (the order in which the metals appear and the distance between any pair of metals, irrespective of the reference metal). The students are then helped to make the generalisation that the electrochemical series is invariant and independent of the reference metal used. The distance between any metal pair on the line graph is the same, which is possible only if the electropotential difference between any pair is invariant. This conclusion is also tested by referring to data from the group working with no reference metal.
4. The additive rule is next derived from Diagram 5.4. Again, this is verified using data from the group using no reference metal.

It is generally agreed that the concept of the electrochemical cell exhibits aspects that can be described at three levels of representation in chemistry: macroscopic, microscopic and symbolic (Wu, Krajcik & Soloway, 2000). As the concepts of the electrochemical series are built on the concept of electrochemical cells, the same can be said of the electrochemical series. The approach planned for the research lesson helps students to integrate these three levels. At the macroscopic level, students work with electro-chemical cells to measure the voltage produced. At the microscopic level, students have to understand how electrons and ions flow in the chemical cell to determine the sign of the voltage measured. At the symbolic level, students represent the measured voltage in the form of line graphs. All of the measured voltages of the various electro-chemical cells used by the different groups are then presented together and are visually present throughout the post-lesson discussion. This situation represents an initial fusion. Students are presented with a 'whole' despite particular aspects being unclear. Then, during the discussion, by comparing and contrasting the data, each aspect



is separated out and discussed, generalisations are drawn, and as the different aspects become clear, the meaning of the ‘whole’ becomes clearer. As the aspects are always discussed in the context of the whole, the relationships of the various aspects to the whole and to each other are always visible, which makes final fusion possible. This teaching arrangement is a good example of the teaching sequence: ‘fusion – separation – generalisation – fusion’.

The research lesson was carried out as planned. To find out whether the students had acquired the intended object of learning, three students were drawn randomly from the class and interviewed after the lesson. The following dialogue is part of the transcript.

***Interview script***

The researcher had been asking the student questions about the factors that affect the measured voltage measured.

*Researcher:* So the only thing that is important is . . .

*Student:* The metal.

*Researcher:* You mean only one metal?

*Student:* No, it should be the two different kinds of metal.

*Researcher:* You mean the metal pairs? So what you mean is, no matter how we set up the cell, the potential difference between the same metal pairs is always the same.

*Student:* Yes.

[The researcher took out the set of transparencies that the teacher used in class and lined them up in the same way].

*Researcher:* Look at these transparencies, what conclusions can you draw?

*Student:* Regardless of the situation, such as the type of reference metal, who carries out the experiment, or what electrolyte is used, the electrochemical series is the same.

This example shows that although the derivation of the pattern of variation to enable a specific type of discernment is sometimes relatively straightforward, it is not always clear how to enact the pattern in the lesson to bring about the desired effect. This is especially true when the object of learning is complex and more than one critical feature must be discerned simultaneously. The ingenious lesson design in the foregoing example shows that teaching is an art, but that Variation Theory provides a scientific basis for lesson design and helps to point the way to achieving the desired result.

## Conclusion

This chapter has shown that Variation Theory is compatible with many commonly promoted teaching principles. Teachers may have different teaching styles, approaches and personalities, and the characteristics of the students in each class are also different, but the same identified pattern of variation can be brought out by a variety of teaching strategies and learning activities. The artistic nature of teaching is often reflected by how a teacher deals with the different views of students and the difficulties that they encounter during the lesson. The dynamic nature of the teaching situation challenges the capability of the teacher to immediately respond to situations that arise. Using Variation Theory as a guiding principle for pedagogical design ensures that teachers employ effective teaching strategy and learning activities that are focused on the object of learning and its critical aspects. This prevents the lesson from deviating from its objective and wasting valuable teaching time, and avoids students discerning other objects of learning that are inappropriate and not worth learning. Variation Theory is applicable to any object of learning that requires learning through discernment. Whether it is effectively applied in the lesson depends on teachers' creativity and experience. An outstanding teacher must acquire more than a deep understanding of the subject knowledge, and should also have excellent pedagogical knowledge of how to bring the subject matter for students and help them to understand of it. Teaching is not just a technical activity; excellent teaching is also an art form. This chapter illustrates that although teachers may have identified the critical features and patterns of variation that are necessary for learning, the expected learning outcome may not be achieved if they do not choose appropriate teaching strategies and learning activities to enact the patterns of variation. Variation Theory serves as a guiding principle for pedagogical design, but does not render the teacher a technician; rather, it provides a scientific basis for the art of teaching.

## Chapter 6

# Analysing lessons using Variation Theory as an analytic framework

The previous chapters have shared some important elements of Variation Theory, with examples from a number of learning studies to demonstrate how the theory can be put into practice to design patterns of variation to help students learn in authentic classroom situations. From its inception in 1999, the development of Learning Study has been closely linked with Variation Theory. As Learning Study is grounded in Variation Theory, it helps teachers to focus on the learning of an object of learning and to focus on the necessary conditions of learning, guided by Variation Theory as a pedagogical principle. Learning study is applied in practice with Variation Theory and tested in research lessons in authentic classroom situations so that important information and feedback can be obtained to further develop the theory. However, despite their close relationship, the development and application of Variation Theory need not always be linked to Learning Study. In the early stage of our contact with Variation Theory, we used it as a framework to analyse lessons in an attempt to establish a relationship between classroom teaching and the learning outcomes of students. The findings have been published (Marton & Morris, 2002; Marton & Tsui, 2004). These lessons were not the products of learning studies. A principal aim of engaging teachers in learning studies is to help them understand and be able to apply Variation Theory in their daily practice so that they can use it skilfully in the diverse and complex environment of their classroom. In this chapter, several lessons are analysed using Variation Theory as a theoretical framework

## Using Variation Theory as a pedagogical principle to analyse lessons and to improve teaching

Two examples serve to illustrate how Variation Theory can be used as a framework to analyse lessons and provide feedback for teachers so that they can improve their teaching to achieve better student learning. First, a research lesson

from a Learning Study is analysed using Variation Theory as a pedagogical principle.

## Analysing a research lesson from a Learning Study

The advantage of using a research lesson for the analysis is that there is always evidence of students' learning outcomes in the form of pre- and post-test results and interview data, which provide evidences to question, support and inform the analysis. It is also a good way to test Variation Theory.

In this example, a Primary 5 General Studies lesson taught as a research lesson in a Learning Study<sup>1</sup> is analysed.

### Description of the Lesson

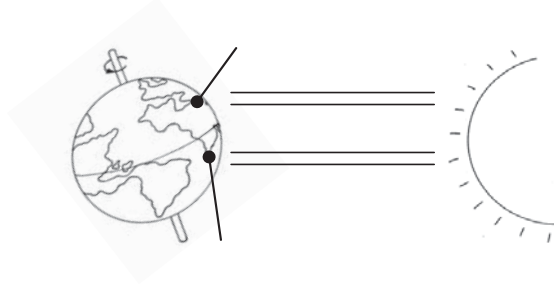
**1. Lead in activity** (about 3 minutes) – Teacher A invited students to demonstrate the Earth's rotation and the Earth's revolution around the sun using a globe. This was intended to be a revision exercise, as concepts such as the direction of the Earth's axis and the angle of tilt of the Earth's axis had been taught in previous lessons. The teacher then discussed with students the temperature changes in summer and in winter in Hong Kong to bring out the relationship between varying temperatures and the change of seasons. She then introduced the next activity.

**2. Activity 1** (about 10 minutes) – Teacher A used a globe to simulate the Earth. Two spots were marked on the globe: spot A was marked on the Tropic of Cancer and spot B on the equator. Teacher A used a beam of light from a torch to simulate a beam of light from the sun and asked students to observe the brightness and the area covered by the beam when she shone the torch on the two spots (keeping the distance between the torch and the globe constant). The students were then asked to record this on a worksheet.

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<sup>1</sup> This example comes from Learning Study VL086 in the "Variation for the Improvement of Teaching and Learning" (VITAL) project carried out by Lo-Fu Yin Wah, Kong Hau Yin, Tsang Yuen Ting, Lee Yin Ying, Lam So Tsang, Mak Chun and Yiu Ming Wah. The project was funded by the Education Bureau of Hong Kong.

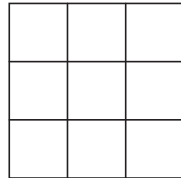
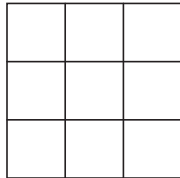
Activity 1:



When the same beam of light ray shines on region A and B:

Surface of region A

Surface of region B



The illuminated area in region A is (larger/smaller) and the weather is (hotter/cooler). Why?

The illuminated area in region B is (larger/smaller) and the weather is (hotter/cooler). Why?

Teacher A emphasised that the light from the torch must be kept horizontal when shining it on the globe. After the demonstration, Teacher A asked the students which beam covered the larger area. The students answered that it was the beam that shone on spot A (on the Tropic of Cancer). Teacher A then asked which spot was hotter. The students were able to answer that it was spot B (at the equator). Using Powerpoint slides, Teacher A then explained why this was so. He used the term ‘oblique sunlight’ to mean a beam of sunlight that strikes the earth at an acute angle, and ‘direct sunlight’ to mean a beam of sunlight that strikes the earth at right angles to the ground. The students were then asked to draw on their worksheets ‘direct sunlight’ and ‘oblique sunlight’ as they struck spots A and B on the globe. By comparing the areas covered by the two equivalent beams of light striking directly or obliquely, Teacher A helped the class to draw the

conclusion that ‘the different temperatures at the spots are caused by whether they receive direct sunlight or oblique sunlight’.

**3. Activity 2** (about 8 minutes) – Teacher A drew the students’ attention to another spot C marked on the Tropic of Capricorn. She then asked students to focus on the two spots (spot A on the Tropic of Cancer and spot C on the Tropic of Capricorn). The distances of both spots A and C from the equator were the same. Teacher A then shone each of the two spots with an equivalent beam from a torch to simulate three situations: 1) when the Earth’s axis did not tilt, 2) when the Earth’s axis tilted to the left, and 3) when the Earth’s axis tilted to the right (see Diagram 6.1). Teacher A then asked students to draw on the worksheet the illumination of the two spots. With the help of Powerpoint slides, Teacher A discussed with the students the differences between the three situations, asking the students whether the brightness of spot A and spot C were the same in each situation, whether the two spots received direct or oblique sunlight, which spot was hotter and whether the spot was in summer or winter. The students were able to answer the questions correctly. Finally, Teacher A asked the students what caused the ‘change’ in the seasons of the two spots, ‘apart from whether they received direct or oblique sunlight’. One student answered that it was due to the ‘the Earth’s spin’. Teacher A then asked what varied in the three situations. A student answered ‘position’. Teacher A then asked which position varied. Eventually, a student answered ‘the Earth’s axis varied’. Teacher A then further supplemented that ‘the Earth’s axis tilted’.

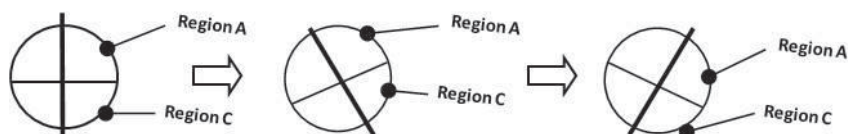
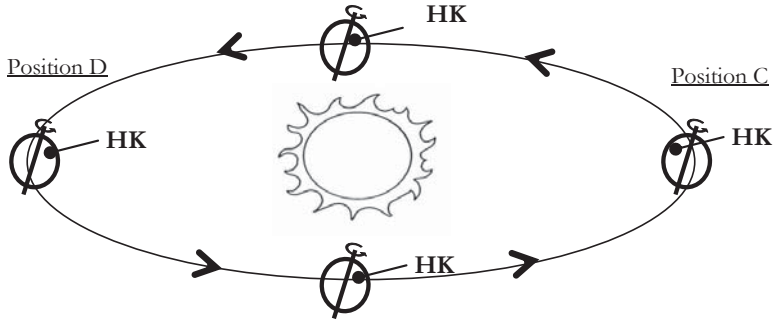


Diagram 6.1 Three situations demonstrated by the teacher in the lesson

**4. Activity 3** (about 14 minutes) – Teacher A asked the students to find out the third reason that causes the change of seasons. The students were first divided into groups, each of which was given a ball and a torch. They then had to simulate the Earth’s revolution around the sun, and to note what changes took place with respect to the illumination of the torch on spot A on the northern hemisphere (Hong Kong). The students had to determine the seasons for spot A

as it revolved from one side of the sun to the other side (from east to west) (see Diagram 6.2), and complete a worksheet.

Activity 3:



Position D

Position C

HK

HK

HK

HK

SUN

What happens when Hong Kong revolves to position C and is facing the sun? What is the season at C?

What happens when Hong Kong revolves to position D and is facing the sun? What is the season at D?

Before the activity, Teacher A reminded students that 1) the torch should be kept in a horizontal position, 2) the Earth's axis should remain tilted at the same angle and 3) the distance between the torch and the Earth should be the same. During the activity, Teacher A observed and provided assistance to each group. After the activity, one group was invited to present their findings, followed by a whole-class discussion with the help of Powerpoint slides. The teacher asked what factors, other than direct or oblique sunlight and the tilting of Earth's axis, caused the change of seasons. One student answered 'its position'. The teacher asked him to elaborate until he answered 'revolution'.

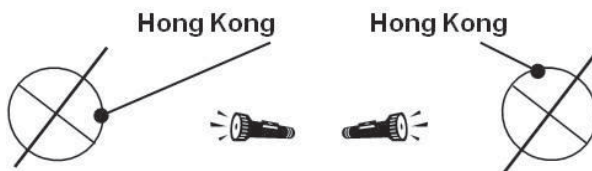


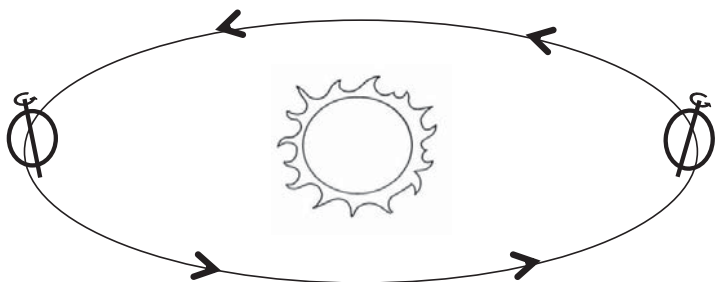
Diagram 6.2 Activity showing the effect of the Earth's rotation on the season

Teacher A then asked the students to pay attention to a spot representing Hong Kong. She shone the torch on the spot and asked what season it was. The students answered that it was summer. The teacher then simulated the Earth's rotation and when the spot was no longer receiving light from the torch she asked the students the same question. Some students answered that it was now winter or autumn. Teacher A then asked if it was possible to have winter and summer on the same day. A student explained that 'it is still summer when the spot is turned to the other side, but it is at night and the temperature is lower.' Teacher A then rotated the globe until the spot came back to the original position and asked the students what season it was. All of the students correctly answered that it was summer. Hence, Teacher A concluded that the Earth's rotation does not cause the change of seasons, but leads to the difference between day and night at a place.

**5. Activity 4** (about 10 minutes) – Teacher A drew students' attention to Activity 4 on the worksheet, which involved a picture showing a situation in which the Earth's axis was changed to point to the opposite direction as the Earth moved from one side to the other side during its revolution around the sun (see diagram 6.3).

Activity 4:

Will this situation ever happen? Why? Please discuss with your classmates.



The diagram shows a central sun with rays. Two Earths are positioned on opposite sides of the sun, connected by an elliptical orbit with arrows indicating a counter-clockwise direction. Each Earth has a vertical axis of rotation. The Earth on the left has its axis tilted to the right, while the Earth on the right has its axis tilted to the left, representing opposite axial orientations.

I think .....

Teacher A then asked the students to discuss in groups whether such a situation was possible in real life. The students enthusiastically discussed and simulated the



situation with a ball. They were then invited to explain their point of view. All of them stated that it was not possible. One student explained that ‘if it happened, we would have winter in June; and the Earth’s axis in the diagram did not always point to the North Pole’. Another student said that ‘the direction of the Earth’s axis is the same and only our perspective of seeing things is changed’. After the students’ explanations, Teacher A showed and explained the situation with some Powerpoint slides and concluded that ‘the changing seasons on Earth is caused by the direction of the tilt of the Earth’s axis remaining unchanged’.

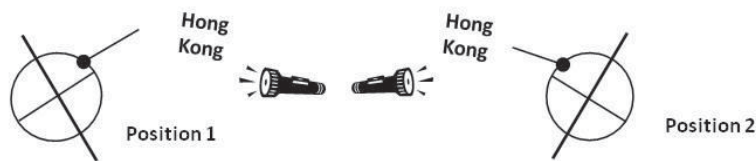


Diagram 6.3 Diagram showing Activity 4

**6. Conclusion** (about 3 minutes) – Teacher A asked why there was a change of seasons in Hong Kong, and asked the students to give three reasons. Some of the students’ answers included ‘the Earth’s revolution’, ‘the tilt of the Earth’s axis’, ‘the area covered by a beam of sunlight when it shines directly or obliquely’ and ‘the Earth’s rotation’. Teacher A rejected the answer ‘the Earth’s rotation’, and accepted the first three. At the end of the lesson, Teacher A used a PowerPoint slide to summarise the three ‘reasons’ for the change of seasons.

### Analysis of the lesson

There are different aspects to understanding and evaluating a lesson, including technical aspects (ways of delivery), the teacher’s personal attributes, and aspects relating to how the object of learning is dealt with, but I will only focus on the last one. To improve teaching and learning, teachers must find out whether students have learnt the intended object of learning and the reasons why they may have failed to learn. The following lesson analysis focuses on how the object of learning was dealt with and analyses whether the lesson designed by the teacher was effective in terms of students’ learning outcomes, so that suggestions for further improvement could be made for more effective teaching and learning.

## Object of learning

In this lesson, according to the teachers, the intended direct object of learning was ‘the changing of seasons at a particular place on Earth’. The following critical features were identified.

CF1: The Earth revolves around the sun, and takes one year to complete a revolution.

CF2: The Earth’s axis is tilted at an angle to the plane of revolution. The tilt and direction of the axis are unchanged during the Earth’s revolution around the sun.

CF3: When a beam of sunlight shines on a place, the angle formed between the light beam and the surface of the Earth affects the area being illuminated. The more oblique the sunlight is to the Earth, the larger the illuminated area and the lower the temperature (winter). The nearer to vertical the beam of sunlight is to the Earth, the smaller the area being illuminated and the higher the temperature (summer).

CF4: The Earth’s rotation does not cause the change of seasons.

The indirect object of learning is ‘the ability to make inferences about the cause of seasons at a place based on observed facts’.

To be a good science lesson, in addition to addressing in-depth scientific content that is worth teaching, the lesson itself should reflect the lines of thinking and the nature of the discipline, that is, what knowledge means and how it should be acquired. The design of this lesson allows students to explore an abstract concept – the formation of seasons – by conducting hands-on simulations with some simple equipment – a torch and two balls of different sizes. The natural phenomena under study, such as the Earth’s rotation, the Earth’s revolution, and the four seasons, are closely related to our daily life, and thus it is likely that the students will develop a relevance structure. The object of learning is worthwhile, but is also very complicated, because the teacher has to deal with many critical features in a single lesson. To understand the changing of the seasons, the students must be able to discern all of the critical features (1, 2, 3 and 4) simultaneously and discern the relationships among them. If the students can only discern individual critical features but fail to achieve the stage of fusion (the simultaneous discernment of all of the critical features and the relationships among them), then they may not be able to understand the object of learning

thoroughly, and will not be able to apply such knowledge to solve new problems. The success of this lesson depends on whether the teacher is able to bring about fusion.

## Analysis of the activities in the lesson

### *Activity 1*

In this activity, the teacher mainly dealt with CF3: when a beam of light shines on a place, the area illuminated by the beam depends on the angle between the light beam and the surface of the Earth. When the same beam of light covers a larger area (when the projection is oblique), the temperature is lower (winter). When the same beam of light covers a smaller area (when the projection is vertical), the temperature is higher (summer). In this activity, the teacher used the following pattern of variation.

*Table 6.1* Pattern of Variation for Activity 1

Invariant	Varied	Discernment
The light beam	The spots (distance between the spot and the equator)	The illuminated area varies depending on how far the spot is from the equator, this leads to different temperatures and different seasons.
The tilt of the axis of rotation of the globe		

This pattern of variation will help students to discern that the temperature of a place depends on where it is on the Earth (its distance from the equator), as its location determines the size of the area receiving the same beam of light and hence the temperature (the season).

This concept was not taught through direct transmission. Instead, the teacher guided the students to draw relevant conclusions through several leading questions. The students were also required to draw oblique and direct sunlight on a worksheet. The majority of the students were able to experience the pattern of variation designed by the teacher and to discern CF3.

### *Activity 2*

In this activity, the teacher enacted the following pattern of variation.

Table 6.2 Pattern of Variation enacted by Teacher A in Activity 2

Invariant	Varied	Discernment
Spot A and spot C	The tilt of the Earth's axis (does not tilt, tilts to the left, tilts to the right)	When the Earth's axis does not tilt, the season in spot A and spot C is the same.
The same light beam shining on the spots		When the Earth's axis tilts (either to the left or right), the season in the southern hemisphere and northern hemisphere will be opposite.

Through the activity, the students were able to discern that if the Earth's axis did not tilt, then it would always be summer in places on the equator and it would always be spring or autumn in places on the Tropic of Cancer and Tropic of Capricorn. If the imaginary axis of the Earth tilts, then places in the southern hemisphere and northern hemisphere are in either summer or winter, but the seasons in the southern hemisphere and northern hemisphere are always opposite. This means that when it is summer in places in the Tropic of Cancer, it is winter in places in the Tropic of Capricorn. However, at this point the students had not come across any learning experience to help them discern the change of seasons, such as how it changes from summer to winter or from spring to autumn in spot A, which is on the Tropic of Cancer.

In this activity, the teacher expected the students to discern that 'the tilt of the Earth's axis causes the change of seasons'. Nevertheless, the aim was not achieved for the following reasons.

- If we ignore the situation of the axis, then this activity is basically very similar to Activity 1. The only difference is that spot B, which was originally on the equator, was changed to spot C, now in the southern hemisphere. The difference in seasons is caused by the different angles at which sunlight strikes the Earth (oblique or vertical). Thus, if the teacher had added spot C at the Tropic of Capricorn in Activity 1, the students would have been aware that when spot B, which is on the equator, is having summer, both spots A and C would be experiencing spring or autumn (with lower temperatures).
- When the teacher simulated the tilt of the Earth's axis, the students observed that the oblique sunlight striking spot A at the Tropic of

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Cancer changed to direct sunlight, and so it was summer in A. At the same time, spot C, which was originally being struck by oblique sunlight, was now being struck by direct sunlight, and the area of illumination at the beam of oblique sunlight striking the Earth around spot C became larger. Thus, the temperature dropped and C experienced winter. In fact, it should have been spring or autumn in spot B, which was on the equator. Up to this point, there were several questions that had not been answered that might have been bothering some students.

- I. Why is the Tropic of Cancer, but not the equator, receiving direct sunlight?
- II. As spot A is having summer, why doesn't the season remain as summer all the time? In other words, what is causing the season at A to change?

Clearly, although the teacher simulated the tilt of the Earth's axis, this may have seemed to the students to be simply a problem of choosing where direct sunlight will strike the Earth. As all of the students would have been aware that places on the Equator are hotter, some students may have been puzzled by the fact it was spot A, which was on the Tropic of Cancer, that was receiving direct sunlight rather than spot B, which was on the Equator. If the Earth did not revolve around the sun, then the tilt of the Earth's axis would not lead to the change of seasons: both are necessary conditions. This activity can at most enable students to see that it is possible for spot A, which is in the northern hemisphere, to have summer. Some students may immediately think that spot C, which is in the southern hemisphere, will have summer if the Earth's axis tilts in the other direction, which may lead to the incorrect inference that the change of seasons is due to a change in the direction of the tilt of the Earth's axis (from left to upright and then to the right).

When Teacher A asked what factors other than direct or oblique sunlight led to the change of seasons, one student answered 'the Earth's spin'. Unfortunately, the teacher was perhaps too focused on the expected answer 'the tilt of the Earth's axis', and did not pay attention to the student's response. The response may actually reflect one of two ways of understanding.

- By 'the Earth's spin', the student might be referring to the rotation of the Earth. He might have thought that the Earth's rotation causes the change of seasons: areas facing the sun are having summer, whereas

areas on the opposite side of the Earth with no sun are having winter. If this is the case, then this misconception must be dealt with.

- By ‘the Earth’s spin’, the student might be referring to the revolution of the Earth around the sun. This is one of the critical features that the teacher should have brought out. If this is true, then the teacher missed a golden opportunity to bring out the fusion of the two critical features: ‘the tilt of the Earth’s axis’ and ‘the Earth’s revolution’.

### Activity 3

In the teacher’s lesson plan, the following pattern of variation was expected to be brought out through Activity 3.

Table 6.3 Pattern of variation for Activity 3

Invariant	Varied	Discernment
The place (Hong Kong)	The location of a place relative to the sun (due to the Earth’s revolution)	The Earth’s revolution leads to the change of seasons at a place.
The light beam		
The tilt of the Earth’s axis		
The distance between the torch and the globe		

Activity 3 is a rather challenging activity for the students, with each group being provided with a ball and a torch to simulate the Earth’s revolution around the sun. The students had to ensure that the tilt of the Earth’s axis remained unchanged and that the Earth’s revolution took place on the same plane. If the students were unable to keep the ball (Earth) in the same plane while moving it around the torch (the sun), then they would not be able to discern the effect of direct and oblique sunlight on the ball. This activity was aimed at providing students with hands-on experience so that they could discover by themselves that spot A would change from being illuminated by direct sunlight to oblique sunlight as the Earth revolved around the sun, and thus understand the reason for the change of seasons. Unfortunately, the objective of this activity may not have been achieved, as the teacher did not remind students to keep the orbit of the Earth’s revolution in the same plane, and the equipment used in the lesson was too crude. It was observed that students did not understand the objective of this activity. For example, in some groups, after the teacher had reminded them that when spot A reached the other side of the sun during the Earth’s revolution,

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it would change from being summer to winter, it was found that some of the students deliberately shone the torch on spot A obliquely. In this way, the objective of the activity was changed. Instead of discovering that sunlight becomes oblique in this new position, the students demonstrated their understanding of what oblique sunlight meant, and the whole activity became meaningless. Although it is important that students have hands-on learning experience and should take the initiative to learn, hands-on experiments done by students are not always better than, and should not replace completely, demonstration by the teacher with suitable equipment. It is a waste of learning time if the expected outcomes are not achieved when students conduct their own experiments, as this example shows. After the activity, when Teacher A asked what other factors apart from direct or oblique sunlight and the tilt of the Earth's axis caused the change of seasons, some students answered 'the Earth's revolution'. However, their answer could not be taken to mean that they had understood the concept thoroughly, as they were asked to simulate the Earth's revolution and might have guessed that the answer that the teacher expected was 'the Earth's revolution'.

The teacher was aware that some of the students might have thought that the change of seasons was due to the Earth's rotation, and deliberately simulated the Earth's rotation and asked the students to pay attention to spot A as it rotated from where it was facing the torch (summer time) to the other side where it was out of reach of the torch. The teacher then asked what season it was in spot A. Some of the students said 'winter', others 'autumn'. Teacher A asked if it was possible to have winter and summer on the same day, thereby making use of the pattern of variation shown in Table 6.4 to help students to discern their own misconceptions. Finally, she drew the conclusion that the Earth's rotation does not cause the seasons to change.

Table 6.4 Pattern of variation used by Teacher A

Invariant	Varied	Discernment
Spot A The season The same day	The position of spot A relative to the sun as the Earth rotates	The Earth's rotation does not cause a change of season.

There is a slight problem with this conclusion. Although the Earth's rotation does not cause the season of a place to change from summer to winter, it does affect the change of seasons to a certain extent. Suppose that the Earth did not rotate. When sunlight shone directly on the Tropic of Cancer, if spot A happened to be facing the sun, then it would receive direct sunlight (summer) and it would be day and would remain so for as long as it was in the path of the sun. Another spot, say D, which is also in the Tropic of Cancer but on the other side of the Earth, would not be in the path of the sun, and it would be winter and night time for a few months at a time. When the sun revolved to the other side of the Earth, spot A would then not be facing the sun, and would experience prolonged winter and night. Spot D would receive oblique sunlight and would be experiencing a warmer season than before, but its 'summer' would not be as warm as that experienced by spot A.

*Activity 4*

In this activity, the teacher made use of the following pattern of variation to deal with CF1 (the imaginary axis of the Earth tilts and the direction of tilt remains unchanged when the Earth revolves around the sun).

*Table 6.5* Pattern of variation enacted in Activity 4

Invariant	Varied	Discernment
The season	The direction of the tilt of the Earth's axis (left, right) The position of spot A relative to the sun as the Earth revolves around the sun	The direction of the tilt of the Earth's axis must be unchanged.

*Conclusion*

In the final teaching episode, Teacher A asked the students to give three reasons why seasonal changes occur in Hong Kong. The students' responses included 'the Earth's revolution', 'the tilt of the Earth's axis', 'the area illuminated by the same beam of sunlight' and 'the Earth's rotation'.

It is interesting to note that although the teacher had pointed out that the Earth's rotation did not cause the change of seasons, some students still thought that it was one of the reasons. This reaffirms that teaching does not necessarily lead to



learning. The actual experience gained by students in a lesson is sometimes different from the learning experience anticipated by teachers. On hearing this answer, Teacher A grasped this opportunity to reiterate that the Earth's rotation did not cause the change of seasons.

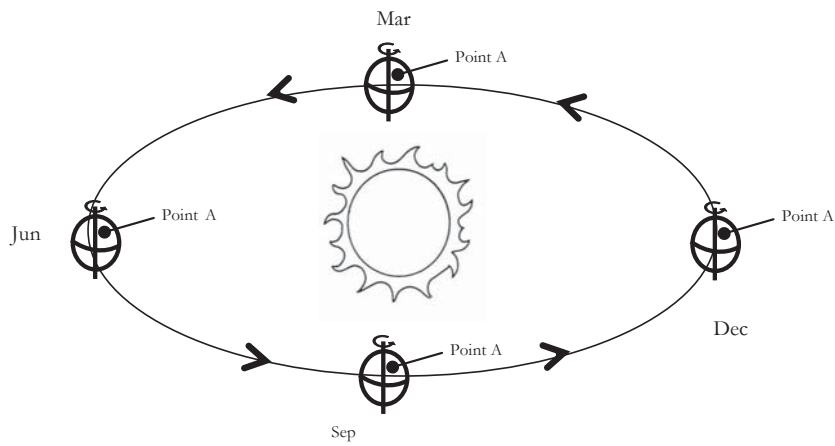
As has been pointed out previously, the success of this lesson depended on the teacher bringing about the fusion of the critical features. When the teacher invited the students to state the three 'reasons' for the change of seasons and accepted the answers 'the Earth's revolution', 'the tilt of the Earth's axis' and 'the area illuminated by the same beam of sunlight', this already revealed that the teacher was considering these three conditions individually and independently of each other, and was not focusing on the relationship between them, or the structure of the internal horizon mentioned in Chapter 2. In fact, these three 'reasons' are not equal in status. The two conditions 'the Earth's revolution' and 'the tilt of the Earth's axis' lead to different areas of illumination when the same beam of light shines on a place, which leads to a change of temperature and thus a different season. The two factors 'the Earth's revolution' and 'the tilt of the Earth axis at a fixed angle and direction' are two necessary conditions for the change of seasons. The area of illumination is caused by both of these conditions together, and the temperature of a place is a consequence of the area of illumination. In this lesson, the teacher did not deal with the change of seasons successfully, as she ignored the relationships among the critical features. Thus far, the lesson has been analysed and its effect predicted using the theoretical lens of Variation Theory. However, whether the analysis is correct must be triangulated with students' learning outcomes.

### Students' Learning Outcomes

Both a pre-test and post-test were given to the students. Two questions were chosen to analyse the students' learning outcomes because they best reflected whether the students had grasped the objecting of learning.

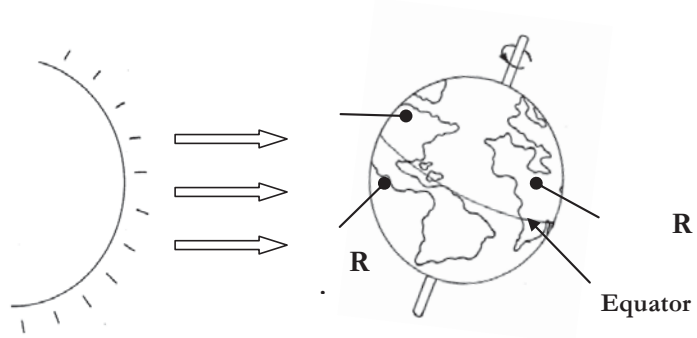
Pre- and Post Test

2.



If the earth's axis was not tilted when the earth revolves around the sun, what will be the weather in position A in the different months? Explain your answer.

3. The following diagram shows the relative positions of three regions on Earth relative to the sun.



3a) Circle the correct season and daytime/nighttime for region A, B and C.

Region	Season	Daytime or nighttime
A	Spring / Summer / Autumn / Winter	Daytime / Nighttime
B	Spring / Summer / Autumn / Winter	Daytime / Nighttime
C	Spring / Summer / Autumn / Winter	Daytime / Nighttime

3b) Which regions will have the same season? Please explain your answer.

3c) Which regions will have different seasons? Please explain your answer.

*Table 6.6* Students' performance on question 2 of the pre-test and post-test

	Pre-test	Post-test
Correct	0%	33%

(Remark) Expected answer: No change, because the Earth's axis does not tilt, and/or the explanation that because the intensity of the light received by spot A is the same in different months of the year, so the temperature does not change, or spot A receives direct or oblique sunlight throughout the year.

Table 6.6 above shows the students' performance on two questions in the pre-test and post-test. To be able to answer this question correctly, the students needed to be able to discern the three conditions – the Earth's rotation, the Earth's revolution and the tilt of the Earth's axis – and the relationships among them to understand their effect on the change of seasons. As the teacher had not directly dealt with the content of this question in the lesson, the students could only infer the answer by using their prior knowledge or knowledge learned in class. No student was able to answer the question correctly in the pre-test, and

only 33% could answer the question correctly in the post-test. This result suggests that the expected learning outcome of Activity 3 had not been achieved. The following are examples of typical mistakes made by students.

1. The experience of Activity 3 showed the students that as the Earth revolves from east to west of the sun, the season in spot A changed from summer to winter. Therefore, following the same line of thought, some of the students inferred that the season in spot A in this question would change from winter to summer, especially as it was originally December in spot A (well-known as winter time for the students), with the new position in June (well known as summer for the students). However, in doing so, they had ignored the tilt of the Earth's axis. The teacher did not provide the students with the opportunity to experience the three conditions and their relationships simultaneously, and the results of the tests show that most of the students were unable to focus on all three conditions and their relationships simultaneously.

2. It was observed that during the lesson, some students thought that the places that were not receiving sunlight were experiencing winter, and this misconception was deep-rooted. When they saw that spot A was on the other side of the Earth (without sunlight), they at once concluded that it was winter in spot A, and the fact that the time that was indicated was December reinforced their thinking. When the Earth revolved around the sun and it was June (which happens to be summer in Hong Kong), they saw that spot A was drawn facing the sun and so conjectured that spot A should be having summer. These students may have failed to discern that whether spot A was facing the sun or not depended on the Earth's rotation, which determines day time or night time only. This learning outcome reflects that the Earth's rotation was not dealt with adequately in the lesson.

The situations of Area A and Area B had been discussed in the lesson, yet only 22% of students could correctly give the season in Area A in the post-test, an increase of only 7%

*Table 6.7* Students' performance on Question 3a of the pre-test and post-test

Correct %	Area A Season	Area A Day time/ Night time	Area A Season +Day time/ Night time	Area B Season	Area B Day time/ Night time	Area B Season +Day time/ Night time	Area C Season	Area C Day time/ Night time	Area C Season +Day time/ Night time
Pre-test	15%	67%	4%	74%	85%	63%	48%	70%	44%
Post-test	22%	100%	22%	93%	89%	85%	74%	93%	67%

Area A was experiencing winter, but 78% of the students wrongly answered that it was experiencing summer. As 100% of the students answered that Area A was in daylight, a possible explanation for the answer 'summer' was that the students thought that the places being exposed to sunlight were experiencing summer. This learning outcome also supports the second point mentioned, that the students thought that the areas not facing the sun were experiencing winter.

Although 93% of the students identified the season in Area B correctly (an increase of 19%), we should not jump to the conclusion that they had learnt this well. It is more likely that they answered correctly because it happened to be day time and summer in Area B. Students who held the misconception that it was summer in areas facing the sun would have got the correct answer, but this was simply because this time their misconceptions led them to answer the question correctly. If Area B in the question had been experiencing night time, then it might have revealed that the students carried this suspected misconception. Unfortunately, we have no interview data that reveals why the students chose the answer that they did, and so we missed the opportunity to find out what might be hindering students' learning.

Area C was experiencing night time and winter. Sixty-seven per cent of the students gave both the season and time of day correctly (an increased of 23% from the pre-test). Unfortunately, it is still difficult for us to be sure whether the students thought that Area C was in winter due to the lack of sunlight. Nevertheless, it is interesting that among the 74% students who answered the season (winter) correctly, 7% got the time of day wrong. Of course, this could have been caused by students' carelessness in answering the question, but it is also possible that these students had a fuzzy concept of day and night when put

into this learning context. Another possible reason may be that the diagram in the test was two-dimensional, and some of the students had difficulties imagining the real three-dimensional situation.

Table 6.8 Students' performance on question 3b in the pre-test and post-test

	Pre-test	Post-test
Correct	0	15%

(Remark) Answer: A and C, because these two areas receive oblique sunlight, and their temperatures are the same.

Table 6.9 Students' performance on question 3c of the pre-test and post-test

	Pre-test	Post-test
Correct	0	19%

(Remark) Answer: B is different from A and C, because A and C receive oblique sunlight whereas Area B receives direct sunlight, and thus the intensity of light received and the temperature are different.

The learning outcomes indicated by Questions 3b and 3c show that more than 80% of the students failed to discern that spot A would take the same position as spot C when the Earth rotates, and so the seasons in these spots should be the same. As spot B is in the southern hemisphere, its season should be different from that of spots A and C, which are in the northern hemisphere.

## Suggestions for Further Improvement

### *1. Fusion of the two critical aspects: tilt of the Earth's axis and the Earth's revolution*

As mentioned, one problem with the lesson is that the critical aspects were dealt with separately without any attempt at fusion. By learning from the students' learning outcomes, the research team made some changes to the research lesson and carried out the next cycle in the Learning Study. Basically, all of the activities remained unchanged except Activity 2, which was altered as follows.

**Activity 2 (about 8 minutes):** Teacher B asked the students to turn to the questions on the worksheet, and gave them 5 minutes to observe the three pictures on the worksheet and work out the seasons in two spots (one on the

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Tropic of Cancer – spot A, the other on the Tropic of Capricorn – spot C, their distances to the equator were the same) in three situations (the Earth’s axis does not tilt, the Earth’s axis tilts to the left, the Earth’s axis tilts to the right). When the students finished the question, Teacher B discussed the first situation when the Earth’s axis does not tilt (it is vertical). The teacher pointed out that the distances of the two spots to the equator were the same, and then asked the students about the intensity of the light received by the two spots. The students knew that the intensity was the same, and thus the temperature of the two places must be the same. Teacher B then demonstrated the Earth’s revolution around the sun by focusing on spot A marked on the globe, and asked the students whether the intensity of the light received was different when the Earth’s axis was vertical. The students answered that the intensity was the same, and so the temperature would be the same no matter where spot A was. Teacher B then used the globe to simulate the Earth with its axis tilted in one direction and then the other. In both situations, Teacher B asked the students about the temperature, the season and whether spot B received direct or oblique sunlight. The students answered all of these questions correctly. Teacher B then pointed out that when the Earth’s axis was vertical, the temperature at a spot did not change. Teacher B then asked why the same place could have different seasons. A student answered ‘direct and oblique sunlight’. The teacher then asked what caused direct and oblique sunlight. A student explained that it is because ‘the Earth’s axis tilts and so spot A experiences different temperatures’. The teacher then summarised the lesson by saying that because the Earth axis is tilted, spot A receives either direct or oblique sunlight. The following patterns of variation were enacted in the lesson.

Table 6.10 Pattern of variation (1)

Invariant	Varied	Discernment
Spot A and spot C Their distance from the equator The Earth’s axis (untilted)	The locations of spot A and spot C with reference to the sun (due to the Earth’s revolution)	If the Earth’s axis does not tilt, the seasons in the two spots on the Tropic of Cancer and the Tropic of Capricorn will be the same (they always receive oblique sunlight).

VARIATION THEORY AND THE IMPROVEMENT OF TEACHING AND LEARNING

Table 6.11 Pattern of variation (2)

Invariant	Varied	Discernment
Spot A The Earth's axis (untilted)	The location of spot A with reference to the sun (due to the Earth's revolution)	If the Earth's axis does not tilt, then there is no seasonal change.

Table 6.12 Pattern of variation (3)

Invariant	Varied	Discernment
Spot A The direction of the tilt of the Earth's axis	The location of spot A with reference to the sun (due to the Earth's revolution)	If the Earth's axis tilts, then the Earth's revolution will result in a change of season.

Table 6.13 Pattern of Variation (4)

Invariant	Varied	Discernment
Spot A The Earth's revolution	The direction of the tilt of the Earth's axis (left, right); The location of spot A with reference to the sun (due to the Earth's revolution)	The Earth's revolution leads to a change of season in spot A, provided that the Earth's axis tilts.

Table 6.14 Pattern of Variation (5)

Invariant	Varied	Discernment
Spot A The Earth's revolution	The tilt of the Earth's axis (does not tilt, tilts to the left, tilts to the right); The location of spot A with reference to the sun (due to the Earth's revolution)	The Earth's revolution leads to a change of season in a place, provided that the Earth's axis is tilted.



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Teacher B then pointed out that the Earth’s axis always tilts in the same direction. When the Earth rotates, the Earth’s axis remains the same, and so does the season. The season only changes when the Earth moves to the other side of the sun. There would be no change of seasons without the Earth’s revolution, on the condition that the Earth tilts in the same direction. The teacher then used some Powerpoint slides to summarise the two necessary conditions for seasonal change: ‘the tilt of the Earth’s axis’ and ‘the Earth’s revolution’. In this section, Teacher B had wished to bring out the following pattern of variation.

Table 6.15 Pattern of variation (6)

Invariant	Varied	Discernment
The tilt of the Earth's axis	With/without the Earth's revolution	The season will not change without the Earth's revolution.

This pattern of variation was expressed by the teacher orally and may not have been experienced by all of the students. Nevertheless, the teacher had at least attempted to bring out the relationships among the tilt of the Earth’s axis, the Earth’s revolution and the change of season by using this pattern in the lesson. A comparison of the performance of the two classes in the same questions as those examined in the analysis of the initial lesson will determine whether the learning outcomes of the students improved with the revised approach.

Table 6.16 Performance of the students in the two cycles on question 2 in the pre-test and post-test

	Cycle 1 - 5B		Cycle 2 - 5C	
	Pre-test	Post-test	Pre-test	Post-test
Correct	0%	33%	0%	58%

(Remark) Answer: No change, because the Earth does not tilt, and/or the explanation that the intensity of the light received by spot A is the same in different months of the year and so is the temperature, or that spot A receives direct or oblique sunlight throughout the year.

Table 6.17 Performance of the students in the two cycles on question 3 in the pre-test and post-test

Correct %	Area A Season	Area A Day time /night time	Area A Season  +Day time/ night time	Area B Season	Area B Day time /night time	Area B Season  +Day time/ night time	Area C Season	Area C Day time /night time	Area C Season  +Day time/ night time	Correct %
Cycle 1	Pre-test	15%	67%	4%	74%	85%	63%	48%	70%	44%
	Post-test	22%	100%	22%	93%	89%	85%	74%	93%	67%
Cycle 2	Pre-test	4%	100%	4%	88%	92%	88%	62%	88%	58%
	Post-test	65%	92%	62%	92%	96%	88%	77%	100%	77%

62% of students in the post-test of the second cycle gave the season and time of day for Area A correctly (an increase of 58% compared with the pre-test and 40% compared with the first cycle). The answers for Area B can be ignored due to the problems already mentioned. The number of correct answers given for Area C increased by 19% compared with the pre-test and 10% compared with the first cycle.

*Relationship between the Earth’s rotation and the four seasons*

As the research team had only focused on the fact that the rotation of the Earth does not cause the season to change, as there cannot be different seasons within the same day, they had taken for granted or were not aware of the relationship between the Earth’s rotation and the change of seasons. Thus, a critical feature – the effect on the seasons if the Earth does not rotate – was not brought out. Dealing with this critical feature is a challenge, as students may question why, as direct and oblique sunlight have such a strong impact on the change of seasons, there is no seasonal change when there is no sunlight. The answer to this question is related to the concept of the insulating effect of the atmosphere. In fact, the change of season is not solely determined by a change in temperature, as there can occasionally be very cold days in summer and very hot days in winter. The teacher needs to pay attention to other defining features, such as the length of days (short days and long nights in winter and long days and short nights in summer).

*Pattern of variation that can bring out fusion*

To help students to discern that the tilt of the Earth’s axis is a critical feature of the change of seasons, we should pay attention to what is varied and what is kept constant. The variation should be the tilt of the Earth’s axis, whereas the other critical features should remain unchanged.

Table 6.18 Suggested pattern of variation (1)

Invariant	Varied	Discernment
Spot A	The Earth’s axis tilts /does not tilt	The season does not change if the Earth’s axis does not tilt.
The Earth’s rotation		
The Earth’s revolution		
The light beam		

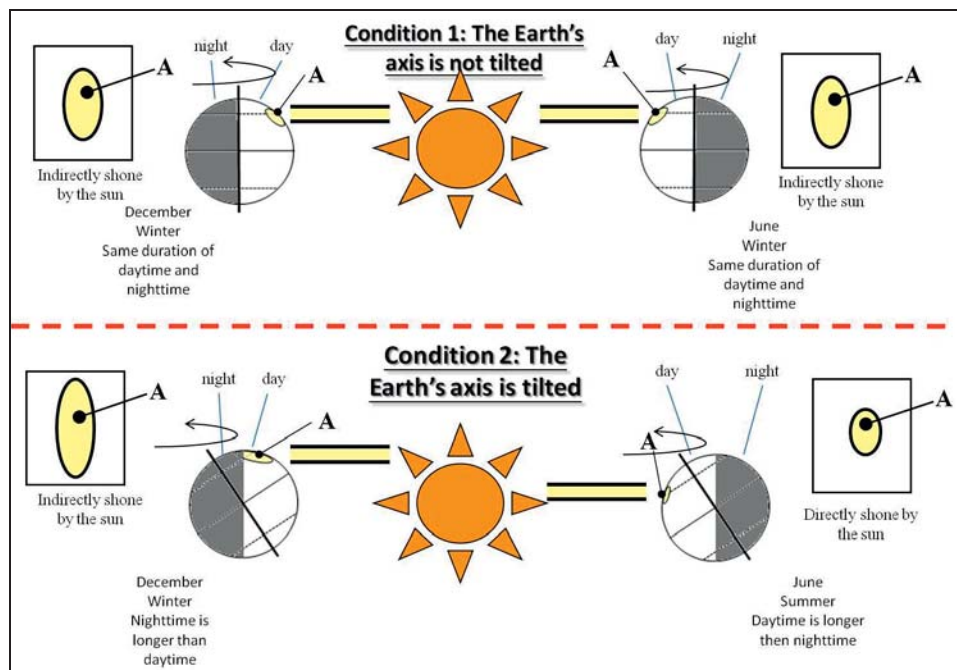


Diagram 6.4 Teaching by varying the tilt of the Earth’s axis (tilting or not tilting)

To help students to discern that the Earth’s revolution is a critical feature of the change of season, the variation should remain focused on the Earth’s revolution while the other critical features are kept invariant.

Table 6.19 Suggested pattern of variation (2)

Invariant	Varied	Discernment
Spot A The Earth's rotation The tilt of the Earth's axis The light beam	With/without the Earth's revolution	The season does not change without the Earth's revolution.

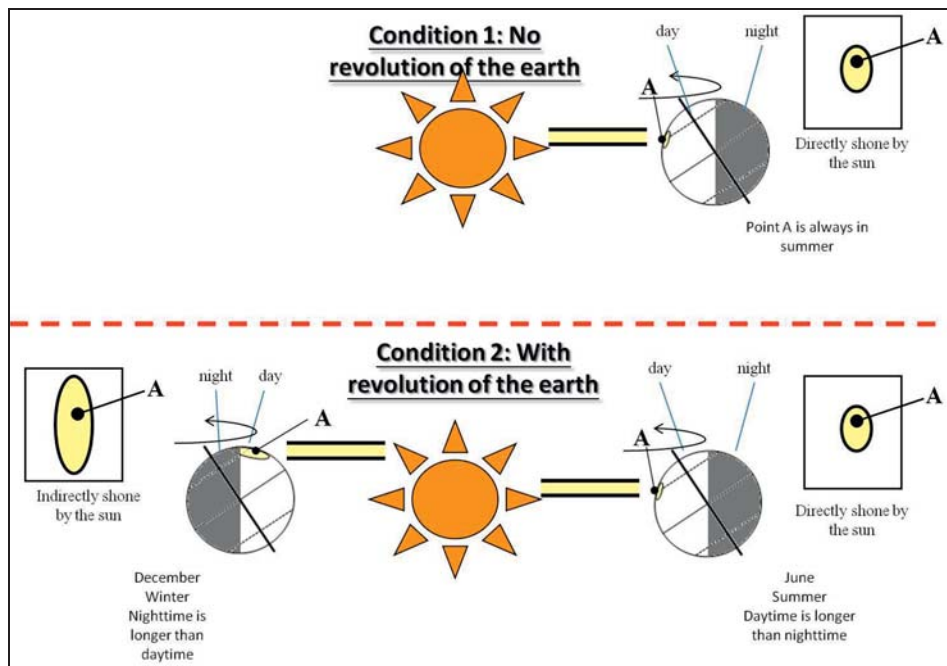


Diagram 6.5 Teaching by varying the Earth's revolution (with and without the Earth's revolution)

To help the students to discern the relationship between the Earth's rotation and the change of seasons, the variation must be on the Earth's rotation while the other critical features are kept invariant.

Table 6.20 Suggested pattern of variation (3)

Invariant	Varied	Discernment
Spot A The Earth's revolution	With/without the Earth's rotation	If the Earth did not rotate, then the seasons would be very

The tilt of the Earth's axis	different from the present situation.
The light beam	

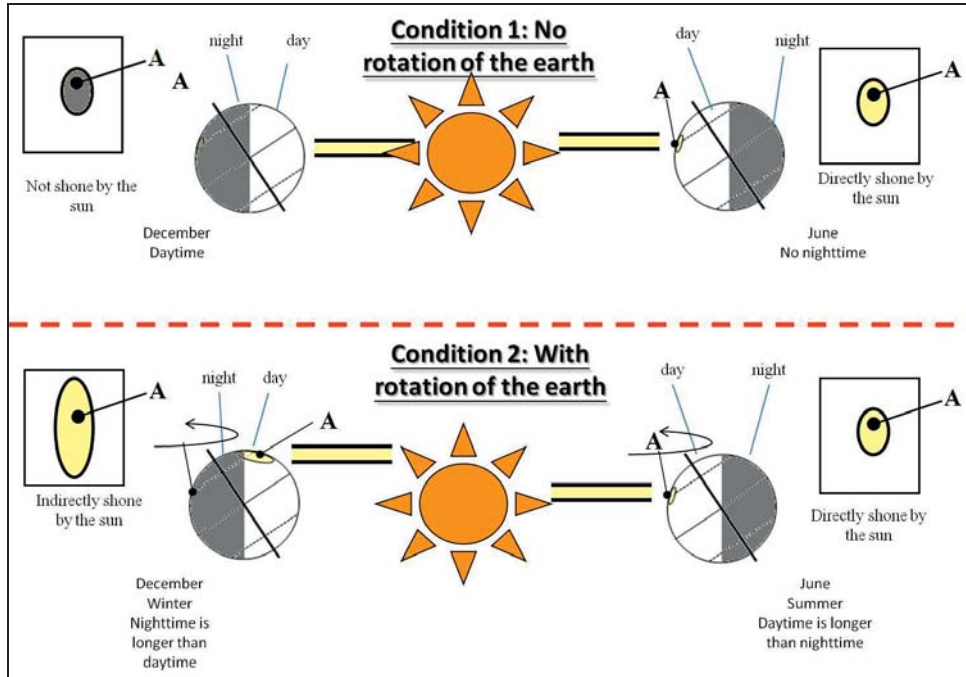


Diagram 6.6 Teaching by varying the situations of the Earth's rotation (with and without rotation)

If the Earth did not rotate, then the seasons would be very different from the present situation that we know. In June, spot A would still be having summer (receiving direct sunlight). The areas facing the sun in the southern hemisphere would be having winter (receiving oblique sunlight). No matter whether it was summer or winter, the whole day (24 hours) would be in daylight and so situations such as long days and short nights or short days and long nights would not happen. In this situation, in December, as spot A is not exposed to sunlight, it would experience winter. The areas in the southern hemisphere without any sunlight would also be experiencing winter, which would be even colder than in June, and it would be constant night.

This example illustrates how Variation Theory can be used as an analytic framework to analyse lessons and to identify ways to improve the lesson.

However, it is not necessary to conduct a Learning Study to obtain information about students' learning outcomes. It is possible to analyse open lessons using Variation Theory, and the research team at HKIEd has tried to do so. The next example is an open lesson taken from the 'Teaching and Learning Observation Network (TALON)' project, which was funded by the Quality Education Fund of Hong Kong. The information on student learning outcomes was obtained by interviewing a few students and collecting students' work during the lesson.

## Analysing an open lesson

The lesson was a Primary Three Chinese reading comprehension lesson. The lesson time was about 50 minutes. The lesson was intended to help students to understand the sequential relationship of the development of events in narrative writing.

### Description of the lesson

**1. Lead-in activity** (about 2 minutes) – The teacher first revised with the students what they had learnt about narrative writing.

**2. Activity 1** (about 15 minutes) – The teacher showed students a passage written in chronological order and invited the students to put the three events described in the passage in order of the time that they happened.

Arrange the major events in chronological order.		
Passage 1	Passage 2	Passage 3
<p>Jacky saw a hawker selling cooked food in a street when he was returning home today. He could not stand the savoury smell of the food so he bought some fish balls. At night, Jacky had an abdominal pain and diarrhoea and his mother immediately sent him to the hospital.</p> <p>Jacky was diagnosed to have an enterogastritis by the doctor.</p> <p>Answer: B → C → A</p>	<p>Jacky was diagnosed to have an enterogastritis by the doctor .....</p> <p>Jacky saw a hawker selling cooked food in a street when he was returning home today. He could not stand the savoury smell of the food so he bought some fish balls. At night, Jacky had an abdominal pain and diarrhoea and his mother immediately sent him to the hospital.</p> <p>Answer: B → C → A</p>	<p>This night, Jacky had an abdominal pain and diarrhoea and his mother immediately sent him to the hospital. Jacky recalled that he saw a hawker selling cooked food in a street when he was returning home today. He could not stand the savoury smell of the food so he bought some fish balls.</p> <p>Jacky was diagnosed to have an enterogastritis by the doctor.</p> <p>Answer: B → C → A</p>

Note: This teaching material is designed by the teacher.

- A Jacky was diagnosed to have an enterogastritis by the doctor.
- B Jacky bought some fish balls from a hawker.
- C Jacky had a stomachache and diarrhea.

The teacher discussed the answers with the students and showed the correct answers on a Powerpoint slide. The teacher then showed a second passage written in a flashback style. Its content was similar to the first passage. Again, the teacher invited the students to put the three events in order of the time that they happened. However, all of the students answered wrongly, as they only arranged the events according to their order of occurrence in the passage. The teacher discussed the answers with the students and again showed the correct answers on a Powerpoint slide. The third passage written in interleaved order was shown to the students. Its content was again similar to the first passage. Once again, the teacher asked the students to put the three events in order of the time that they happened, discussed the answers with the students and showed the correct answers on a Powerpoint slide. After discussing the correct time sequence each time, the teacher asked the students what writing technique had been used in each passage. After each of the three passages had been discussed, the teacher showed the three passages and the time sequence of the three events simultaneously on a Powerpoint slide. She then asked students about the similarities and differences among the three passages. Some of the students stated that the difference was in the order (referring to the order in which the events appeared in the passage) and the similarity was that the events were the same and 'the sequence of events' (the actual sequence in which the events took place) was the same. The teacher took this opportunity to reiterate that different writing techniques affect the order in which the events appear in text, but does not affect the actual sequence in which the events happened. The teacher also stated that time markers such as 'originally' and 'at night' could help to determine the sequence of events.

**3. Activity 2** (about 30 minutes) – The teacher first showed six sentences and asked the students to arrange the sentences in the correct time sequence. The students had an enthusiastic discussion. After a while, the teacher asked the students to arrange the sentences in the correct time sequence, but some students said that they could not. The teacher then asked the students what information was missing which prevented them from arranging the sentences. The students

said that they lacked opening sentences, conjunctions, time phrases, discourse markers, and places. Finally, the teacher pointed out that the passage from which these six sentences was taken was missing, and reiterated that it would be difficult to arrange the order if the students did not understand the text clearly, and that they should not try to arrange the order before reading the text. The teacher then introduced three steps that the students should follow.

1. Read the whole passage.
2. Circle the sentences relevant to the events.
3. Work out the time sequence of events by paying attention to the writing techniques, the causal relationship among the events and the keywords.

The teacher then distributed a passage called 'Disposing of trash' and asked the students to read the passage and circle the events referred to by the six sentences in the previous order-arranging activity. The students tried to arrange the sentences in the right sequence. The teacher checked the answers with the students and asked them how they had found the events in the passage. This section lasted about 20 minutes. The teacher then wrote two of the students' answers on the whiteboard and discussed which answer was correct. During the discussion, the teacher drew the students' attention to keywords such as 'it is already midnight', 'recalling', 'tonight' and '8 o'clock'. However, as time had run out, the teacher was not able to elaborate on how these time markers could be used to determine the time sequence of events.

#### **Depositing of trash**

It's already deep in the night, my brother and I are still lying on the bed and cannot sleep. We felt guilty about what happened tonight.

Tonight, Mum forgot to put the litter outside the door at 8 p.m. to let the cleaner collect them. In order not to affect others, mother asked my brother and I to deposit the litter directly to the refuse collection centre near our building. Both of us did not want to walk around with the litter which gave out disgusting smell so I winked at my brother as a sign for him. My brother understood immediately and applauded, "How clever you are! Such a good idea!"

After we went home for a while, our neighbours started discussing loudly at the corridor. Dad and Mum went out to see what happened. My brother and I followed them to have a look. It turned out that an old woman aged around 70 fell down the staircase. Luckily, she was discovered by the security guard. Our neighbours all talked at once with others.



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Someone said, “Who put the litter at the staircase? Such an immoral act!” After hearing that, my brother and I were frightened. We felt a bit relaxed only after we saw that the security guard supported the old woman with his hands to stand up. When my brother saw that the old woman could still walk, he immediately asked me to leave. Our mother was so clever. She stared at us and said, “You should know who put the litter there.” “You two!” my father shouted at us after knowing the truth. My brother and I did not dare to say even a word.

Dad said reproachfully, “Are you apologetic? You hurt others only you're your own convenience. It is lucky that the old woman only sprained her back without serious injury. You should never do this again! The staircase is the fire safety passage, it is the only way to flee for our lives in case of a fire. If everyone put their litter there like what you did, could you imagine what will happen?”

We felt even more ashamed and sorry after Dad's scolding. After waiting a while for all the people who gathered around the corridor had left, my brother and I took the litter to the refuse collection centre secretly.

Note: This teaching material is designed by the teacher.

### **Arrange the following events according to their time sequence**

- A. My brother and I took the litter to the refuse collection centre secretly.
- B. Mum forgot to put the litter outside the door at 8 p.m.
- C. My brother and I are still lying on the bed and cannot sleep deep in the night.
- D. My brother and I decided to put the litter at the staircase.
- E. Dad blamed my brother and I.
- F. An old woman aged around 70 fell down the staircase.

**4. Activity 3** (about 15 minutes) – The teacher distributed a passage ‘Little Tomato’ and asked the students to finish the exercise individually in the lesson to consolidate what they had learnt. Upon completion of the exercise, some of the students were invited to explain their answers and feedback was given.

Answer the following questions after reading the article.

**Little Tomato**

“One, two, three, four.....” When I am counting the “small lantern” in the garden, I smile broadly.

I still remember that when the academic term just began, there is nothing planted in the garden of our school. After discussing with our teachers, our class decided to plant tomatoes there. We ploughed the land and then sowed the seed.

Starting from that day, I would visit the garden once I was free no matter it was sunny or cloudy. The seed germinated and grew up and leaves turned green day by day. I also felt more excited day by day. Oh, there was a blossom! The yellow little flower hid itself under the green leaves shyly. There were more flowers. They blossomed, withered, fell, and then bore green little fruit. I knew that the day for harvesting was near, so I visited the garden more frequently.

Today, each of us receives two red tomatoes from our teacher. The tomatoes are lovely and they are as red as red jewel. Oh! What is the sticky thing on my face? It's tomato juice! When Annie is eating the tomato, she spills the tomato juice on my face! However, I don't feel angry. I put my own tomato into my mouth. It's the most delicious food that I have ever tried! I should bring the remaining one to my mother so that she can try. Oh, I am too excited that the tomato rots a bit. What should I do? There are no tomatoes in the garden already, so I put mine in a little box carefully and bring it home for my mother.

2007-TSA-CHIN-3CR2-2

Note: This article is the exam paper of TSA (Chinese subject) in 2007.

**Arrange the following events according to their time sequence**

- A. I tasted my own harvest – the tomatoes.
- B. I ploughed the land with my classmates.
- C. I counted the number of fruit in the garden.
- D. I brought my own harvest home and share with my family.

**5. Conclusion** (about 3 minutes) – The teacher invited different students to state what they had learnt in the lesson, and reminded students of the three steps that they should follow when arranging events in a sequence.

### Pre-lesson interview and post-lesson interview

Before analysing the outcomes of the lesson, we must first collect evidence on the students' learning outcomes. This will help to explain the outcomes of the lesson and generate suggestions for improvement. As this was an open lesson, a pre-test and post-test was not administered to all of the students. However, we had the opportunity to conduct pre-lesson and post-lesson interviews with three students of different achievement levels: high-achieving, average and low-achieving. These three students were also invited to complete a pre-test and a post-test. We also studied the worksheets that all of the students had completed in class.

#### *Pre-lesson interview*

The interviewer first asked the students to read a passage 'Brother, I was wrong!' and then arrange the eight events in the passage in the correct time sequence.

#### **Brother, I was wrong!**

It's already 8:30 at night, why haven't Mum and little brother returned home yet? They left at 5 p.m., and now 3 hours have passed. It really makes me nervous. This afternoon, I had just finished my writing assignment when my mother asked me to buy some soya sauce from the supermarket. As I had already completed my homework, I took this opportunity to go out for a walk. When I bought a bottle of soya sauce and went home, my little brother ran to me and said happily, "Brother, see my aeroplane!" Immediately after this, he threw the paper aeroplane to me and I held it. When I took a look at the paper aeroplane, I was very angry as I found that the paper aeroplane was made by my writing assignment which took me one and a half hour to finish! At that moment, I could not control myself so I took the telephone and hit my brother on the head. I used too much force so that my little brother's head was broken and he bled heavily. My mother heard the noise. When she came out to see what happened, she had no time to blame me but to carry little brother to the hospital at once.

I can only hear the ticktock sound of the clock. 1 hour has passed again. Why haven't Mum and little brother gone home yet? What happened to little brother? I cannot imagine.....

I recall that little brother always kept all the delicious food for me. He would leave all the good toys to me. Sometimes, when Mum asked me to take the narcissus to the balcony for a sunbath, I would ask little brother to finish this troublesome task for me, and he does it

without saying a word of complaint. Today, I hit him seriously only because of a writing assignment. I really should not have done this!

The ticktock sound of the clock never comes to an end but 1 hour has passed again. Why haven't Mum and little brother come home? The sound of the clock is like a sword that stabs into my heart. I am so nervous. God, Buddha, Allah, I beg you. Please let my little brother return home healthily. From now on, I will take good care of him. I will give all the delicious food to him. I will give my precious toy to him. I will be calm and think carefully so as not to make any mistakes. My dear brother, I know I was wrong, please come back quickly!

Note: This article is extracted and translated From <http://blog.xuite.net/wang4231/1219/56174>

**Arrange the following events according to their time sequence.**

- A. Mum and little brother haven't come back from the hospital.
- B. Little brother helps me to take the narcissus to the balcony for a sunbath.
- C. I hit my brother's head with a telephone and broke his head.
- D. I'll give my precious toy to my little brother.
- E. I finished a writing assignment.
- F. Little brother made a paper aeroplane with my writing assignment.
- G. Mum asked me to buy some soya sauce from the supermarket.
- H. Mum took little brother to the hospital.

All three students failed to put the events in the correct order. The interviewer then interviewed the three students.

*Interviewer: When you read the story, how did you arrange the events in order?*

*Student 1: I first finished reading the whole passage, then found out the place [where the events took place in the story]. Then I wrote down the first one on the answer sheet.*

*Interviewer: Does that mean that you arranged the order according to the order that the events appeared in the passage?*

*Student 1: Yes.*

*Interviewer: How about you two?*

*Student 2: I also used the places.*

*Interviewer: Apart from places, what else did you pay attention to in arranging the events in order?*

*Student 2: The account of the events.*

*Interviewer: How did you know the order of the account of events?*

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- Student 2:* By analysing.
- Interviewer:* How did you analyse? In what way?
- Student 2:* Using the passage.
- Interviewer:* [To the other student] How about you? How did you analyse?
- Student 3:* Using the passage
- Interviewer:* How did you analyse with the passage? Can you teach me?
- Student 3:* Read the words like 'now', 'tomorrow', 'next month'.
- Interviewer:* Apart from these, any others?
- Student 3:* . . .
- Interviewer:* No more?
- Student 3:* No more.
- Interviewer:* When reading a passage, do you think that the writer has to write the events in chronological order?
- Student 1:* Not necessarily.
- Interviewer:* Why?
- Student 1:* Because there are many ways of writing, like flashback and interleaving, that can be used when writing a composition.
- Interviewer:* That means different description techniques, right?
- Student 1:* Yes.
- Interviewer:* Do you two agree?
- Student 2:* Yes, we agree.
- Interviewer:* If the writer uses different description techniques, then the events may not be written chronologically. So how do we know the chronological order of events?
- Student 1:* By reading the words like 'yesterday' and 'now'.
- Interviewer:* What do you two think?
- Student 2:* Same as what he thinks.
- Student 3:* Me too.
- Interviewer:* That is not what you have just said.
- Interviewer:* OK, how can you deal with arranging as many as four or five events?
- Student 1:* By reading slowly and analysing slowly.
- Interviewer:* But there are so many events. Is it enough to just read words like 'yesterday' and 'now'?
- Student 1:* No, it is not enough.
- Interviewer:* Then, what should you do?
- Student 1:* . . .

### 2. Comparison of the pre-test and post-test results of the three students

After the lesson, the interviewer asked the students to read a passage and arrange the eight events described in the passage in sequential order. The questions in the

post-test were exactly the same as those in the pre-test. The students' answers in the pre-test and post-test are compared as follows.

Events appearing in the passage:

- A. Mum and my little brother have not yet come home from the hospital.
- B. My little brother helped me to take the daffodils to the balcony for the sunshine.
- C. I hit my little brother hard with my mobile phone.
- D. I gave my favourite Pikachu to my little brother.
- E. I finished writing a composition.
- F. My little brother made a paper aeroplane with the composition I had written.
- G. Mum asked me to buy a bottle of soy sauce at the grocery.
- H. Mum held my little brother and rushed to the hospital.

**Comparison of the pre-test and post-test results**

Correct order	B	E	G	F	C	H	A	D
Student 1 - Pre-test	B	E	C	G	H	F	A	D
Student 1 – Post-test	B	E	G	F	C	H	A	D
Student 2 - Pre-test	G	F	C	H	B	A	E	D
Student 2 – Post-test	E	G	F	C	H	B	A	D
Student 3 - Pre-test	E	G	F	B	H	C	A	D
Student 3 – Post-test	G	E	F	B	C	H	A	D

### 3. Post-lesson interview

Upon completion of the post-test, the interviewer interviewed the three students again.

*Interviewer:* Let me first ask this student. Your answer is different from the one that you gave the first time. Which one do you think is correct?

*Student 1:* This time is correct.

*Interviewer:* Why?

*Student 1:* Because the teacher taught us three steps to tackle this type of question. First, read the whole passage. Then, circle the key points. Lastly, arrange the events in time sequence.

*Interviewer:* Then, how did you arrange the order?

*Student 1:* I found the key points in the passage.

*Interviewer:* How did you decide the time sequence of events?

*Student 1:* Discourse markers.

*Interviewer:* What are discourse markers?

*Student 1:* For example 'last month', 'afterwards', 'tomorrow', 'today'.

*Interviewer:* When I asked you before, you also said you used this method. However, why couldn't you do it at that time?

*Student 1:* I used to read the passage in a jumbled way, a bit from here and a bit from there.

*Interviewer:* Do you think the events are causally related?

*Student 1:* Yes.

*Interviewer:* What kind of causal relationship? Can you illustrate with this story?

*Student 1:* . . .

*Interviewer:* Maybe think about it first. Let me ask another student. Your answer was also different from the first time. Why did you put B here?

*Student 2:* Because in the passage it said, 'Mum told me to take the daffodils to the balcony for the sunshine'

*Interviewer:* When did this event take place?

*Student 2:* . . .

*Interviewer:* Does it happen during the course of the story?

*Student 2:* Yes.

*Interviewer:* However, where did the little brother go?

*Student 2:* He went to hospital.

*Interviewer:* The little brother had gone to hospital. How could he take the daffodils to the balcony?

*Student 2:* . . .

*Interviewer:* Do you think it is problematic to put B here?

*Student 2:* Yes.

*Interviewer:* What is the problem? Can you tell me?

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- Student 2:* The little brother was not there. How could he take the daffodils to the balcony?
- Interviewer:* [Addressing the third student] Do you know what she has missed?
- Student 3:* She missed 'recalling that every day', this is an interleaving technique.
- Interviewer:* Yes, what have you missed?
- Student 2:* Interleaving technique.
- Interviewer:* This is a writing technique, isn't it?
- Student 2:* Yes.
- Interviewer:* Let me ask the last student. Do you think you got it correct this time?
- Student 3:* Not bad.
- Interviewer:* Why?
- Student 3:* Because I listened to the teacher in the lesson and understood it a bit more.
- Interviewer:* Is there anything that you do not understand?
- Student 3:* A bit.
- Interviewer:* What don't you understand?
- Student 3:* . . .
- Interviewer:* Let me ask all three of you. Does the first paragraph necessarily tell the ending of a story?
- Student 1:* Yes.
- Interviewer:* Does the first paragraph necessarily tell the last event?
- Student 2:* Not necessarily.
- Interviewer:* Is it necessarily the beginning of an event?
- Student 2:* Not necessarily.
- Interviewer:* Also not necessarily. How do you know the beginning and ending of an event?
- Student 2:* Make the decision after reading the whole passage.
- Interviewer:* This student has mentioned time markers. Apart from this, what else did you learn in the lesson? Anything new?
- Student 2:* We learnt some steps. Following these steps help me avoid making mistakes.
- Interviewer:* How about you?
- Student 3:* I learnt how to read the time sequence.
- Interviewer:* What should you pay attention to?
- Student 3:* First circle the key words and then read the question.
- Interviewer:* How about you?
- Student 1:* We should first circle the relevant sentences to understand the content of the passage.

Using the description of the lesson, the pre-lesson interview, and the post-lesson interview, and the pre-test and post-test results of the three students, we can now analyse the lesson using Variation Theory. Before reading the following analysis, readers are encouraged to try analysing the lesson by themselves first.



## Lesson Analysis

### 1. Is the chosen object of learning appropriate?

Before the lesson, the teacher had read in a report on the Chinese TSA (a system-wide test given to all Hong Kong students at specified intervals) (2006 – 2008) that students performed badly when answering questions about arranging events in a time sequence. Only 40% of students in Hong Kong could answer such questions correctly. When the teacher checked her students' performance on this type of question, she similarly found that less than 40% answered the question correctly. In the interview, it was found that all three students (high-achieving, average and low-achieving) had not grasped the time sequence of the events in the passage. The teacher had chosen this topic in light of students' learning difficulties in this area, and intended to help students understand the time sequence of events in a story. The direct object of learning for this lesson was thus 'the time sequence of events in a passage' and the indirect object of learning was the capability to arrange events in any passage in the correct time sequence. As the object of learning was chosen to address student difficulties, the choice was appropriate.

### 2. What are the critical features identified?

From previous experience of teaching reading comprehension, the teacher knew that a common problem among students is that after they have read the questions, they rely on the order in which events appear in the passage, rather than the actual time sequence of the events, to arrange the order of events. In addition, some students arrange the order of events based on their own logic without in-depth understanding of the passage. They neither look for clues in the passage nor try to determine the causal relationship among events. As a result, the students' performance is rather disappointing.

As revealed from the pre-lesson interview, although the students recognised that there are many writing techniques in addition to chronological order, they could not tell how to determine the sequence of events. Only one student stated that time markers serve as a clue. The other two students merely arranged the order based on their own perception. Additionally, the students' answers in the pre-test showed that none of them had grasped how to make use of the causal relationships among events. Two of them mixed up events in the past, present and future. This led the teacher to believe that the students' learning difficulty was due to their failure to grasp the writing technique used, the causal

relationships among events and the time markers in the passage when arranging the order. The teacher thus identified the following critical features.

- 1) The writing technique used in a passage affects the events' order of appearance in the passage, but has no impact on the time sequence of the events.
- 2) The understanding of the time sequence of events in the passage requires an awareness of the writing technique used, the causal relationships and the keywords.

There is a problem with these two critical features, which will be discussed later in the chapter.

### 3. What patterns of variation were enacted?

#### *Activity 1:*

The pattern of variation used in Activity 1 was as follows.

*Table 6.21* Pattern of variation used in Activity 1

Invariant	Varied	Discernment
The content of the passages; The time sequence of events	The writing technique used in the narrative (chronological order, flashback, interleaving)	The writing technique used in the passage has no impact on the time sequence of events.

This intended pattern of variation will help the students to discern that the time sequence of events is not affected by their order of appearance in the passage due to different writing techniques, which corresponds to the first critical feature. It is good that the teacher used this pattern of variation to start the lesson, as this is in line with a Variation Theory principle of moving from the whole to the parts. It should be noted that this activity will only help students to gain a vague impression of the object of learning. However, it is still useful, as it helps students to create a relevance structure to make the subsequent teaching activities more meaningful.

Was the lesson enactment able to bring out the intended pattern of variation? It was observed that the teacher showed the students the three narratives about the same events (invariant) but written with different writing techniques (varied) one

after the other. When the first passage was shown, as the order in which the events appeared in the passage was the same as the order in which the events actually happened, no dimension of variation was opened up. When the second passage was shown, the order in which the events appeared in the passage and the order in which the events actually happened were different. This variation helped to open up a dimension of variation (ways of ordering events). ‘According to time of occurrence’, and ‘according to the order of appearance in the passage’ were the two values in this dimension of variation. When the first passage was contrasted with the second passage, the pattern of variation (the technique of writing varied while the time sequence of events was invariant) experienced by the students should have enabled them to discern that the two different techniques of writing did not change the time sequence of events. When the third passage was contrasted with the first and second passage, the effect should have been similar. The students should have been able to discern that the technique of writing did not change the time sequence of events in a passage. At the end of this activity, the teacher summarised the activity by showing the three passages and the time sequence of events corresponding to each passage (which of course, was the same for all three passages) simultaneously on the same Powerpoint slide. The teacher was able to achieve what she intended through the use of the last Powerpoint slide, which enabled the students to contrast and experience the variation in writing techniques and the unchanging order of events when arranged in a time sequence in all three passages simultaneously. Nevertheless, there is still room for improvement. In the lesson, the three passages were shown and analysed one by one, which took up a lot of class time and slowed the lesson pace. Also, some students were not fully engaged in the activity, as they could not see the purpose of it. More importantly, instead of allowing the students to explore and experience the intended variation pattern by themselves, the teacher took a highly structured and controlled approach. One suggestion for improvement is for the teacher to give the students all three passages at once and ask them to work in groups to discuss their commonalities and differences and try to order the events according to the time sequence and compare the results for the three passages. The teacher could also draw on the variation in the students’ responses, and invite students to explain their ordering. This would allow the teacher to give appropriate feedback to address students’ misconceptions and difficulties. Different answers provided by students are excellent resources for teaching, as they provide extra variation for students to contrast the correct and incorrect answers and the explanations for them.

*Activity 2:*

The intended pattern of variation for Activity 2 was as follows.

*Table 6.22* Intended Pattern of Variation for Activity 2

Invariant	Varied	Discernment
Series of events	With/without the text	One must refer to the text to arrange events in the correct time sequence.

In the second activity, the teacher intended to help students to discover that different time sequences will result if the order of events is arranged based on the students' own subjective thoughts without referring to the text. In contrast, when the text is used as reference, everyone should arrive at the same order because the ordering is based on the writer's logic. Unfortunately, in the lesson it was the teacher who brought out the point that there was insufficient information to arrange the events in the correct time sequence without the text. It was not clear whether the students were able to discern this. The suspicion that they were not able to discern this was confirmed later in the lesson when the students were working on the class exercises and some of them were still arranging the time sequence of events based on their subjective ideas without paying attention to the logic of the writer. For instance, when students read the passage 'Deposing of trash', one student said that the character in the story could only dispose of the trash after his parents slept, otherwise he would be scolded. This point was not mentioned in the passage. It was clear that the student had made use of his own subjective ideas and common sense to draw this conclusion. This learning difficulty can be dealt with by using variation to allow students to discern that although their own subjective idea may seem logical, the actual order of the events might not necessarily be the same order as their idea because the writer might have a different way of thinking. To bring out the necessity of referring to the text, the teacher could ask students to arrange six sentences with and without referring to the text. For example, in the lesson, a passage 'Eating Fish Balls' was used. The students generally thought that if Siu Keung suffered from diarrhoea and abdominal pain, he would not eat fish balls anymore. The students' subjective logic was that Siu Keung had bought a string of fish balls from a stall first, and after that he suffered from diarrhoea and abdominal pain. In this case, the teacher could prepare two situations as follows.

## Situation 1

*Siu Keung suffered from diarrhoea and abdominal pain.* → *Siu Keung was diagnosed with gastroenteritis.* → Siu Keung found the medicine distasteful. → Siu Keung could not stand the taste of the medicine in his mouth and longed for something with a good taste. → *Siu Keung brought a string of fish balls from a stall.* (The writer's logic)

## Situation 2

Siu Keung brought a string of fish balls from a stall. → Siu Keung suffered from diarrhoea and abdominal pain. → Siu Keung was diagnosed with gastroenteritis. (Students' subjective logic)

If the teacher gives students three events: (1) 'Siu Keung brought a string of fish balls from a stall', (2) 'Siu Keung suffered from diarrhoea and abdominal pain' and (3) 'Siu Keung was diagnosed with gastroenteritis' and asks them to arrange these sentences in order, most students will arrange the order as in the second situation. At this point, the teacher should show the first situation to the students so that students realise the importance of understanding the writer's logic.

It is a pity that the teacher was only able to achieve the purpose of allowing students to discern the importance of referring to the text. In fact, even this part could be dealt with in a more in-depth way. For instance, students could be helped to discern why they need to refer to the text or what information they can find from the text to decide the time sequence of events. The present lesson design may be suitable for high-achieving students who already know what time markers are. However, as the teacher did not teach the students how to find time markers, it may constitute a difficulty to average and low-achieving students. The students' post-test results show that the high-achieving student could arrange the eight sentences in the correct time sequence, but the other two students could not. This suggests that the teacher's approach may not be able to tackle the individual differences in the class. Although the students knew that they had to refer to the text, they could not arrange the events in the correct time sequence, as they overlooked the keywords in the text.

After this part, the teacher introduced three steps that the students should follow to determine the time sequence of events in a passage, and asked the students to practice and to explain their answers. This part was rather lengthy (about 25 minutes), but may not have helped the students to learn the object of learning. Let us consider each of these three steps with reference to the exercise 'Disposing of trash' used in the lesson.

The first step was that the students should read the whole passage. This is certainly useful, as they would get an overall impression about the passage. In the second step, the students were required to circle the sentences relevant to the events. Circling the sentences in the passage will help students to relocate these sentences more easily later when they wish to refer to them. However, the sentences given by the teacher had been summarised, with sentences such as ‘My brother and I decided to put the trash on the back staircase’ and ‘Dad scolded the two brothers’ not occurring in the original passage. This may have presented difficulties for some students. In the third step, the students were asked to work out the time sequence of events by paying attention to the writer’s writing techniques. However, the students first needed to know the time sequence of events to know the writing technique. For example, if the students did not know the order in which events occurred in time, they could not know that the passage was written using a flashback technique. It is meaningless to ask the students to pay attention to the writer’s writing technique, because if the students were able to identify the writer’s technique, it would imply that they were already able to work out the time sequence of events, and teaching it would be unnecessary.

Instead of asking students to circle the sentences to be arranged, it may be better to ask them to circle the time markers and the keywords that demonstrate causal relationships. If we want students to discern the importance of keywords, then they must experience variation in these keywords. For example, the teacher could discuss with students whether the sentence ‘G: I took the trash to the garbage station silently with my brother’ should be put before or after ‘C: The two brothers did not fall asleep until midnight.’ It is not possible to determine when the two brothers took the trash to the garbage station by reading the first paragraph, because even if the word ‘midnight’ was noticed, then it is equally feasible for the two brothers to have got up out of bed after being kept awake by the feeling of guilt and so decided to take the trash to the garbage station quietly. The students should thus also consider the two sentences with the addition of the time markers ‘soon after getting home’ and ‘after a while, when people in the corridor dispersed’. The phrase ‘soon after getting home’ shows that Grandma could not have fallen down at midnight, and the phrase ‘after a while, when people in the corridor dispersed’ shows that the two brothers could not have fallen asleep yet. By combining these three clues about time, it will be clear that Sentence G should be put before Sentence C.

In this part of the lesson, the teacher could also delete the phrase ‘after a while, when people in the corridor dispersed’ and discuss with students the time

sequence of sentences G and C. By so doing, students should be able to discern that it is very difficult to determine the time sequence of sentences C and G without this phrase, as both situations are possible. The sentence could then be changed again to include 'at last, not being able to stand the feeling of guilt', and the teacher could again discuss with students the time sequence of sentences G and C. This time, it would be clear that C should be followed by G. Varying the time markers would help students to discern their importance.

The post-test results showed that the students had not paid attention to the time markers in the passage (e.g., 'recalling that everyday' reveals that the event is recalled from memory). This learning outcome reflects that time markers had not been dealt with in an in-depth way in the lesson.

In the passage used in the post-test, the writer interleaved event B, which had already taken place, with Events E, G, F, C and H, which had all happened that afternoon. The order of the first three events could be determined by paying attention to the time markers and the latter three events were causally related. The order of Event A could also be determined by using the time markers, while Event D will happen in the future.

The pre-test and post-test results revealed that only student 1 (the high-achieving student) got all of the answers correct. Student 2 (the average student) answered correctly but did not recognise that the narrative was interleaved. The order arranged by student 3 (the low-achieving student) might seem at first glance to be completely wrong. In fact, she simply overlooked the word 'just' and so was unable to discern the relationship between events G and E to correctly order these two events. She also made the same mistake as student 2 in not being aware that the interleaving technique had been used in writing about event B. Generally speaking, the post-test results show that the students had gained a general idea of the intended object of learning, but were not aware of keywords such as time markers. In the post-lesson interview, the students were able to state that they had learnt some steps, but only one student stated that it is necessary to pay attention to time markers.

Finally, as has been pointed out already, using writing techniques to determine the time sequence of events is putting the cart before the horse. Writing techniques should not be considered prior knowledge for putting events in a time sequence; it should be the other way round. Instead, the teacher should focus on teaching students how to determine the time sequence of events based on words

or phrase that indicate time or a casual relationship. Once the students are able to identify the time sequence of events, the classification into the three writing techniques will follow naturally.

At the end of the lesson, the worksheet on which the students had been asked to arrange the time sequence of events in the passage 'Little Tomato' was collected. Among the 29 students in the class, 24 had arranged the events in the correct time sequence, that is, B, C, A, D. This shows that the lesson was quite successful. However, as we were not able to compare the students' performance in a pre-test and post-test, we cannot attribute the result to the teaching, because these 24 students (or some of them) might have already mastered this knowledge well before the lesson. We thus cannot eliminate the possibility that they have not learnt anything new in the lesson.

It was found that among the four students who answered wrongly, all of them wrote down B, A, D, C, that is, they put C in the wrong order. One of the reasons is that when the students recognised that the passage was written with a flashback technique (mentioned by the teacher during the lesson), they put C, which was in the first paragraph, to the last position mechanically. This also shows that these students had not truly understood the relationship between the sequence of events and the flashback writing technique. The majority of students had mastered the object of learning. However, if the teacher wishes to tackle the individual differences among students, the teaching should not stop at leaving students to comprehend the passage by themselves. Teaching students how to decide the time sequence of events by time markers is also a critical aspect of this object of learning.

The foregoing two examples analyse completed lessons supported by students' learning outcomes, which can be used to test whether the analysis using the analytic framework derived from Variation Theory is supported by empirical data on student learning outcomes. However, in addition to using Variation Theory for post-lesson analysis, it is equally useful for teachers to make use of Variation Theory to design appropriate patterns of variation and to analyse the appropriateness of these intended patterns before the lesson is enacted. The next section gives some examples to help readers to grasp the skills of analysing whether the designed patterns of variation are appropriate. Readers are encouraged to test their skills in applying Variation Theory in this way before reading on.



## Other Examples of Lesson Analysis using Variation Theory

### A Science Lesson: The reaction of metals with dilute acids

In a Secondary Two Science lesson, the teacher aims to teach students the reaction of metals with dilute acids. As the reaction between metals and dilute acids is actually the reaction between the metal and the hydrogen ions in the dilute acids, as long as the concentration of the hydrogen ions in the acid remains constant, the reactivity of that metal with any acid will be the same.

In the lesson, students are divided into groups to conduct an experiment. Each group is given two kinds of dilute acid: dilute sulphuric acid and dilute hydrochloric acid (with the same concentration of hydrogen ions), and four metals: magnesium, zinc, tin and copper. The teacher then guides the students to put the four types of metal into four test tubes, each containing the same volume of dilute sulphuric acid, and to record the reaction inside each tube. The four metals are next placed into four test tubes containing dilute hydrochloric acid and the reaction is recorded. After the experiment, the teacher discusses the experimental results with students and the conclusion that the reactivity of a metal with different acids remains unchanged will be drawn. Can you predict whether this lesson will be effective?

The effectiveness of the lesson can be predicted by analysing the patterns of variation designed by the teacher. In the lesson, the students will be able to observe the reactions of the four metals first with dilute sulphuric acid simultaneously, and then the reaction of the four metals with dilute hydrochloric acid simultaneously. The enacted pattern of variation will be as follows.

*Table 6.23* Enacted pattern of variation

Invariant	Varied	Discernment
Acid (X); The concentration of hydrogen ions in the dilute acid	The reactivity of the metals	The reactivity of acid (X) with different metals.

What students will be able to discern is the different reactivity of acid (X) with different metals, which does not agree with the intended object of learning. If we

want students to discern that the reactivity of the same metal is the same with different acids provided that the concentration of the hydrogen ion is kept constant, the following pattern of variation should be used instead.

Table 6.24 Correct pattern of variation

Invariant	Varied	Discernment
Metal; The concentration of hydrogen ions in the diluted acids	Acid (dilute sulphuric acid, dilute hydrochloric acid)	The different acids do not affect the reactivity of the same metal.

If we want students to discern that the reactivity of the same metal with different acids remains constant, then the students must put the same metal (e.g., magnesium) into two test tubes containing dilute sulphuric acid and dilute hydrochloric acid, respectively. In this way, students can observe and discern that the reactivity of the metal remains the same with different acids provided that the concentration of hydrogen ions in the acids remains the same.

### A Mathematics Lesson: The Concept of Fractions<sup>2</sup>

Two teachers wish to teach students about the concept of fractions, and especially the concept of equal sharing.

Teacher A plans to let students see 10 oranges and ask, ‘how many oranges do we get if we take 1/2?’ She then divides the oranges into two groups with five oranges each, and tells the students that five is 1/2 of 10 oranges. After that, Teacher A divides the 10 oranges into two groups, one with four oranges and the other with six oranges. She points at one group and asks, ‘is this 1/2?’ If some students say no, then Teacher A double checks the answer with the students. Teacher A then takes away two oranges and points to the remaining eight oranges and asks, ‘how many oranges do we get if we take 1/2?’ She invites a student to divide the eight oranges into two groups with four oranges each. The teacher again divides the eight oranges into two groups with an unequal number

<sup>2</sup> This example is taken from Pang and Lo (2011) ‘Learning Study: Helping Teachers to Use Theory, Develop Professionally, and Produce New Knowledge to Be Shared’, Instructional Science, open access at Springerlink.com.

of oranges, and asks students if each group is equal to  $1/2$ . The same method is used to deal with six oranges and four oranges.

Teacher B also plans to show 10 oranges to students. She picks up an orange and asks students to express the number of oranges held by her and the remaining oranges as a fraction (i.e.,  $1/10$  and  $9/10$ ). Then, she picks up two oranges and asks the students to express the number of oranges held by her and the remaining oranges as a fraction (i.e.,  $2/10$  and  $8/10$ ). The teacher continues in the same way, picking up different numbers of oranges. Teacher B uses oranges as teaching tools specifically because she hopes that students will be able to see that each orange is the same, and constitutes one part of the whole. In fractions, each part must be the same because of equal sharing.

Which teacher, Teacher A or Teacher B, is more likely to teach the intended object of learning successfully?

The pattern of variation designed by Teacher A is as follows.

Table 6.25 Pattern of Variation 1 designed by Teacher A

Invariant	Varied	Discernment
Fraction (always one half)	Equal sharing/unequal sharing	The whole must be divided into two equal parts.

Table 6.26 Pattern of Variation 2 designed by Teacher A

Invariant	Varied	Discernment
Numerator (always one)	Denominator (from 10 parts to 8, 6, etc.)	The denominator represents how many equal parts the whole must be divided into.

These two patterns of variations should take place simultaneously. Thus, students should be able to discern a critical aspect of fractions: that the whole must be divided into a number of equal parts represented by the number indicated by the denominator.

The pattern of variation designed by Teacher B is as follows.

Table 6.27 Pattern of Variation designed by Teacher B

Invariant	Varied	Discernment
Denominator (10 oranges)	Numerator (the oranges being taken away and the remaining oranges)	The value of a fraction depends on the numerator (the amount being taken away or remaining).

As the size of the oranges does not change, the students will not be able to experience the variation of equal sharing and unequal sharing, and so may not be able to discern the concept of equal sharing. Also, if we want students to discern the concept of equal sharing, their attention should be focused on the denominator and not the numerator – they should experience the variation of the denominator. However, what students will experience in the lesson of Teacher B will be the variation of the numerator. Thus, the teacher has not made it possible for the intended object of learning to be learnt by students.

## Conclusion

The examples in this chapter show that a small change in teaching activities may cause a large change in the pattern of variation that leads the enacted object of learning (and thus the lived object of learning) to be different from what was intended. It is thus necessary to analyse a lesson and determine the enacted pattern of variation to secure the desired learning outcomes. Some readers may feel that although students fail to learn the intended object of learning, learning the enacted object of learning does not cause any harm as the enacted object of learning may include worthwhile teaching content, and may be an equally worthwhile object of learning that students are required to learn in the curriculum. However, apart from the fact that it very often happens that students learn something that may be completely worthless or may even be a wrong concept, even if what is learnt is itself worth learning, as teachers we must know what our students have learnt and not just leave it to chance. This can be explained with an analogy: a hunter sees a rabbit and shoots an arrow at it, but the arrow misses and hits a deer instead. Do you think he is a good hunter? If the hunter realises that his aiming and shooting technique needs to be improved and he brings the deer home feeling lucky, then he may finally become a good hunter. However, if the hunter does not know that he has missed but congratulates

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himself for his shooting skill and brings the ‘rabbit’ home, then he will remain a bad hunter.

Although students may be able to learn something valuable, if teachers are not aware that the intended object of learning has not been taught successfully, then those students may never have the opportunity to learn the intended object of learning again. If the intended object of learning is a basic concept upon which other concepts must be built, then students may later experience learning difficulties because they lack this basic knowledge. Many experienced and effective teachers naturally use variation in their teaching. However, its usage is often implicit and remains as tacit knowledge. Unless teachers are aware of the patterns of variation that they are using in lessons and the intended discernments that such patterns aim to bring about, it will not be possible for them to learn from experience and improve their teaching. An important part of teachers’ self-learning and professional development is to be able to analyse their own lessons and know why they work and why they do not work. Variation Theory provides teachers with a very useful guiding principle for doing this.

## Chapter 7

# The Development of Variation Theory – Reflection and the Way Forward

## The Impact of Variation Theory on Teaching and Learning

### The view on learning

Variation Theory reminds us that learning is always directed towards an object; indeed, we cannot talk about learning without specifying an object of learning. When we say that someone learns 'X', it means that he or she has changed his or her original way of seeing 'X'. He or she may have acquired a more in-depth understanding, a broader understanding or even a completely different view of 'X'. Thus, teachers can no longer say that they have fulfilled their duties by merely telling; they must also ask themselves whether they have helped their students to change their ways of seeing the object of learning. That also means that teachers must try to find out what prior knowledge students possess and their initial ways of seeing the object of learning. If we do not know how the students originally saw 'X', then how can we know that they have learnt such that they have changed the way that they see 'X'?

Variation Theory reminds us that there are two aspects to learning: the 'what' and the 'how' aspects. The 'what' aspect refers to the direct object of learning, or the content that is being learnt. There is also an indirect object of learning that refers to the quality of the act of learning, what the act of learning aims at, in other words, the kind of capability the learner is to develop (Marton & Booth, 1997, p. 84-85). Current educational reforms tend to focus on the 'how' aspect, yet we cannot consider how to learn alone without taking into consideration what to learn. Variation Theory links the two closely so that when we try to help students to develop certain capabilities (such as higher order thinking, communication skills and learning how to learn) we must at the same time consider the kinds of content or subject matter that can best help to develop such capabilities.

### The role of the teacher

In most cases, the classroom is not an authentic environment for students to learn school subjects, because the content, artefacts and knowledge of the subject are not naturally embedded in the classroom environment. Variation Theory reminds us of the important role of the teacher in designing learning experiences for students to *make it possible* for them to appropriate the object of learning. This involves the teacher studying the object of learning carefully, finding out students' learning difficulties, identifying the object's critical features, and designing appropriate patterns of variation that help students to discern the critical features and their relationships. The term '*make it possible*' is used advisedly, because we cannot force students to discern anything. Whether or not a student discerns an object and how it is discerned depend on certain characteristics of the student, such as the student's previous knowledge, current state of mind, interest in learning and many other complex factors. We cannot place the blame solely on the teacher for the student's failure to learn. Even the best teacher can only make learning 'possible'. Of course, good teachers will use a variety of methods to deal with the factors that impede student learning. However, even if the teacher is very caring, the students are highly motivated to learn and the environment of the classroom is very comfortable and supported by advanced technology, if students do not have the opportunity to discern the critical features of the object of learning in the classroom, then the desired learning is still unlikely to occur.

### Views on how to cater for the individual differences of students

Variation Theory offers an alternative view of why students do not learn. Of course, there are children who are unfortunately born with mental defects, and society needs to give them special care and attention. However, the reason for the low academic achievement of children of normal intelligence who are studying in mainstream schools is not an issue of intelligence. How children understand an object of learning depends on which features of the object they focus on, and an object usually has many features and variation in the ways it can be viewed, and thus different learning outcomes should be a norm rather than an exception.

Lo and Pong (2005) summarise this as follows.

*What prevents students from fully understanding their lesson in school is not primarily due to their lack of ability or the failure of teachers to arrange the classroom in certain ways (e.g., pair work, group work), but mainly due to students' incomplete ways of understanding what is to be learnt in the lesson. This may be caused by a number of reasons:*

1. *Students bring with them 'intuitive' ways of understanding which may become obstacles to new ways of understanding when the two seem to be in conflict.*
2. *Students fail to focus on all the critical aspects of what is to be learnt.*
3. *Students have not been exposed to suitable learning experiences in the lesson which would have enabled them to learn. (p.12).*

They continue by pointing out that to cater for students' individual differences, teachers must undertake the following.

- Find out from all students in the class their intuitive ways of understanding the object of learning, especially where this might impede them from re-examining their views on the object of learning. Fortunately, for any object of learning the different ways of seeing can be divided into a limited number of qualitative categories.
- Carefully study the object of learning and obtain an insight into what critical features/aspects – and the relationships between these different aspects, the parts and the whole – to which students must pay attention to appropriate the object of learning, then design appropriate patterns of variation to help students discern them. In particular, teachers must pay attention and try to deal with views that may impede students from taking on a new view of the object of learning.
- Design appropriate teaching activities that will best enable students to experience the desired patterns of variation that will help to bring about learning.

If we simply try to make adjustments to the curriculum according to the academic performance of students, such that students with good academic results will have the chance to learn more advanced subject knowledge whereas students with poor academic results will only be allowed to learn more elementary subject knowledge, then we will be unfairly limiting the learning opportunities of students. This will only widen the gap between the academic



achievements of students and aggravate the problem. A detailed discussion of this is given in our book 'For Each and Everyone' (Lo, Pong & Chik, 2005). The book also reports the results of a three-year study that provides evidence that our ways of catering for students' individual differences are effective. The study found that in 25 out of 27 learning studies the weaker students showed significantly greater gains than that of the high achievers (Lo, Pong & Chik, 2005, p. 121). In a number of cases, the 'weaker students' who started at a much lower level than their classmates even caught up with and occasionally surpassed them. As a Learning Study starts with revealing the difficulties that exist in a group of students as far as the mastering of a particular object of learning is concerned, and continues by creating the necessary conditions for bridging those difficulties, it is easy to understand why those who have such difficulties profited most from having them addressed.

### **Paying attention to each lesson – Learning Study**

Paying attention to educational aims and setting educational goals and objectives are important, as these help to set the direction for the development of the school curriculum. Unfortunately, many educational reforms stop at the policy documentation level and are unable to realise their ideals at the classroom level. This would be deemed incredible and would never happen in other trades or industries. For example, when designing an aircraft, a designer must first make clear the ultimate goal, such as the targeted speed of the aircraft, how it will be fuelled and the desired comfort level of the passengers. The design work does not stop here, however, allowing the workers to completely take over and assemble the aircraft freely by themselves. The design work continues and the ideas follow through at each level until the smallest detail has been attended to meticulously, down to the type or size of screws to be used. Every single detail has to be taken seriously, including the specifications for the installation of each part. This is because the final product is made up of these seemingly trivial parts, but how these parts are assembled will affect the safety and functions of the entire aircraft. Similarly, for an educational curriculum to achieve its desired objectives depends on the accumulative effect of each seemingly insignificant lesson throughout the school years. The ultimate goal will be reached by making a small step towards it in each lesson. If we are serious about achieving educational goals, we must also be serious about each lesson, and ensure that each lesson is contributing to the overall goal and is helping to move us in the correct direction.

Variation Theory is concerned with how students experience the object of learning. Thus, unlike many learning theories that only explain learning at a general macro level, its applications are useful at the micro level of the classroom. As a Learning Study, which is premised on Variation Theory, normally focuses on a lesson as the unit of study, it facilitates the application and further development of Variation Theory at the micro-level, where students are learning particular objects of learning. The evidence from the more than 300 learning studies carried out by the Learning Study research team at the Hong Kong Institute of Education demonstrates that although each Learning Study initially focuses on one lesson, the impact on learning for both students and teachers goes far beyond the content of one lesson. Learning studies improve students' learning of particular objects of learning, enhance the professional development of teachers, improve teacher collaboration and help to promote a learning culture that facilitates the development of the school as a learning community (Lo, 2009; Cheng, 2009). As a lesson is not independent of other content in the curriculum, the teacher must first consider the external horizon of the object of learning; that is, the relationship between this object of learning and other objects of learning and its position in the subject discipline to which it belongs. Paying careful attention to how to teach an object of learning in a lesson will help teachers to develop a better understanding of the curriculum as a whole, and enhance their ability to develop school-based curriculum.

## Some Reflections on the Future Development of Learning Study and Variation Theory

After ten years of practice, evaluation and reflection on Learning Study and Variation Theory, I have the following insights and suggestions on several important issues for the future development of Learning Study and Variation Theory.

**1. Put Variation Theory to the test by developing learning studies in more subject areas and grade levels, and develop more learning studies that target objects of learning outside of the cognitive domain that are directed at skills and attitudes.**

In the past, most learning studies were conducted on the main subjects in the school curriculum, such as English, Chinese and Mathematics. This was due to various constraints, such as the wishes of the funding bodies and of the schools

and teachers. Most principals wished to have more teachers in the school involved in Learning Study projects, and the main subjects were the obvious choices as they involved a higher number of teachers. Further, the teachers involved tended to focus more on the teaching of knowledge and less on the development of skills or attitudes, and this was reflected in the choice of the object of learning. Although in the past ten years we have developed learning studies in subjects such as Fine Art, Physical Education, General Studies, Chemistry, Physics, Liberal Studies, Business Studies, Geography and History, thus covering almost all of the subjects in the school curriculum, unfortunately there are not enough studies in each subject to generate sufficient examples to generalise the findings. However, the experience is sufficient to give us confidence that it is possible to apply Variation Theory to these subjects. Future research directions should thus try to apply Variation Theory to more subjects and at different grade levels. It is also important to explore the application of the theory to the teaching of skills and attitudes.

## 2. More extensive and intensive application of all elements of Variation Theory

We should continue to develop the application of the various elements of Variation Theory, as follows.

*Fusion:* In previous learning studies, the research groups were found to be good at identifying the critical features of the object of learning and using appropriate patterns of variation to help students focus on and discern the critical features. Unfortunately, less attention was paid to helping students to discern the relationships among these critical features and to the whole. Such relationships may be part-whole relationships, or may be superordinate-subordinate relationships. *'Learning is mostly a matter of reconstituting the already constituted world'* (Marton & Booth, 1997, p.139). In other words, after deconstructing the object of learning, it is also necessary to put it back into its original form as we always encounter it. To do this is called 'fusion'. To enable fusion to take place, the students must be able to see the position of the individual critical features in the overall picture and how it is related to other critical features and to the whole, and should be able to anticipate what would happen when more than one critical feature is varied at the same time. As cited in example 1 in Chapter 6, when the teacher dealt with 'the tilting of the axis of the globe' as a standalone critical feature, he did not simultaneously take into account the relationship of the other critical features to the tilting of the globe, and so the learning outcome of the

students was unsatisfactory. This example shows that rather than isolating the critical feature and considering it on its own, it would be better to vary this aspect while keeping the whole and all of the other critical features unchanged. As suggested in example 1 in Chapter 6, to discern the relationship between the tilting of the axis of the globe and the changing of the four seasons, the teacher must keep other critical features such as ‘the Earth rotates’, ‘the Earth revolves around the sun’, ‘the location (e.g., Hong Kong)’ and ‘the beam of sunlight’ unchanged, and only change ‘the tilting of the axis of the globe (tilted or not tilted)’. In the example, the teacher considered the tilting of the Earth but kept the Earth in the same position (i.e., with no rotation and no revolution), and in so doing in fact introduced two other variations (no rotation of the Earth as opposed to rotation as is the usual case, and no revolution of the Earth as opposed to revolution as is the usual case) in addition to the one on which he wanted to focus. Only after dealing with each critical feature while keeping the whole and the other critical features unchanged would he be in a position to discuss situations in which more than one critical feature or a number of critical features varied simultaneously. For example, using different situations, such as ‘the axis of the globe does not tilt and the Earth does not revolve’, while keeping all other features unchanged (the Earth’s rotation, the point, the beam of sunlight); or ‘the Earth does not rotate and the Earth does not revolve’, while keeping all other features unchanged (the axis is tilted, the point is Hong Kong, the same beam of sunlight) to test the students’ level of understanding of the object of learning.

*Relevance structure:* The relevance structure that is established between the learner and the object of learning explains how the external horizon affects our ways of seeing and thinking. For example, when we see a pair of eyes in the jungle, we may associate it with a tiger, but if we see the same pair of eyes at home, we would associate it with the family cat. This explains why we should pay attention to the object of learning and its relationship to students’ everyday experience. This is in line with the teaching strategies promoted in many subject disciplines, such as task-based learning in English teaching, so that what is learnt is embedded in meaningful tasks that are related to students’ everyday experiences. In science, it is considered that teaching should start from an inquiry into everyday or naturally occurring phenomena. Thus, when planning for a lesson, the teacher should consider how to help the students to establish a relevance structure for the object of learning so that they understand why they are learning it. This is in fact very similar to the idea of using motivation strategies.

*Using variation in students' understanding of the object of learning (V1) as a resource for teaching:* A main concern of Variation Theory is how different people experience the same object. Knowing other peoples' ways of seeing the same object makes our own way of seeing more powerful. Teachers thus do not have to 'eliminate' students' ways of seeing. What is more important is to help them to realise that there are other ways of seeing the same thing. This helps to widen or deepen the students' ways of seeing. Teachers should thus try to find ways to expose students to different ways of seeing and listen to them carefully, which is also the most effective way of catering for individual differences. When teachers allow students to express their views, they can then react and deal with any misconceptions that arise accordingly.

*External horizon:* To have a deep understanding of 'X', in addition to knowing the defining features of X (as espoused by disciplinary experts), we also need to know what 'X' is not so that we can separate 'X' from its external horizon. We also need to know the whole of which 'X' is a part, so that its relationship to other objects in the external horizon is clear.

### 3. Clarify the relationships between Variation Theory and other learning theories

Chapter 5 points out that at the level of lesson design, Variation Theory is compatible with most other teaching theories. Although we emphasise that every Learning Study should begin by focusing on the object of learning rather than teaching strategies, nevertheless, patterns of variation must be brought about through teaching and learning activities in the classroom. Learning activities are thus very important and must be designed in a way that allows students to experience the desired variation pattern and thus discern the critical features of the object of learning. The research lessons developed by our Learning Study research team have mostly adopted the currently promoted teaching approaches for the subject, using interesting and creative strategies and affording strong opportunities for student participation. However, it must be stressed that teaching strategies must target the object of learning, and all teaching strategies should serve to bring about the learning of the critical features. The object of learning and its choice should not depend on the format of learning activities, such as group work or task-based learning.

'Variation' as a teaching strategy has been used in China for many years. Gu Lingyuan started a study on 'teaching with variation (Bianshi)' in Mathematics

back in the 1980s. The study significantly enhanced the effectiveness of learning Mathematics in China. His ‘teaching with variation’ and Marton’s Variation Theory have much in common and yet each has its own characteristics (Sun, 2011). Variation Theory is theoretically derived and then applied to actual classroom teaching, whereas Gu’s ‘teaching with variation’ is empirically derived from actual practice. The advantage of the former is that it has a firm theoretical foundation, whereas the advantage of the latter is that it is based on actual practice in the local teaching situation. If the purpose of teaching is to enable students to learn, then any empirically derived principles of teaching must be generalisable, and must eventually be theorised to explain learning and developed into a learning theory. Conversely, any theoretically derived learning theory must be thoroughly tested in practice for it to be useful to teachers. Gu, Huang and Marton (2004) argue that Variation Theory can provide an epistemological foundation and conceptual support for the Chinese theory. If researchers of Variation Theory and ‘teaching with variation’ engage in more dialogue and learn from each other, then both will benefit and make large steps forward.

#### 4. Variation Theory and nurturing the capability to face future challenges

Chapter 1 details three implications for the enterprise of teaching and teacher preparation as identified by Donovan, Bransford and Pellegrin (1999). The third implication states that ‘The teaching of metacognitive skills should be integrated into the curriculum in a variety of subject areas’ (p. 17). It is argued that a metacognitive approach to instruction will help students learn to learn by themselves, because they will be able to set goals for learning and monitor their own progress in achieving the goals (p.13-14). It is also advocated that teachers teach students metacognitive skills.

The contribution of Variation Theory is mainly towards learning that requires discernment. If students are also aware of how they come to discern by experiencing suitable patterns of variation that can bring about contrast, separation, generalisation and fusion, then they will have acquired a useful method for learning new knowledge by themselves.

##### Example 7.1

I wish to illustrate with an example of what happened to my own self-learning. A good way to be in touch with nature is hiking. Hiking is even more fun if we know some of the names of the plants that we encounter. When I first started hiking all I saw was a field of

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green. I could not discern the characteristics of individual plants. As I became familiar with the sight of more and more plants, I started to have a deeper impression of some of them. I even started to distinguish between them. At this time, although I could name some of the plants, I only had a vague impression of them. In other words, as I experienced variation in plants – a dimension of variation – I was able to organise different plants as values of this dimension of variation.

Throughout my learning process, I was fortunate to have known a group of plant lovers. I benefited from these knowledgeable people in the community and read some related books, and came to be able to recognise many plants. I also learned that plants can be classified into families and species. I also get some easy tips to help memorising some of the characteristics of certain families of plants. However, as a beginner, this kind of knowledge remained superficial, and I found the taxonomy too complicated and beyond my understanding. I still relied on rote memory to recall the names of plants. When I came to know more plants, I began to discern that certain plants have characteristics that are different from other plants, for example, when their leaves are crushed I can smell a special aroma. Noticing this difference helped me to separate this type of plant from other plants. Then I encountered more plants with similar characteristics, and yet each one was different. When I noticed their differences, the dimension of variation based on the family 'Rutaceae' opened up, and each plant became a value on this dimension of variation. I noticed more critical features than I had previously and in greater detail, and the overall impression I had of certain plants switched from vague to clear. Plants such as orange (*Citrus sinensis*), orange jasmine (*Murraya paniculata*), rosewood (*Acronychia pedunculata*), prickly ash (*Zanthoxylum avicennae*) and thin evodia (*Melicope pteleifolia*) could then be organised as values of this dimension of variation (Rutaceae). Comparing these different plants enabled me to make generalisations about the characteristics of Rutaceae: they all have visible oil dots underneath their leaves and when their leaves are crushed I can smell a special aroma.

Although I had discerned some of the critical features of this family of plants, I had not discerned them all, and had taken many features for granted. This is interesting, because although I could discern certain plants such as thin evodia, I was not clear about all of its critical features. It is because I had a blurred overall impression of thin evodia that was just enough to allow me to identify it from the other plants, but I was not able to recognise all of its critical features. For discernment of a critical aspect to occur, I had to experience variation in the critical feature; without having such an experience, it was not possible for me to discern. Suddenly one day, I came across a plant that was very similar to thin evodia, particularly the shape of the leaves. It too had a compound leaf with three leaflets, but the shape and colours of the flowers were completely different. It was



obvious that this plant and thin evodia were two different kinds of plants! I began to compare the two, and I realised that in addition to the flowers being different, the compound leaves grew alternate to each other, and its stems, branches and leaf rachis were armed with many downward curved sharp spines. The compound leaves of the thin evodia are opposite to each other and there are no spines on the plant. From that moment on the differences between these two plants became very obvious to me. I could now discern more of the critical features of the thin evodia, and had a clearer image of this plant as a whole. With this more in-depth knowledge I started to notice the critical features that I had not noticed before, and more importantly I not only knew what a thin evodia is but also what a thin evodia is not. I realised that whether leaves grow alternate or opposite is not a defining feature of Rutaceae, but is an aspect that can vary. As my knowledge of plants grew, I was able to discern more subtle features. The information I had previously read or heard about plants began to make sense to me. When I was able to simultaneously notice the different features of thin evodia (such as compound leaves, three leaflets, compound leaves being opposite, no spines on the stem), I had also discerned the dimensions of variation of which these critical features are values. To be able to identify a plant means that all of these features are discerned together in 'fusion'. Because I noticed the similarities between the new plant that I encountered and thin evodia and I already had the concept of the family of 'Rutaceae', I knew that this plant was another variation of 'Rutaceae'. With this knowledge and the known critical features of the plant, I easily found it in the Flora and found that it was an 'orange climber' (*Toddalia asiatica*). In this example, by experiencing variation I was able to achieve self-learning. Understanding how I came to learn thin evodia and orange climber means that I can apply the same strategies to learn other plants.

One of the important goals of education is to prepare students for the future and to enable them to solve new and unseen problems in the future world in which they will live. Many advocates of educational reforms justify the need for them with rhetoric such as 'The world has changed, our education is lagging behind the times, we must prepare students to take up the unknown challenges of the future. In this era of information explosion, when students graduate from school, what they have learnt will already be obsolete and will be replaced by new information. They should not be taught knowledge that will be replaced; students need to be taught the ability to adapt to the future!' or similar arguments. In my opinion, such arguments assign too much importance to the changes that are currently being experienced, while forgetting that in the history of mankind, change has taken place all the time. Our environment is forever and eternally changing. Man encounters new things every day and there are new problems to be solved. Take



a simple act like walking: every step we take is different and will not be the same as any of the previous steps that we have taken. The condition of the ground may be different, it may be wetter, more slippery, there may be holes on the ground; the environment may be different, it may be more crowded and we have to avoid bumping into others; our physical condition may be different, we may be older, more tired, but we always use the knowledge and skills that we have learnt to solve new problems. As long as we have an in-depth and thorough understanding of the knowledge that we have, we can then draw on it to solve new problems or create new knowledge.

A work of creation does not usually come out of thin air; we can trace the evolution of the idea from existing ideas. Sometimes, novel ideas or artefacts are built up from existing units, but combined and arranged in different ways. Gaining a deep understanding and mastery of existing knowledge provides the foundation for us to resolve new problems. To solve new problems, two capabilities are of importance.

- To be able to see that any problem can be solved in many different ways.
- To be able to apply the knowledge and capability that one already possesses to solve new problems.

These two capabilities can be nurtured through variation. The following sections give two examples.

### *Ability to find different solutions to the same problem*

#### Example 7.2<sup>31</sup>

In a secondary 4 mathematics Learning Study, teachers designed a research lesson, in which the direct object of learning was cyclic quadrilaterals. The teachers found that when the students were required to prove that four given points were concyclic, they often just copied down all the known information given without considering whether such data were relevant to their problem, and then started calculating aimlessly. The result was that they either had to find a solution in a roundabout way and thus worked through a large number of steps before getting the answer, or were not able to find the answer at all. The teachers attributed this failure to the lack of problem-solving strategies

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<sup>31</sup> This example comes from Learning Study VL102 in the “Variation for the Improvement of Teaching and Learning” (VITAL) project carried out by Chan Wing Sum, Kong Hau Yin, Cheng Mei Shan, Chow Chui Shan, Lai Yuk Kwan and Tam Kim Hung. The project was funded by the Education Bureau of Hong Kong.

rather than a lack of knowledge about cyclic quadrilaterals. With this in mind, the teachers decided that the indirect object of learning of the lesson would be ‘the capability to apply both forward thinking and backward thinking to solve mathematics problems relating to cyclic quadrilaterals’. Backward thinking involves observing the required result first, and then looking for information that matches or will lead to the end result. The teachers hoped that once the students had learnt this problem-solving strategy, they would be able to apply it to solve other geometric problems.

For example, if students used the forward-thinking method, they would use all of the known information given and try to see if any of these led to the proof. Usually they would stop once they found one solution.

In contrast, when using the backward-thinking method, students would first consider what the end result is, and what conditions are required to get the end result, then work backwards by selecting the relevant given information that can support these conditions, there is often the chance of finding more than one solution to the problem.

*Table 7.1* Pattern of variation enacted in the lesson

Invariant	Varied	Discerned
Problem	Method (forward thinking or backward thinking)	The same problem may be solved by different methods.

Through this pattern of variation, teachers can help students to discern that there is more than one way of solving a problem. They can use both the forward-thinking method and the backward-thinking method. As long as they know what the end result requires, they can work backwards step by step to find the necessary information. During this process, more than one solution may present itself.

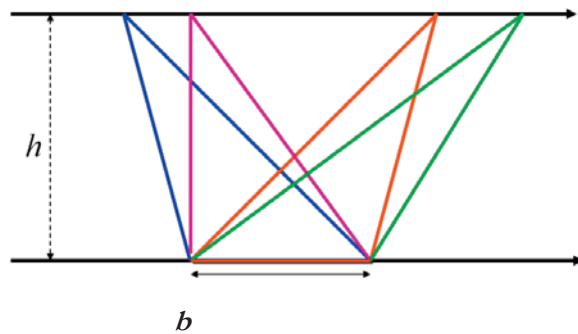
*The ability to use existing skills and knowledge to solve new problems*

Many new problems can be broken down into many smaller parts. If we consider the nature of these smaller parts, we may find that some of them may be tackled by knowledge we already have. To be able to discern the nature of a problem from a complex environment is a very important capability. As long as we can find out the nature of the problem, we can use our existing knowledge to solve it. The following is an example of an attempt to develop such a capability.

## Example 7.3

The data for this example are taken from a video of a Japanese Secondary 2 Mathematics lesson from the Third International Mathematics and Science Study (TIMSS). Although the teacher did not use Variation Theory as the conceptual framework or guiding principle in designing his teaching, he brought out a very effective pattern of variation. A brief description of the lesson is first given.

Introduction: The teacher first reviewed with the students the mathematical theorem that they had learnt in the previous lesson: the areas of triangles with the same base and between the same two parallel lines are the same.



*Diagram 7.1* Diagram used in the introduction by the teacher to show that triangles with the same base and between the same parallel lines have the same area

$$\text{Area} = h \times b$$

*Activity 1:*

The teacher asked the students to solve the following problem: two pieces of land belonging to two students in the class are separated by a fence. There is an attempt to straighten the fence; how should the straight line be drawn?

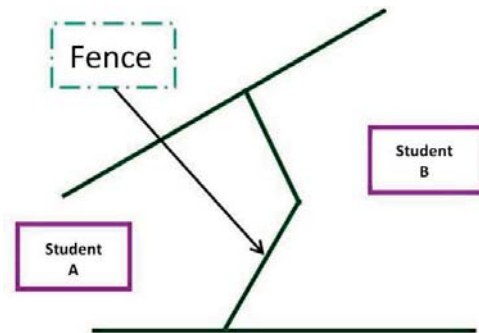


Diagram 7.2 Diagram showing the first problem

- First, the students spent three minutes on their own to think about the problem. They then formed their own groups freely and discussed the problem with the friends that they had chosen. Some discussed the problem with the teacher, and some took the cue cards prepared by the teacher and continued to try to solve the problem.
- The teacher then invited two students to show their answers on the blackboard and to explain their ideas, and then gave them feedback.

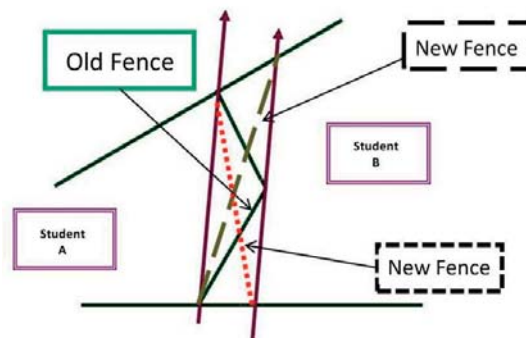


Diagram 7.3 Diagram showing the solutions to the first problem

*Activity 2:*

- The teacher gave the students a second challenge: to turn a quadrilateral into a triangle with the same area.
- Students had three minutes to think about the answer and again formed discussion groups.
- The teacher asked each group to draw their answers on the blackboard.

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- The teacher summarised the students' answers. Eight answers were given.

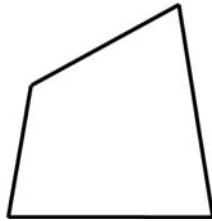


Diagram 7.4 The quadrilateral in the second question

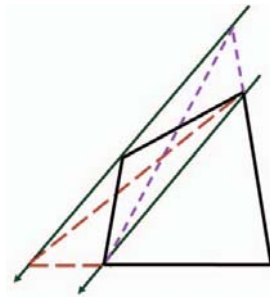


Diagram 7.5 First two answers for Activity 2

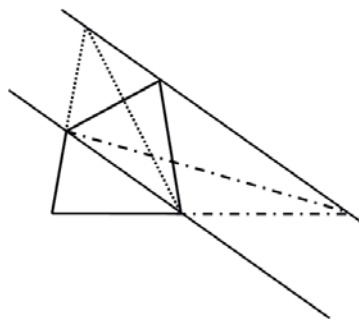


Diagram 7.6 Third and fourth answers for Activity 2

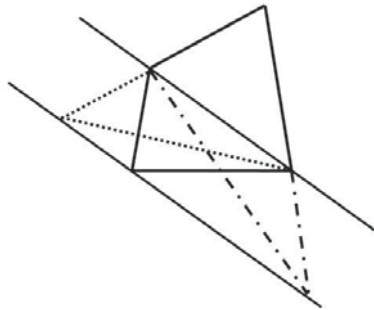


Diagram 7.7 Fifth and sixth answers for Activity 2

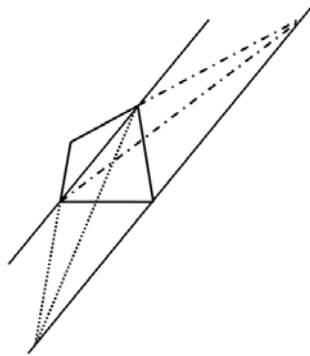


Diagram 7.8 Seventh and eighth answers for Activity 2

*Conclusion:* The teacher asked the students if they could use the same method to turn a pentagon into a triangle with the same area. The teacher gave this question as homework for the students.

During the lesson, the teacher enacted the following pattern of variation.

Table 7.2

Invariant	Varied	Discerned
Nature of the problem	The context and complexity in which the problem is situated/framed	The same basic method can be applied to solve all problems of a similar nature.

In fact, all of the problems can be solved with the same mathematical theory: ‘The areas of triangles with the same base and between the same two parallel lines are the same’.

Mathematics teachers may have encountered similar problems with their own students; that is, after students have learnt a theory they do not know how to apply it. This problem usually does not present itself at the time the topic is taught, because the exercises and tests are all set on that same topic. However, when there is a slight change to the question, such as a change in context or in the complexity of the question, then students have difficulty recognising the nature of the question. A large number of questions in examinations must be solved using theorems learnt throughout the term, yet students are unable to choose the appropriate theorem for solving the problems. The aforementioned lesson focused on a difficulty that most students encounter, and aimed to help students to understand that if problems are of the same nature, then they can be solved with the same theorem. The teacher changed the context and the complexity of the problem but kept the nature of the problem unchanged, hoping to develop the students’ capability to see the nature of a problem in different situations and of different levels of complexity.

The foregoing two examples demonstrate how teachers can apply Variation Theory to design lessons that improve students’ problem-solving skills to solve new problems in the future. We all encounter new problems every day. If we manage to identify and consider a variety of methods to solve a problem, then it will help to improve the quality of the solution. Moreover, each new problem may be made up of a number of relatively simple problems. If we can identify the nature of these relatively simple problems, then we may well discover that we have encountered these problems before or already have solutions for them. In this way, we can work out a method to solve new and more complex problems.

### **5. Helping to solve the problems associated with teachers’ language of instruction**

In Learning Study, the classroom language of the teacher is rarely the focus of study. I will not discuss the issue of choice of language, whether the mother tongue, Mandarin or Cantonese, is the medium of instruction. On the contrary, what I wish to explore is the issue of teachers’ use of instruction language where the choice of language has already been specified. Teaching and learning can only take place through language. Language is needed to convey meaning and to clarify concepts, but at the same time it can also hinder the formation of

concepts. There is a saying that all teachers are language teachers, because the language that they use in class can help students to understand and express the concepts that they have learnt. In our Learning Study cases, we often find examples in which the teacher was not careful with the terms used, which lead to misunderstanding among the students, especially in the subjects of Mathematics and Science. This is illustrated with the following three examples.

Example 7.4

In a primary General Studies lesson, the intended object of learning was ‘evaporation’. The teacher demonstrated boiling a glass of water in the classroom, then pointed to the steam emerging from the surface of the water and said to the class, ‘Look, when the water is boiled, water will turn into vapour, escape from the liquid water and disappear into the air’. Because the teacher used the word ‘disappear’, some students thought that when water evaporates it ceases to exist. Their intuitive ways of thinking led them to conclude that the water had turned into other gases, such as hydrogen and oxygen (see example 3.10 of the students' interviews).

Example 7.5

In a secondary two Science lesson, the object of learning was ‘the chemical reaction between acid and metals’. The language of instruction was English. The teacher led the students to arrive at four possible hypotheses about the reaction between acids and metals.

1. All acids react with all metals.
2. Some acids react with some metals.
3. All acids react with some metals.
4. Some acids react with all metals.

According to the teacher, these were the only possible hypotheses, and there could not be any other options. The problem lay in how the word ‘some’ was understood by the teacher and by the students. To the teacher, ‘some’ meant not all, thus, if we can find one counter-example then the ‘all’ hypotheses can be rejected. In other words, if a counter-example cannot be found, then the ‘all’ hypotheses cannot be rejected. The students then carried out experiments to find out how different metals reacted with different acids, and arrived at the following results.



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*Table 7.3* Table showing the reactions of metals with acids

	Zinc	Copper	Tin	Iron	Calcium	Magnesium
Dilute sulphuric acid	v	x	v	v	v	v
Dilute hydrochloric acid	v	x	v	v	v	v
Dilute ethanoic acid	v	x	v	v	v	v

The students found that copper did not react with any of the acids. The teacher thus guided the students to draw the conclusion that hypotheses 1 and 4 cannot be established because copper is a counter-example. They could not say that ‘all metals’ react with some/all acids, and hypotheses 1 and 4 were rejected. The teacher then guided the students to decide which of hypotheses 2 and 3 could not be rejected for the time being. The teacher pointed out that as the students could never test all of the acids and metals, they must follow a principle of the scientific method that one can never prove a hypothesis, but only reject a hypothesis based on the evidence collected so far. In the circumstance that one cannot reject a hypothesis, one has to retain it for the time being. Because the students could not find a counter-example of an acid that did not react with any metal, hypothesis 3 could not be rejected. To say that hypothesis 3 was established, the students needed to find an acid that did not react with any metal, but so far had been unable to do so, and thus could not say that hypothesis 3 was correct.

During the post-lesson interview, we found that some students understood ‘some’ differently from the teacher. To them, the word ‘some’ meant more than one. As they could not test all of the acids, based on the tests of three types of acids, they thought that they could safely say that some acids will react with some metals, so they selected hypothesis 2. The students’ understanding, which was based on what they had learnt about the meaning of ‘some’ in their English language lesson, was different from the teacher’s thinking, which was based on the language of logic where some is equivalent to NOT ALL. Thus, to use the word ‘some’, one must find at least one counter-example to prove that it cannot be ALL.

Example 7.6<sup>32</sup>

In a secondary three Mathematics lesson on probability, the teacher asked the students to give an example of ‘impossible events’. A boy answered, ‘It is impossible that I am a girl’. The teacher did not notice the error in the answer and did not correct him. In fact the correct answer should have been ‘I am a girl’.

As the probability of an ‘impossible event’ is zero, here we see that the students did not realise that the probability of ‘It is impossible that I am a girl’ is in fact equal to one, not zero, as the statement is always true when spoken by a boy, which makes it a certain event (100% chance it will happen with a probability equal to 1) and not an impossible event (0% chance it will happen with probability equal to 0). The student's answer appeared to be reasonable from the perspective of everyday language use, but it is incompatible with the meaning of ‘impossible’ from a mathematical language perspective. One of the objectives of teaching mathematics is for students to acquire mathematical language so that they can begin to understand and later master mathematical ways of thinking.

From these examples, it is clear that if teachers are more precise in their use of language, then the misunderstandings of students are more likely to be clarified. In Example 7.4, if the teacher had clearly pointed out that ‘Liquid water will evaporate and become water in the gaseous state. Although water in the gaseous state is invisible, it mixes with other gases in air and is distributed throughout the air’, then it would have been less likely that the students would have thought that water no longer exists after being boiled. In Example 7.5 if the teacher had not used the word ‘some’ but instead ‘not all’, then the difficulties in learning may have been reduced. Teachers must train themselves to be more sensitive to the response of students if they are to apprehend students’ problems. In a real teaching environment, even a very good teacher cannot avoid the occasional use of inappropriate language, but Variation Theory can help to address this issue. Variation Theory draws teachers’ attention to the variation in students’ ways of seeing the object of learning. In Example 7.6, if the teacher had created opportunities for the students to express their understanding in class, then the students’ difficulties in interpreting what ‘some’ meant would have come to the fore, and the teacher could have reacted accordingly. Variation in students’

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<sup>32</sup> This example comes from Learning Study VL047 in the “Variation for the Improvement of Teaching and Learning” (VITAL) project carried out by Man Yiu Kwong, Tang Oi Lin, Yung Sai Kit, Gu Wing Hong, Poon Man Yiu, Tsang Sin Yu, Lo Mei Wah, Wong Kam Tong, Tang Mei Shing and Chan Man Sum. The project was funded by the Education Bureau of Hong Kong.

understanding will also be revealed in the other examples quoted. In a lesson, teachers should create a lot of opportunities for students to express their understanding of the object of learning and make good use of variations in the students' understanding as a teaching resource so that students can compare correct, incorrect, superficial, deep, narrow or multi-perspective understanding. This will address students' misconceptions in class in a timely manner, and will ultimately help students to learn better.

## Conclusion

The aforementioned points are areas to be focused on as we further develop and apply Variation Theory in real classrooms. As pointed out in the previous chapter, so far the development of Learning Study and Variation Theory have been tightly coupled. However, Variation Theory can be used independently of Learning Study to analyse classroom teaching and learning, which in itself has the power to predict and interpret learning results and can definitely be developed independently. However, through Learning Study we can obtain more data from different aspects, such as students' pre and post lesson test results, pre and post lesson interviews, video recordings of the lesson and several teaching cycles of research lessons, which provide an evidence base with which to test the application of Variation Theory. For example, one can use Variation Theory as a theoretical framework to analyse lessons and to explain student learning outcomes, or to design patterns of variation and plan lessons accordingly, then to test if the predictions are supported by student learning outcomes.

Similarly, a Learning Study that is used as a platform for the professional development of teachers need not necessarily be based on Variation Theory. In fact, many countries have developed Lesson Study (which is based on the Japanese model, but with no specific learning theory as the conceptual framework), and in Hong Kong there are researchers who collaborate with schools to develop lesson studies. However, as Chokshi and Fernandez (2004) note, the challenge facing the development of Lesson Study in the United States is that some newly established Lesson Study groups neglect the effective factors of Lesson Study, such as being able to design classroom activities that reflect the thinking of students and understanding the process that helps them to focus the discussion on students' learning, with the result that some lesson studies may focus on elements that are unrelated to students' learning. This is probably because the teachers involved did not pay enough attention to the object of

learning and lack a common learning theory that can help them to design, enact and evaluate whether the research lesson is focused on the object of learning.

That is not to suggest that a research lessons designed through a Learning Study must be better than a research lesson from a Lesson Study that does not use Variation Theory as the theoretical framework, or even lessons that are designed by teachers drawing upon their past teaching experiences. The insight that I have drawn from my many years of involvement in Learning Study is that when Learning Study draws on Variation Theory as a principle of pedagogical design, it offers teachers another tool for improving their teaching. Some of the important objectives of Learning Study are to develop teachers' sensitivity to the views of their students and to help teachers to understand and apply Variation Theory as a pedagogical tool to design lessons. Of course, teachers can use other learning theories in designing teaching or conducting lesson studies. However, the advantage of having a learning theory as the framework is that every time teachers tests the theory in practice, they will have a better grasp of the application of the theory. Cochran-Smith and Lytle (2001) point out that this dual process of testing the theory through practices and using the theory to evaluate practice is necessary to narrow the gap between theory and practice. We need to carefully analyse the object of learning enacted in class and take an enquiry approach towards teaching to really understand what actually happens during a lesson. Learning Study, which takes the object of learning as the point of departure, that uses Variation Theory as a conceptual framework provides teachers with a platform to participate in action research about their own teaching, and ultimately achieves effective teaching and learning. Variation Theory guides and supports teachers in dealing with the object of learning. The combination of Variation Theory and Learning Study is a powerful one, as the two are mutually reinforcing.

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## About the Author

Professor LO Mun Ling is Adjunct Professor of the Department of Curriculum and Instruction, and co-director of the Centre for Learning Study of the Hong Kong Institute of Education. She was formerly Head of the Department of Curriculum and Instruction and Director of the Centre for Learning Study and School Partnership (CLASP) of the Hong Kong Institute of Education. She is internationally well known for her pioneering work on Learning Study which contributes to improving teaching and learning, and teachers' professional development. Through a series of projects, supported by the Quality Education Fund and the Education Bureau, she led a research team to support over two hundred primary and secondary schools in Hong Kong to develop Learning Studies. She is a founding member of the World Association of Lesson Studies, and was elected its first president. Her research interests include: Teaching and Learning, Learning Study, School University Partnership, Mentoring, Teachers' professional development and Curriculum Evaluation.



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