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Drawing on the variation theory to enhance students' learning of Chinese characters

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The variation theory of Ference Marton and his collaborators has widely been used as a framework for explaining what can possibly be learned in a particular classroom and what cannot. This paper reports on an experiment that put this theory to test in the context of students' learning of the orthographic structures of Chinese characters. The experiment was carried out in the classrooms of two primary schools in Hong Kong. In each of the schools, two classes of students were taught differently, as informed by the theory, about the significance of the location of a component in the orthographic structure of a character in relation to whether the component provided a clue to the meaning of the character (called the part-part relations). The results of the experiment are consistent with the prediction of the theory that those students who were given the possibility to experience variation in the locations of components in the orthographic structures significantly outperformed those who were not. The results of the experiment demonstrate the power of the theory in guiding the design of teaching that affords students' learning to happen.

The variation theory, learning Chinese characters, phenomenography, and student learning

Introduction

The variation theory emerged from the work of Marton's phenomenographic studies of learning, and aims at finding out what makes it possible for people to develop a powerful way of seeing or experiencing a certain phenomenon. Because of this, the theory has widely been adopted in the studies of classroom teaching in Hong Kong and Sweden. In these studies, the theory was used to provide a principled account of what makes it possible (or impossible) to learn something in a classroom (Marton & Tsui, 2004; see also Holmqvist, Gustavsson, & Wernberg, 2008; Ki, Tse, & Shum, 2005; Lo, Chik, & Pang, 2006; Lo, Pong, & Chik, 2005; Marton & Booth, 1997; Marton & Pang, 2006; Marton, Tse, & Cheung, 2010; Pang & Marton, 2003, 2005; Runesson, 2006).

In essence, the variation theory views learning as a change in a learner's way of seeing or experiencing a specific *object of learning* (i.e., what content learners have to learn and what capability learners have to develop). A learner's "way of seeing" is defined as those aspects of the object of learning that the learner focally attends to (Marton, Runesson, & Tsui, 2004, p. 9). *Critical aspects* are then those crucial aspects

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that learners ought to focus on in order to appropriately see the object of learning. (Such experience of different co-existing aspects of the same thing at the same time is called *synchronic simultaneity*.) In other words, the appropriation of the object of learning requires learners to develop a certain structure in their awareness with a few critical aspects in the foreground and a very large number of other aspects receding to the background.

It follows that, in order for learners to be able to focally attend to an aspect, they must have discerned the aspect, which requires them to have experienced the variation in that aspect. That is to say, learners have to experience at the same time the different instances of the aspect that varies. (This experience of different instances of the same aspect at the same time is called *diachronic simultaneity*.) To quote Bowden & Marton (1998), "To discern an aspect is to differentiate among the various aspects and focus on the one most relevant to the situation. Without variation there is no discernment" (pp. 7-8).

The implication of this is that teachers have to structure the learning experience of learners in such a way that will make it possible for them to discern the critical aspects of the object of learning. In the words of Marton, Runesson, & Tsui (2004), "it is necessary to pay close attention to what varies and what is invariant in a learning situation [i.e. the pattern of variation and invariance], in order to understand what it is possible to learn in that situation and what not" (p.16). More specifically, to make a critical aspect discernible, teachers must vary the critical aspect while keeping the other aspects unchanged. As Bowden & Marton (1998) suggest, "When some aspect of a phenomenon or an event varies while another aspect or other aspects remain invariant, the varying aspect will be discerned" (p. 35). The provision of such pattern of variation and invariance is regarded as the *necessary condition* for learning to take place.

Thus the theory gives insight into how teaching in classrooms should be planned and conducted. According to this, we designed an experiment to put the theory to test. The context in which the theory was tested was the teaching of the structuring of the components in Chinese characters (called *orthographic structures* [1]) to students in primary schools. The testing of the theory will be the main thrust of this paper. In what follows, we will first provide a brief description of the linguistic characteristics of Chinese characters as the background to the experiment and explain how students actually learn characters. Next to this, we will describe the setup of the experiment, which was carried out in the classrooms of one school and then repeated in another school in Hong Kong. The results of the experiment will then be reported, followed by a discussion of the results in light of the variation theory.

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Linguistic Characteristics of Chinese Characters

To set the stage for subsequent discussion, we shall begin with a linguistic analysis of Chinese characters. In brief, Chinese characters are not written in ways unrelated to their meanings. There are certain ways that the characters are structured to denote what they mean.

Chinese characters can be analyzed into one or more components. The simplest cases are those characters of only one component. These are the earliest-formed characters, which were written to directly represent the syllables in speech using the outward appearances of the items that they stand for. For example, as shown in Figure 1 below, the ancient forms of the characters 水 *seoi2* [2] 'water,' 木 *muk6* 'tree [3,]' 手 *sau2* 'hand,' and 女 *neoi5* 'female' came from the drawings of water drops, a tree, a hand, and a girl respectively.

Figure 1. The ancient and present forms of four characters having one component

Chinese characters of other kinds consist of more than one component. An overwhelming majority of 72% of all characters falls into the category of *semantic-phonetic characters* (Shu, Chen, Anderson, Wu, & Xuan, 2003). These are made up of exactly one *semantic radical* and one *phonetic radical*, which provide a clue to the meanings and the sounds of the characters respectively. For example, the character 溶 *jung4* 'to dissolve' is composed of the semantic radical 氵 'water' on the left and the phonetic radical 容 *jung4* 'appearance' on the right.

Semantic radicals are the components of characters that provide a clue to the meanings of the characters. For example, the characters 溶 and 海 *hoi2* 'sea,' sharing the same semantic radical 氵, both have meanings related to 'water.' In other words, the two characters belong to the same semantic field of 'water.' Similar to this, phonetic radicals provide a clue to the sounds of the characters. For example, both of the characters 溶 and 榕 *jung4* 'banyan' share the same phonetic radical 容 and their sounds are the same. (In this paper, when the sound or the meaning of a character is not specified in the main text, it can be found in Appendix I.)

Some phonetic radicals are themselves characters comprised of two or even more components (Gao, 1996). For example, the character 菠 *bo1* 'pineapple' has the phonetic radical 波 *bo1* 'wave,' which on its own as a character is made up of the two components 氵 and 皮 *pei4* 'skin.' Multiple-component phonetic radicals also occur in characters of other configurations. For example, the characters 裟 *saa1* 'cassock' and 湖 *wu4* 'lake' have 沙 *saa1* 'sand' and 胡 *wu4* 'northern tribes'

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respectively as their phonetic radicals, which are in turn made up of the two components 氵 and 少 *siu2* 'few,' and 古 *gu2* 'old' and 月 *jyut6* 'moon' respectively. Figure 2 analyzes the characters 菠, 裟, and 湖 into hierarchical structures with two levels.

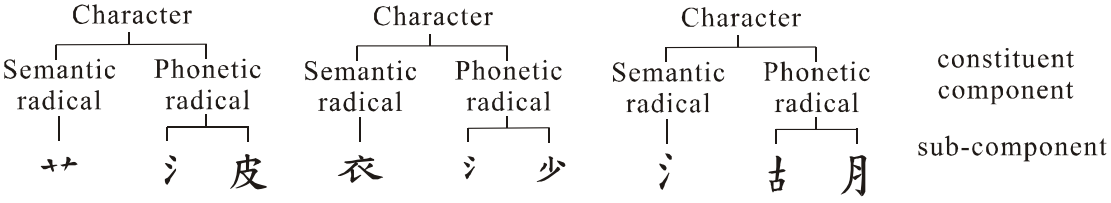

Figure 2. The hierarchical analysis of the characters 菠, 裟, and 湖

Of particular importance is that components at different levels in a character actually take on completely different functions with regard to the clues that they provide to the character. For example, in the character 裟, the 衣 *ji1* 'dress' and the 沙 provides a clue to the meaning and the sound of the character respectively, while, in contrast, the 氵 and 少 are only parts of the phonetic radical 沙 and have nothing to do with the meaning or the sound of the whole character 裟. Thus there are two distinctively different functions that components in characters can take on. Those components that, according to their locations in the orthographic structures, provide a clue to either the meanings or the sounds of the characters are called *constituent components*, while those that do not are called *sub-components* (Lam, 2006, 2010).

To give readers a sense of how often components take on the functions of constituent component and sub-component in characters, we have examined all of the 2,600 characters listed in the Hong Kong primary school curriculum (Curriculum Development Council, 1990) that consist of the components 氵 or 木 *muk6* 'tree.' Of those 154 characters having the component 氵, 137 (88.9%) have it serving as a constituent component (e.g. the character 海), while in 17 (11.0%), it serves as a sub-component (e.g. the character 婆 *po4* 'dame'). For the component 木, the relative proportions are 62.8% and 37.2% respectively. Thus it is not uncommon that components take on these different functions in characters (See appendix I of Lam, 2006).

The above is a brief account of the linguistic characteristics of Chinese characters. The next question is how these characteristics of characters have to do with the ways that students actually go about learning characters.

Students' Learning of Chinese Characters

When students encounter an unknown character, if they recognize a certain component in the character and also understand how the same component gives a clue

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to the meanings of other known characters, they may be able to make an inference about this unknown character. For example, if the character 湖 is unknown to a student, from the student's knowledge of other characters having the same component 氵 such as 海, the presence of the component 氵 in the unknown character 湖 may help the student to infer that 湖 probably means something related to 'water.'

In our study, we refer such a clue that a component provides to the character as a *part-whole relation* between the component and the character (Lam, 2006, 2010). We have previously examined developmentally whether primary school students at different levels are aware of this part-whole relation (Lam, 2006, 2008). Primary 1 students were found to correctly interpret those unknown characters with a certain known component (e.g. 溶 with the 氵) as related to the meaning of that component (i.e. 'water'). (Hereafter, we will refer to this component as the *target component*, which is the component in question.) Conversely, they also correctly interpreted those unknown characters without the target component (e.g. 榕 without the 氵) as not related to the meaning of that component. Thus the students could take into account what the target components signify in characters when deciding on the meanings of the characters; that is, they were able to recognize the part-whole relations.

This result converges with that of Shu & Anderson (1997). In their study, students in Beijing were asked to replace the sound *tung4* [4] in "*tung4* 孔 'the eye pupil'" with one of the characters 瞳 *tung4* 'pupil,' 撞 *zong6* 'to bump,' 僮 *tung4* 'boy servant,' and 潼 *tung4* 'the name of a place.' Primary 3 students were found to perform better when the characters were morphologically transparent (e.g., the 氵 in 溶) than when the characters were morphologically opaque (e.g., the 氵 in 法 *faat3* 'method [5]'), where the semantic radicals had been subjected to historical transformation and their present meanings were no longer related to those of the characters. Shu & Anderson concluded, "Many children have a functional awareness of the relationship between the radical in a character and the meaning of words containing the character. Knowledge of morphology was found to develop with grade level." (p. 87) (See also Ho & Bryant, 1997a, 1997b; Shu, Anderson, & Wu, 2000)

Thus students might not have much difficulty with recognizing what meanings components signify in characters. A much more complicated issue is whether students realize what functions components take on in characters; that is, whether they function as a semantic radical or as a sub-component. This happens especially in characters with more than two components. In these characters, there are multiple possible ways for students to interpret the orthographic structures of the characters. For example, students may relate the meaning of the character 湖, when unknown, not only to that of 氵, 古 and 月, but also to that of 沽 *gu1* 'to sell' and 胡. The character 湖 can in principle be seen in many different ways, namely, (i) as three

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isolated components 氵, 古 and 月, (ii) as a combination of 氵 and 胡, (iii) as a combination of 沽 and 月, and (iv) as an indivisible whole 湖. But, out of these interpretations, only the division of the character 湖 into 氵 and 胡 is appropriate because the 氵 gives a clue to the meaning of the character while the 胡 gives a clue to its sound. We refer this as a *part-part relation* between components in characters (Lam, 2006, 2010); that is, the knowledge of which of the components in a character join together as one unit that provides a clue to the understanding of the whole character. If students cannot take into account these part-part relations, they will not be able to make sense of the orthographic structures of the characters and will have to turn to rote memory for learning the characters. Thus understanding the part-part relations plays a very crucial role in the learning of characters.

We have previously examined developmentally whether primary school students at different levels recognize these part-part relations. These were found to be one of the major difficulties of the students, especially at junior levels. For instance, Primary 2 students not only interpreted the character 湖 as having a meaning related to 氵 but also wrongly interpreted the characters 菠 and 裟, in which the 氵 only serves as a sub-component, as belonging to the same semantic field of 氵. This shows that the students were probably confused about which of the components (e.g. the 氵 and 少 in 裟) join together to form a constituent component (e.g. the 沙) in the character; that is, they failed to recognize the part-part relations.

Above all, to fully make sense of the orthographic structure of a character (e.g. the character 裟), students have to understand the clues that components provide to the whole character; that is, what meanings the components signify in the character (e.g. the 衣 signifies the meaning of 'dress'). In this respect, students are well aware of the part-whole relations. What the students experience difficulty with is to understand which of the components in the character join together to form a constituent component (e.g. the 氵 is part of the phonetic radical 沙 and only serves as a sub-component). In other words, the major difficulty of the students lies in understanding the part-part relations. In the next session, we will discuss how we draw on the variation theory to design teaching that affords students' learning of the part-part relations.

Bringing about Understanding of Part-part Relations

In schools, teachers may deal with the above concepts of the part-whole and part-part relations in their teaching of characters. But, this is often done only intuitively and is not guided by any theories of learning. Conscious efforts to systematically teach students how to analyze the orthographic structures of characters (i.e. how the components are structured to denote the meanings of the characters) are rare, if made

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at all. Moreover, one may be prone to think that so long as teachers teach these part-whole and part-part relations to students, the students will be able to learn them. But, all too often, the teachers who are themselves clearly aware of the part-whole and part-part relations may be misled by their own intuition about what the effective ways of teaching the students are.

In the following, we will draw on the variation theory to design teaching that helps students to understand the part-part relations in characters. In particular, the object of learning is that students are able to determine, according to the orthographic structure of a character, whether or not a component provides a clue to the meaning of the character. We will examine below two ways of teaching such part-part relations with the use of the same four characters paired up in two different ways, called *Contrast pair* and *Generalization pair* [6].

Table 1

Two Ways of Teaching Part-part Relations in Characters

No.	Pairs shown to students	Explanation of teacher
	Contrast Pair	Question: Are either of the two characters related to the meaning category in brackets?
1	溶 (氵) 裟 (氵)	Answer: The first character 溶 is related to 'water,' while the second character 裟 is not. In the first character, the component 氵 is located on the left and thus provides a clue to the meaning of the character, while in the second character, the component 氵 is part of the component 沙 and thus does not provide a clue to the meaning of the character.
2	紮 (木) 梅 (木)	Answer: The second character 梅 *mui4* 'peach' is related to 'tree,' while the first character 紮 *zaat3* 'to tie' is not. In the second character, the component 木 is located on the left and thus provides a clue to the meaning of the character, while in the first character, the component 木 is part of the component 札 *zaat3* 'note' and thus does not provide a clue to the meaning of the character.
	Generalization Pair	Question: Are either of the two characters related to the meaning category in brackets?

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1	溶 梅 (氵) (木)	Answer: The two characters 溶 and 梅 are related to 'water' and 'tree' respectively. Both of the components 氵 and 木 are located on the left and thus provide a clue to the meanings of the characters.
2	紮 裟 (木) (氵)	Answer: The two characters 紮 and 裟 are not related to 'tree' and 'water' respectively. The components 木 and 氵 are part of the components 札 and 沙 respectively and thus do not provide a clue to the meanings of the characters.

In each of the contrast pairs, the same component varies in its location in the orthographic structures and in whether it serves as a semantic radical in the two characters. For example, the component 氵 serves as a semantic radical on the left of 溶 but not at the top-left of 裟. In contrast, both of the characters in each generalization pair have the target components located at the same location in the orthographic structures and serve (or do not serve) as a semantic radical at the same time. For example, the components 氵 and 木 both serve as semantic radicals on the left of 溶 and 梅 respectively.

According to the variation theory expounded earlier, one would predict a better improvement in the performances of those students who have been taught using the Contrast Pair than the Generalization Pair. Let us analyze the two ways of teaching as follows. In order to understand why the meaning of the character 溶 is related to 'water' but that of 裟 is not, students must simultaneously discern and attend to both the part-whole and part-part relations. This means that the students must realize the part-whole relation that the component 氵 signifies 'water.' They must also realize the part-part relation that when a component is (or is not) located on the left of a character, it serves as a constituent component (or a sub-component) in the character and thus provides (or does not provide) a clue to the meaning of the character. [7]

As discussed earlier, Primary 1 students and above were found to be well aware of the part-whole relations (Lam, 2006). Thus, if we assume that the students who receive the above teaching are in Primary 2, they should realize that whether or not a character is related to 'water' somehow has to do with the component 氵 in the character. On this basis, in a contrast pair, what varies with the component 氵 in the characters 溶 and 裟 is its location. This focuses the students' attention on the difference in the locations of the component 氵 in the orthographic structures. When the component 氵 is located on the left, it serves as a semantic radical and thus the character 溶 is related to 'water.' In contrast, when the 氵 is located at the top-left of the character 裟, it becomes part of the component 沙 and thus the character 裟 is not related to 'water.' In other words, in the contrast pair of 溶 and 裟, the students

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can simultaneously experience the variation in the locations of the component 氵 in the orthographic structures of the two characters.

In contrast to this, a generalization pair such as 溶 and 梅 has respectively the components 氵 and 木 located in the same way on the left of the two characters. What varies between the components 氵 and 木 in the characters are the components themselves; they are two different components. This focuses the students' attention on this difference in the components, which is however not helpful to understanding the significance of the location of the components (i.e., they are both located on the left and both serve as a semantic radical). In other words, since there is no variation in the location of the component 氵 or 木 in the orthographic structures, in a generalization pair the students cannot simultaneously experience how the component varies in its location in the orthographic structure, which is crucial to their distinguishing between its function as a constituent component or a sub-component. Thus, using the variation theory, we have arrived at the prediction that a greater effectiveness of the Contrast Pair over the Generalization Pair will be obtained.

To put this to test, we conducted an experiment first in a primary school and then repeated it in another primary school to confirm the results obtained in the first school. In each of the two schools, one class of students was taught using the Contrast Pair while another class was taught using the Generalization Pair. A comparison was then made between the improvements in the performances of the two classes. For the sake of simplicity, we will group together the two sets of data from the two schools in the following discussion. [8]

Method

School Context

The experiment was conducted in Primary 2 classes in two typical primary schools in Hong Kong chosen by convenient sampling. The students in the schools were mostly from the working class and were native speakers of Cantonese, which was also the medium of instruction in the schools. During the time of this study, no innovative approach to teaching characters, as advocated in recent educational reform, had been tried out in the schools. Chinese characters were basically taught in a traditional manner. The teachers closely followed the textbooks in their instruction, and the students learned the characters in the model texts. An analysis of the textbooks used by one school reveals that the students were taught to use approximately 200 new words in one of the two terms in a school year. See Table 2.

Table 2

Number of New Words Introduced in the Textbooks Used in One School

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Level	Primary 1		Primary 2	
Term	1st	2nd	1st	2nd
Number of words [a] for recognition only [b]	112	93	108	112
Number of words for use [c]	211	192	208	227
Number of model texts	20	20	20	20

[a] The word is used as the unit for instruction since students are expected to learn characters in the context of their usage in words. Lists of new words are available in the textbooks. In these lists, the number of characters in a word ranges from 1 to 4. The majority are two-character words.

[b] Students are expected to be able only to recognize these words after instruction.

[c] Students are expected to be able to use these words after instruction.

The students were expected to learn the characters used in the model texts. Only on a few occasions, would the teachers analyze the characters into components in lessons. Bu-shou (i.e., 部首), which were common components useful for looking up characters in Chinese dictionaries, were taught to the students (starting from Primary 1 in one school and mainly from Primary 3 in the other). Besides this, the topic of one of the model texts was about the six principles for constructing Chinese characters (i.e., 六書). During the lessons on this model text, the students might gain a brief understanding of how a few characters were constructed from their components. Moreover, the students in one school were required to write characters in boxes such as □□, which were for the practice of writing characters with a left-right configuration. However, the purpose was only to teach the students to write in a legible manner rather than to understand how components are structured to denote the meanings of characters. Apart from the above occasions, the students in the schools were essentially taught the characters in the model texts using a look-and-say method. Thus during the instruction of characters, limited attention would have been given to the orthographic structures.

Participants

In the two schools, a total of 132 students (74 boys and 58 girls with a mean age of 7.7), roughly matched in age and ability, participated in the experiment. In each of the two schools, the students were recruited from two Primary 2 classes of average ability with 33 students in each of the classes in the first school, and 32 and 34 students respectively in the classes in the second school.

Teaching Plan

The Primary 2 students in the experiment were taught a list of pairs of characters, which were all made up of two constituent components, one of which was in turn made up of two sub-components. Table 3 shows the list of characters taught in one school. According to the curriculum (Curriculum Development Council, 1990), the

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students in this level had not yet learned the written forms of these characters. During the experiment, what the characters mean was orally explained to the students by way of illustration with pictures. Since spoken language development of children is basically complete at age 5 and children of that age are able to orally communicate with other people in social situations (Tse, 2006; Curriculum Development Council, 2006), the students in the experiment (of mean age 7.7) should have had no problem in understanding the explanation of the teachers regarding the meanings of the characters in spoken forms. All of the written forms of the characters chosen had a total number of 13 ± 3 strokes. As the curriculum requires, students at this level are learning characters ranging from 3 to 26 strokes with a mean of 11.0.

Table 3

Characters (Target Component) Taught to the Two Classes in One School

Order	Contrast Group	Generalization Group
1	裝(氵)、溶(氵)[a]	裝(氵)、恕(女)
2	梅(木)、箱(木)	梅(木)、溶(氵)
3	娶(女)、恕(女)	娶(女)、柴(木)
4	浙(扌)、撕(扌)	莉(艹)、菠(艹)
5	莉(艹)、描(艹)	浙(扌)、蜥(木)
6	傭(亻)、堡(亻)	描(艹)、搭(艹)
7	紮(木)、柴(木)	紮(木)、堡(亻)
8	聆(耳)、爺(耳)	爺(耳)、箱(木)
9	搭(艹)、菠(艹)	聆(耳)、傭(亻)
10	蜥(木)、桃(木)	撕(扌)、桃(木)

[a] 箱 *soeng1* 'box,' 娶 *ceoi3* 'to marry a wife,' 恕 *syu3* 'to forgive,' 浙 *zit3* 'the name of a river,' 撕 *si1* 'to tear off,' 莉 *lei6* 'jasmine,' 描 *miu4* 'to sketch,' 傭 *jung4* 'maid,' 堡 *bou2* 'castle,' 柴 *caai4* 'firewood,' 聆 *ling4* 'to listen,' 爺 *je4* 'grandpa,' 搭 *daap3* 'to put up,' 蜥 *sik1* 'lizard' and 桃 *tou4* 'peach.'

As mentioned earlier, in each of the two schools, two classes of students were separately taught the same list of characters using different teaching methods, namely, the Contrast Pair and the Generalization Pair. Accordingly, the two classes from the two schools that received instructions using the Contrast Pair are given the name of *Contrast Group* in the experiment, while the other two classes taught using the Generalization Pair are called *Generalization Group*.

Each class of students was taught in a whole class fashion, with the whole lesson lasting for about forty-five minutes. As an illustration of the teaching procedures, the ways that a pair of characters was taught to the students in the Contrast Group and the

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Generalization Group are described in four steps below.

Contrast Group

Step 1: The students were asked whether the meanings of the two characters were related to 'water.'

Step 2: After soliciting responses from the students, the teachers offered the answers for the two characters (See the left panel in Figure 3).

Step 3: The target components in the characters were then circled and the teachers explained that a component at a certain location in the orthographic structure provided a clue to the meaning of the character, while the component at another location did not.

Step 4: Pictures representing the meanings of the characters were shown to the students (See the right panel in Figure 3).

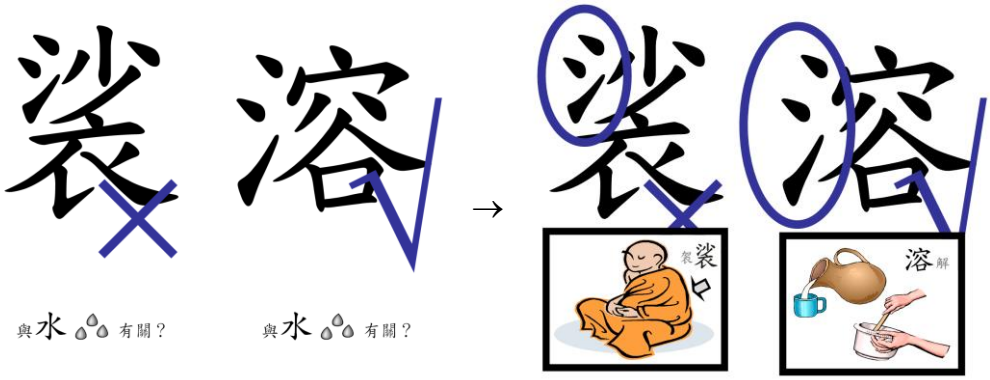

Figure 3. The teaching of the contrast pair 裝 and 溶

Generalization Group

Step 1: The students were asked whether the meanings of the two characters were related to 'water' or 'tree.'

Step 2: After soliciting responses from the students, the teachers offered the answers for the two characters (See the left panel in Figure 4).

Step 3: The target components in the characters were then circled and the teachers explained that a component at a certain location in the orthographic structure provided (or did not provide) a clue to the meaning of the character.

Step 4: Pictures representing the meanings of the characters were shown to the students (See the right panel in Figure 4).

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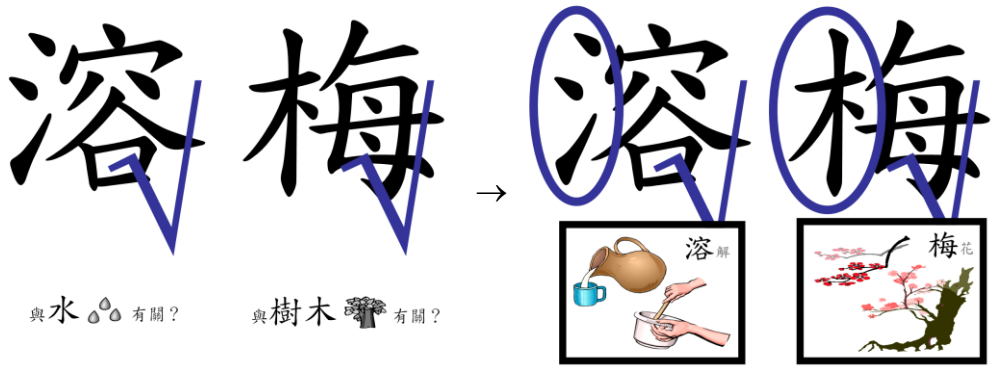

Figure 4. The teaching of the generalization pair 溶 and 梅

Test

The students were given paper-and-pencil tests, administered in a whole class fashion, before and after the lessons. In both tests, the same set of items was used except that the orders of the items were randomized. For each item in the test, the students were asked to indicate whether or not a stimulus character was related to a certain meaning category. For example, is 泬 related to 'water?' See the sample item in Figure 5. The students were told that there was no penalty for any incorrect answer. This should encourage them to make guesses when the stimulus characters were unknown to them.

Figure 5. A sample test item

The stimulus characters were different from the real characters taught in the lessons and were fabricated (hereafter referred to as *pseudo-characters*). The reason for using pseudo-characters was that if real characters had been used, the students' knowledge about the actual meanings of the characters would have affected their decision in choosing the answers to the questions. For example, students might interpret the character 海 as related to 'water' because they knew the actual meaning of the character 'sea,' rather than because they recognized the component 氵 in the character as a clue to its meaning.

Five types of items (the A to E items), of 6 pseudo-characters each, were constructed for the test, comprising a total of 30 testing items. See Table 4. For each type of items, the target components were located in a different position in the orthographic structures and thus should or should not provide a clue to the meanings of the pseudo-characters. (See Appendix II for all items)

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Table 4

Five Types of Items Used in the Test

Item	A	B	C	D	E
	Part-whole relations		Part-part relations		
Pseudo-character (target component)	港 (氵)	涕 (氵)	莎 (氵)	溫 (氵)	徜 (氵)
Configuration [a]					
Expected response	Yes	Yes	No	No	No
Number of items	6	6	6	6	6

[a] The darkened part in the configuration indicates the location in which the component should actually provide a clue to the meaning of the pseudo-character.

The A and B items were designed to measure students' awareness of the part-whole relations. In these items, the target components were located in positions in the orthographic structures such that they should serve as semantic radicals, thus providing a clue to the meanings of the pseudo-characters. If students were aware of this, they should interpret these items as "related."

The C, D, and E items were designed to measure students' awareness of the part-part relations. In these items, the target components were located in positions in the orthographic structures such that they should serve only as sub-components, thus having nothing to do with the meanings of the pseudo-characters. If students were aware of this, they should interpret these items as "not related."

The target components used in the pseudo-characters were all of high frequency of use in real characters that students commonly encounter in reading, for example, 氵, 木, 扌, and 女. The total number of strokes per character was limited to 12 ± 2. In the test, the pseudo-characters were printed in point size 36.

Beside the pseudo-character items, 24 simple real characters were added to the test as fillers to equalize the total number of plausible "yes" and "no" answers. This also makes the test seem easier to students because if the items in the test were all unknown, the students might find them too difficult and might eventually give up trying to complete the test. The real characters were all taken from Primary 1 or 2 textbooks so that they were familiar to the students. In the "yes" filler items, the meanings of the characters were clearly related to those of the target components. For example, is the character 海 related to 'water?' In the "no" filler items, the characters did not have the target components. For example, is the character 結 *git3* 'knot' related to 'water?' The students were not expected to have difficulty with these filler

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items. Their responses to these items were not analyzed.

Results

A total of 132 students participated in the experiment. Twelve students left out more than 10% of all items in the test, and thus their data were eliminated from the analysis. Other missing values were mostly due to careless omission and were replaced with the student's mean score on that item. In this way, the data of 120 students were analyzed. Since the portion of invalid data was small, this should not have affected the analysis of the data.

To determine the internal reliability of the items in the test, we calculated the inter-item correlation of the students' performance in the pre- and post-tests on each type of the items using Cronbach's Alpha model. As shown in Table 5, the correlation estimates are satisfactory with most types of items having reached an acceptable level of .7.

Table 5

Internal Reliability

Item	A (pre, post)		B (pre, post)		C (pre, post)		D (pre, post)		E (pre, post)	
	.660	.844	.733	.833	.753	.799	.787	.752	.687	.670

We also determined whether the Contrast Group and the Generalization Group were comparable before the lessons. The performances of the two groups in the pre-test were compared on each type of item using one-way ANOVA. Unexpectedly, significant main effects at the .05 level were found on the A and B items with $F(1, 118) = 5.248$ and 6.746 and $p = .024$ and .011 respectively. On the C, D, and E items, there was no statistically significant difference. This means that one group was apparently more aware of the part-whole relations than the other. However, this should not have affected the overall results of our experiment. This is because the students' awareness of the part-whole relations (not the part-part relations) is not the main focus of our study and in our analysis, we did not merely compare the students' performances in the post-test, but actually used the gain scores (i.e. post-test score minus pre-test score) to determine which of the two groups made a better improvement during the lessons.

Table 6 shows the results of the Contrast and Generalization Groups on each of the five types of items in the tests.

Table 6

Mean Correct Percentage (Standard Deviation) of the Students' Performances

	Contrast Group (n = 59)	Generalization Group (n = 61)

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	Part-whole		Part-part			Part-whole		Part-part		
Item	A	B	C	D	E	A	B	C	D	E
Pre-test	71.3	66.7	56.3	55.7	54.1	59.7	52.0	58.0	58.6	46.8
	(28.2)	(31.2)	(35.9)	(36.6)	(34.4)	(27.3)	(31.1)	(30.4)	(31.5)	(25.5)
Post-test	76.8	78.0	83.6	82.8	91.0	67.8	68.0	68.0	70.2	76.3
	(31.6)	(30.7)	(26.9)	(24.0)	(17.0)	(34.2)	(33.8)	(31.2)	(30.7)	(26.7)
Gain score	5.5	11.2	27.3	27.1	36.8	8.0	16.1	9.9	11.6	29.6
Effect size	0.2	0.4	0.8	0.7	1.1	0.3	0.5	0.3	0.4	1.2

Contrast Group

After the lesson, the students in the Contrast Group showed significant improvement in their awareness of the part-part relations. It was evident that the students had become more able to recognize that sub-components in the orthographic structures did not serve as semantic radicals. Clear indicators of this are the C, D, and E items (i.e., are 涉, 溫, and 徜 related to 氵 'water?'). The students' performances on these items improved from 56.3%, 55.7%, and 54.1% in the pre-test to 83.6%, 82.8%, and 91.0% respectively in the post-test. See Table 6. Statistically, using repeated measure ANOVA, significant main effects at the .01 level were found with $F(1, 58) = 38.255$, 32.463, and 72.091, all $ps < .001$.

In addition to this, full understanding of the orthographic structures of characters also requires students to recognize what meanings constituent components in the orthographic structures signified, that is, their awareness of the part-whole relations. Looking at the students' performance on the A and B items (i.e., are 港 and 涕 related to 氵 'water?'), the Contrast Group showed a slight improvement. On the A item, little improvement was observed. The score for this item rose from 71.3% to 76.8%, with no statistically significant difference being observed. The score for the B item increased from 66.7% to 78.0%. Using repeated measure ANOVA, a statistically significant difference at the .05 level was obtained with $F(1, 58) = 6.499$, $p = .013$.

Generalization Group

The Generalization Group also made some considerable improvement in their awareness of the part-part relations. There were progresses in the scores for the C, D, and E items (i.e., are 涉, 溫, and 徜 related to 氵 'water?'), which increased from 58.0%, 58.6%, and 46.8% in the pre-test respectively to 68.0%, 70.2%, and 76.3% in the post-test. See Table 6. No statistically significant difference was detected on the C item. On the D and E items, using repeated measure ANOVA, significant differences between scores in the pre- and post-tests were found at the .05 and .01 levels with $F(1, 60) = 5.488$ and 37.895, $p = .022$ and $< .001$ respectively.

There were also slight improvements in this group in their awareness of the

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part-whole relations. These were revealed in the A and B items (i.e., are 港 and 淜 related to 氵 'water?'). The score for the A item rose from 59.7% to 67.8%. Statistically, there was no significant difference. The score for the D item increased from 52.0% to 68.0%. A statistically significant main effect at the .01 level was obtained with $F(1, 60) = 12.054$, $p = .001$.

Comparison between Contrast and Generalization Groups

When the Contrast Group was compared to the Generalization Group, the Contrast Group had clearly improved more in their awareness of the part-part relations. The gain scores of the Contrast Group for the C, D, and E items were 27.3%, 27.1%, and 36.8%, while those of the Generalization Group were only 9.9%, 11.6%, and 29.6% respectively. The effect sizes of the Contrast Pair were calculated to be 0.8, 0.7, and 1.1, while those of the Generalization Pair were 0.3, 0.4, and 1.2. Using repeated measure ANOVA, significant main effects at the 0.05 level were found in the interaction between the two groups and the pre- and post-test results on the C and D items with $F(1, 118) = 6.743$ and 5.011, $p = .011$ and .027 respectively. On the E item, no statistically significant main effect was detected.

In terms of progress in the students' awareness of the part-whole relations, the results of the Contrast and Generalization Groups were similar with the improvements of the Generalization Group slightly greater than those of the Contrast Group. The gain scores of the Generalization Group for the A and B items were 8.0% and 16.1%, while those of the Contrast Group were only 5.5% and 11.2%. The effect sizes of the Generalization Pair were calculated to be 0.3 and 0.5, while those of the Contrast Pair were 0.2 and 0.4. This means there was no statistically significant difference in the two items between the two groups.

Discussion

Superior Effectiveness of Contrast Pair

In short, the Contrast Group outperformed the Generalization Group in their improvements in the awareness of the part-part relations, which is what the lessons were designed to help the students to learn. Thus the use of the Contrast Pair was the most effective in helping the students to recognize the relations between the locations of components in the orthographic structures of characters and whether these components served as semantic radicals in the characters, that is, the awareness of the part-part relations.

This lends support to the prediction of the variation theory and shows the power of the theory in guiding the design of teaching by way of identifying variation in the object of learning and opening up the variation to students in lessons. Let us use the theory again to more fully explain what happened when the students in the lesson

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were shown a contrast pair such as 溶 and 裘 and asked whether these were related to 'water.' Being aware of the part-whole relation, the students realized that the question here was related to the component 氵. They as such focused their attention on the component 氵, which varied in its location in the orthographic structures of the two characters. It thus became possible for them to simultaneously experience the component 氵 as located on the left of 溶 (as a constituent component) and at the top-left of 裘 (as a sub-component), which was essential to understanding why the character 溶 was related to 'water,' while 裘 was not. In other words, the students could contrast the difference in the locations of the component 氵 in the orthographic structures of the two characters and relate this to whether or not the meanings of the characters were related to 'water.' This explains how the students experienced one contrast pair.

Then, across the different contrast pairs, the students could also experience simultaneous variation in both of the part-whole and part-part relations. For example, instead of having the target component 氵, another contrast pair such as 梅 and 絮 has the component 木 as the target component. Again, in the two characters, the students could contrast the difference in the locations of the component 木 in the orthographic structures, serving as a constituent component in 梅 and as a sub-component in 絮. In other words, within a particular contrast pair, there was variation in the locations of the target component in the orthographic structures of the two characters (e.g., left or top-left), while across the contrast pairs, there was variation in the use of the different target components (e.g., 氵 or 木). In a sense, the pairing provided the students with the experience of synchronic simultaneous variation whereas the entire list provided the experience of diachronic simultaneous variation. In this way, in the lesson the students could experience how both of the critical aspects of the part-part and part-whole relations varied. This gives a possible explanation for the superior performance of the Contrast Group over the Generalization Group.

Some Effectiveness of Generalization Pair

What we did not expect from the experiment is that the Generalization Group would also make considerable improvement during the lesson. Consider the encounter of a generalization pair such as 溶 and 梅 with the question of whether they were related to 'water' and 'tree' respectively. In the two characters, both of the target components 氵 and 木 were located on the left of the characters and served as constituent components. If we use the variation theory to analyze this, there was no variation in the location of the target components in the orthographic structures of the characters. Thus the necessary condition for the students to discern the significance of the location of the target components was not available. But then how can we explain

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the considerable improvement of the Generation Group, which we found empirically from the experiment? Is this evidence against the epistemological assumption of the variation theory, that the experience of variation is a necessary condition for learning to happen?

We have theoretically discussed this in depth in Lam (2012), which "poses an apparent problem of the possible occurrence of learning in the situation of generalization, where one aspect is kept invariant, while other aspects vary. Eventually some of the learners can learn the invariant aspect" (p. 1). In connection with this, the results of this study can be regarded as empirical evidence to support that it is indeed possible for learning to occur when generalization is used. Actually this is in line with the intuitive practice of teachers that students learn by making analogies (Gick & Holyoak, 1980; Holyak, 2005). Thus learning could occur with the use of generalization. What this study has added further to this is that contrast, as compared to generalization, is even more effective in affording learning to happen, which was revealed in the greater improvement of the Contrast Group over the Generalization Group in this study. This result may shed light on further development of the variation theory.

Unplanned Improvement during the Lessons

The lessons in the experiment were designed to help the students to understand the part-part relations but interestingly a slight improvement in the students' awareness of the part-whole relations, were also obtained, which was unplanned during the design of the lessons. As discussed earlier, our previous developmental study has shown that students in Primary 1 were already quite aware of the part-whole relations, and thus little room had actually been left for further improvement of the Primary 2 students in this experiment in their awareness of the part-whole relations. Then how can we account for the slight improvement observed empirically from this study? Clues may perhaps be found from the result of this study that the improvements in the students' awareness of the part-whole relations in the Generalization Group were actually greater than those of the Contrast Group. In our earlier discussion, we used the variation theory to analyze a generalization pair such as 溶 and 梅 and whether these were related to 'water' and 'tree' respectively. We came to the point that the attention of the students was drawn to what varied in the two characters, which was the difference in the target components, namely, 氵 and 木. Although this was not helpful to understanding the part-part relations, the students could experience in it the variation in the target components, which was essential to the students' understanding of the part-whole relations, namely that the 氵 signified 'water,' while the 木 signified 'tree.' Thus here again the variation theory provides us with a reasonable explanation for the possible occurrence of the unplanned improvement in the students'

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awareness of the part-whole relations during the lessons.

An Object of Learning about Seeing the Difference

A caveat about the superior effectiveness of the Contrast Pair to the Generalization Pair is that this result may only have to do specifically with the nature of the particular object of learning that we have chosen for this experiment, that is, the capability of seeing the difference rather than seeing the sameness. This means that what we aimed to achieve in the lessons depended mainly on whether the students could develop a differentiated understanding of the location of a target component in the orthographic structure of a character (i.e. being a constituent component or being a sub-component). This specific nature of the object of learning matches with the kind of learning that the Contrast Pair is more likely to bring about than the Generalization Pair. However, if the object of learning was different and instead involved the kind of situation where the students already knew something about the characters but they just had not yet realized that the same thing could be applied elsewhere in other characters, that is, the capability of seeing the sameness across situations, the Generalization Pair might in this case be more effective.

In addition, the special nature of the object of learning here, that is, with an emphasis on seeing the difference, also sheds light on the students' development of the concepts of a constituent component and a sub-component. The two concepts cannot actually be developed in the students' mind as two separate things. Rather, the students must realize the concept of a constituent component together with that of a sub-component at the same time. In other words, it is impossible to know what a constituent component is, without knowing what a constituent component is not (e.g. a sub-component). Learning the two concepts thus involves a renewal of the existing students' understanding of the significance of the location of a component in the orthographic structure of a character, which proceeds from a more primitive understanding (i.e., is a component on the left or at the top-left of a character?) to a more sophisticated one (i.e., does a component serves as a constituent component or a sub-component in the character?). To quote Marton & Booth (1997),

> You can only learn something new about *something*, and by learning *something new* about something, that *something* will change…Learning is mostly a matter of reconstituting the already constituted world. (p. 139, original emphasis)

Conclusion

In summary, this paper is an attempt to put the variation theory to test in the context of students' learning of the orthographic structures of Chinese characters. A linguistic distinction is made between constituent components (e.g., the 衣 and 沙 in the character 裟) and sub-components (e.g., the 氵 and 少 in 裟). We then argue that in

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order to see or experience a character in a powerful way, students must be aware of the part-whole relations between the constituent components and the character (i.e., what constituent components signify in the character) and the part-part relations of the components (i.e., which of the components are parts of the same constituent component in the character). An experiment was then set up to investigate how we can effectively bring about students' understanding of the part-part relations. In the experiment, two different ways of teaching were designed, as informed by the variation theory, and were used to teach 132 Primary 2 students in the classrooms of two primary schools in Hong Kong. The results are: the Contrast Pair (e.g., are 溶 and 裟 related to 'water?') was found to be far more effective than the Generalization Pair (e.g., are 溶 and 梅 related to 'water' and 'tree' respectively?) in helping the students' to recognize the significance of the locations of components in the orthographic structures of characters, in determining whether or not the components serve as semantic radicals in the characters (i.e. gaining a better understanding of the part-part relations that the sub-components 氵 and 少 in the character 裟 are parts of the constituent component 沙 in the character). Thus the theory was found to be powerful in guiding the design of effective teaching of the orthographic structures of characters and more generally in explaining what makes it possible for students to learn in classroom teaching.

Notes

[1] Other studies have proposed a notion of character structure, which is however different from our notion of the orthographic structure of a character. For example, Ho, Yau, & Au (2003) and Ho, Ng, & Ng (2003) refer to students' knowledge of character structure simply as to whether the students realize that some components appear only at a certain position in characters (e.g. 亻 'man' on the left). Besides this, there is also a body of research on skilled adult readers' cognitive processing of the character structure or configuration of characters (e.g. Feldman & Siok, 1997, 1999a, 1999b). But it does not necessarily follow that children must learn characters in the same way as how adults process the characters.

[2] All of the sounds of the characters throughout this paper are written in Cantonese, which is a dialect of Chinese used by the vast majority of people in Hong Kong. The sounds of the characters are transcribed using the Romanization developed by the Linguistic Society of Hong Kong (2002).

[3] In this paper, we refer to the meaning of character when it was created, that is, 造意 (Wang, 2002; Wang & Zou, 1999). The historical meanings of the characters are based on the dictionaries of Gu (2003) and Gao (2004).

[4] The sound here was originally transcribed using Hanyu Pinyin, that is, *tong2*, as the study was conducted in Putonghua.

[5] Although the character 法 is now commonly used to mean 'method,' it has the component 氵 as the

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semantic radical because the character originally meant 'nomads, who move from a water source to another water source.'

[6] We use the term "Contrast Pair" (with the first letters in upper case) as the general name of this method while "a contrast pair" (in lower case) refers to a particular pair of characters using in this method. The same applies to "Generalization Pair."

[7] Strictly speaking, according to the variation theory, the components other than the 氵 in the two characters (i.e. the 宀 'hut' and 谷 *guk1* 'valley' in 溶, and the 少 and 衣 in 裟) should be held constant. But in practice there is no such real character, which can be used to illustrate the variation in the locations of the components in the orthographic structures, while at the same time having all the other components the same.

[8] Actually there were minor differences in the ways that we implemented the experiment in the two schools. However, the differences were so slight that they should make no difference to the results reported here. For separate and detailed analysis of the results from the two schools, see Lam (2006).

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Appendix I

The Sounds and Meanings of Characters or Components Used in the Main Text

氵 or 水 *seoi2* 'water'	菠 *bo1* 'pineapple'	湖 *wu4* 'lake'
木 *muk6* 'tree'	波 *bo1* 'wave'	胡 *wu4* 'northern tribes'
扌 or 手 *sau2* 'hand'	皮 *pei4* 'skin'	古 *gu2* 'old'
女 *neoi5* 'female'	裟 *saa1* 'cassock'	月 *jyut6* 'moon'
溶 *jung4* 'to dissolve'	沙 *saa1* 'sand'	梅 *mui4* 'peach'
容 *jung4* 'appearance'	少 *siu2* 'few'	紮 *zaat3* 'to tie'
榕 *jung4* 'banyan'	衣 *ji1* 'dress'	札 *zaat3* 'note'
海 *hoi2* 'sea'		

Appendix II

Pseudo-character Items Used in the Tests

Item	Pseudo-character
A	
B	
C	
D	
E