

Designing learning objects that afford learners the experience of important variations in Chinese characters

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Abstract

Effective teaching should focus the attention of learners to its essential aspects. It follows that instructional software can be designed in such a way that allows learners to experience the important variations in the critical aspects of the content to be learned. This paper reports on the experience of designing such special kinds of instructional learning objects for the learning of Chinese characters. The design of these learning objects takes into consideration not only what Chinese characters are all about but also how learners commonly make errors while they learn to write the characters. Out of the analysis of these learners' errors, variations in the structural features of Chinese characters were pulled out and embodied in the design of the learning objects. Learners tinkering with the learning objects can thus implicitly develop a sense of the structural features or regularity of Chinese characters, which most importantly should prepare the learners to learn more new characters in the future. The main proposal of this paper is the notion of this variation-affording instructional software that allows learners to attend to the essential aspects of what is to be learned. Furthermore, the idea of the learning object also differs from other instructional software in its small, self-contained and reusable nature, such that teachers can flexibly embed the learning objects into their own teaching materials.

Keywords

instructional software design, learning Chinese characters, writing errors and theory of variation

Introduction

The human mind cannot attend to everything at the same time with the same degree of prominence (Gurtwitsch 1964). At any particular instant, only certain things come to the fore as the focus of attention, while others will recede to the background. Effective handling of the world depends on the effective structuring of the field of perception. By way of this, a

person can attend to any parts of the things without losing the whole and can effectively switch attention so as to attend to the right thing at the right time.

Put this into the context of language learning. Let us consider the experience of learning a foreign language. The perception of the language will go from chaotic to organized. The person begins with hearing a lot of sounds that do not make any sense to him. As he gradually picks up the language, he becomes able to discern some regular patterns out of the language. The processing of the language structures can be implicit so that it does not necessarily mean that the person has to learn a meta-vocabulary to talk about the structures of the language. In fact, supporting this, cognitive

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research has well established that phonological and morphological processing involves segmentation and manipulation of the sub-lexical units of the language.

Similar meta-linguistic processing on the structures of the Chinese language has also been found. Early in the 1960s, Tsao and Shen (1965a, b) observed that the learning of unfamiliar characters by children grows rapidly between the first and second grades during the period that the children have picked out the similarities among the characters. In line with this, the studies of Tzeng *et al.* (1986) on brain-damaged patients have also shown that Chinese characters are not processed simply as whole pictures. The speed of recognizing the characters is indeed affected by the number of well-defined units of stroke patterns¹ rather than that of the individual strokes (Chen *et al.* 1996). More recently, Chan and Nunes (2001) have further confirmed that young children, from the age of three to nine, gradually develop some implicit knowledge of the orthographic properties of the characters from their experience of the language. In short, this paucity of research comes to the point that the discernment of the language structures with reference to their meanings is of vital importance to the learning of Chinese characters.

This paper is organized as follows: the next two sections will describe the learning of two key aspects, orthographic and functional aspects respectively, of the constituents of Chinese characters. Each of the sections will begin with the description of relevant structure features of the characters. After that, writing errors that students made in learning these features will be mentioned followed by a discussion on designing specific learning objects to cope with such learning difficulties. Subsequent to the mention of a whole range of various learning objects, the different ways that teachers of our partnership schools put these learning objects into practice in classrooms will be reported. Finally, we will conclude the paper by summarizing the main proposal on the notion of variation-affording learning objects.

Learning the orthographic aspects of the forms of the Chinese characters

What precisely are the structural features of Chinese characters? The ancient Chinese writings derive from

¹A stroke-pattern is a group of strokes organized in the same configuration that appears repeatedly in different characters.

a pictographic script. For example, Fig. 1(a) is the drawing of a tree, which has evolved into the present form of the character 木 ('tree' or 'wood'). Besides this, some other characters are indicative symbols, which highlight a certain part of a thing. For example, in Fig. 1(b), a mark is added to the base of the tree and thus the form 本 is the character for 'base'.

The more complex Chinese characters are mostly made up of more than one component or radical. As shown in Fig. 2, the radicals are put together to form characters according to common configurations.

In the conventional curriculum, these structural properties of Chinese characters are not explicitly taught. However, the teachers may mention this when they come across characters in the standard texts that share the same pattern of composition. In that case, how well have the students mastered these structural patterns in their writings? The answer to this question can probably be found in the writing errors of the students that were collected by the teachers of our partnership schools.

Figure 3(a)–(c) shows what the students actually wrote. The characters on the side in the bracket indicate the correct forms of the characters that the students intended to write. The nature of errors that the students made were: in Fig. 3(a), the stroke at the right bottom was mistakenly written as a straight slanted

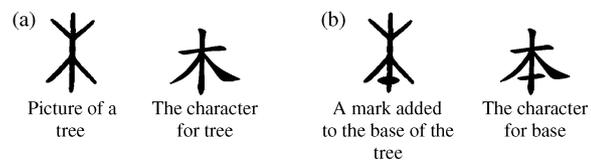


Fig. 1 Chinese characters as pictorial and indicative symbols.



Fig. 2 Chinese characters as structured composition (from Ki *et al.* 1994).



Fig. 3 Students' writing errors collected from teachers.

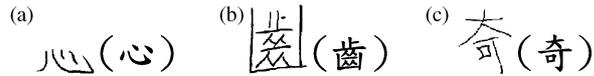


Fig. 4 More Students' writing errors.

stroke \searrow instead of an \cup -shaped stroke; in Fig. 3(b), the stroke at the bottom of the character 士 was made too long in both ends and in Fig. 3(c), the bottom stroke went too far to the right.

You may say that these little mistakes should not matter much because the students have already vaguely written out the characters as a whole. However, the problem is that these slight deviations of the characters often suffice for changing them into other characters. Both Fig. 3(a) and (b), in fact, look more adjacent to two other valid Chinese characters, 失 (lose) and 士 (earth or soil), as compared with the intended ones – 先 (first) and 士 (person), while Fig. 3(c) lies in the midst of the two characters 目 (eye) and 且 (further).

The errors in Fig. 3 are mainly at the stroke level, while those in Fig. 4 concern the spatial configurations of the characters. In Fig. 4(a), the rightmost dot was misplaced inside the \cup -shaped stroke at the bottom; in Fig. 4(b), the radical 止 fell inside the lower part 齒 of the character and in Fig. 4(c), the radical 大 (which means 'big') was made too large.

Interestingly, think about the above errors, especially the one in Fig. 4(b). If the student really recognized the character 齒 as a top-bottom composition of two distinctly separated parts – 止 and 齒, the student should never have written the characters in that way. This further confirms to us the importance of recognizing the structural patterns in the learning of the characters.

Then, what happens if teachers find students making errors of this sort? The likelihood is that the teachers will circle the incorrect part and, maybe using a ball pen in a different colour, write beside the characters the correct forms of the characters, as shown below.

What the teachers believe is that the students can follow the writing of the correct forms given as a

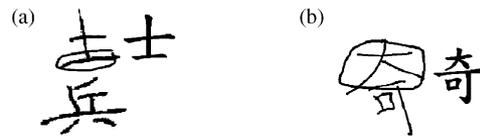


Fig. 5 How teachers usually correct students' writing errors.

standard model. However, would it simply happen in this way? Would the students interpret the correct forms in the same way as the teachers? Another alternative interpretation of Fig 5(a) is that the form 士 is entirely wrong and it must be written like 士. It follows that the next time when the students really want to write the character 士 as in 泥土 (soil), would they make an error like 泥土?

Let us leave this for a moment to mention briefly our own background. The Dragonwise Team at the University of Hong Kong began to work on how to design instructional software for children to learn Chinese characters in the late 1980s. Since then, several generations of software have been developed and revamped, which have been reported previously in Ki *et al.* (1994) and Lam *et al.* (1993, 2000, 2001). Our previous work focused on the linguistic specialty of Chinese characters and made use of general activities such as the categorization task to help students to develop awareness on the regularity among the characters. Moving beyond this, the work reported in the present paper moves to take into consideration the learning experience of the students (see also Ki *et al.* 2003; Chung *et al.* 2003). In other words, we not only pay attention to what content to be taught but also, more importantly, what actually happens when students go about learning the content (Lam & Ki, 2003). This forms the basis of the design rationale of the learning objects to be described in due course.

Referring back to the previous writing error, we believe that simply showing the students the standard models of writing is not enough. In addition to this, we subscribe to the instructional belief guided by the theory of variation (Marton *et al.* 1997, 2003), which in essence suggests that if there is no variation, and there cannot be discernment of the critical aspects in what is to be learned. By this means, the use of contrastive examples is necessary and indispensable. In view of this, we have designed and developed a variety of ICT learning objects² to provide students the necessary variations, which makes it possible for

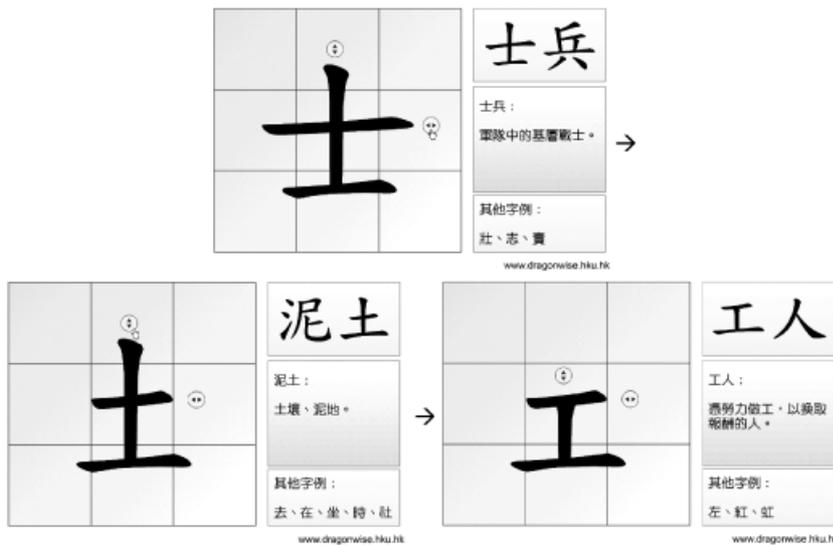


Fig. 6 Stroke-varying game – 士, 土 and 工.

the students to discern the essential features of the structures of Chinese characters.

Stroke variation game

Figure 6 shows the learning object called the Stroke Variation Game. The character 士 is shown in focus alongside with the word 士兵 (soldier) as an example using the character. As the learners move the pointer around over some of the strokes of the character 士, the pointer changes its shape, which indicates a point of interest. By dragging the little handler near the end of a stroke, the learners can lengthen or shorten the stroke. By doing so, the character 士 can be made to become a different character, for example, 土, in which case, the word will change to 泥土 (soil) accordingly with the sound produced – 泥土 (nai4 tou2). In this way, the learners can vary the lengths of the different strokes and more importantly thoroughly examine the difference among the three characters 士, 土 and 工 in relation to their meanings as in 士兵 (soldier), 泥土 (soil) and 工人 (worker).

It is in this way that we believe learners can discern for themselves the critical feature that distinguishes the three different characters. Perhaps, prior to this experience, the learners may regard that the length of a stroke does not matter. After playing with the learning object, the learners can realize that the lengths of the

strokes do make a difference. 士, 土 and 工 are indeed three distinct characters with completely different meanings. Put more generally, the learning objects designed in this way have embodied the pedagogical principles of the theory of variation, which provides the learners an experience to go through the variations in some specific critical aspects in the orthographic forms, in this case, the different lengths of the strokes. In this manner, the learners can open up a new way of seeing the three characters in light of the length of the strokes.

Component positioning game

Figure 7 shows another learning object that deals with a different critical feature of the Chinese characters: the spatial configurations of the different components of a character. In this learning object, the learners can move around the relative positions of the components. The task is to move the three separate components 口, 此 and 角 together so as to compose the character 嘴. As the components are moved closer to the correct configuration, the character flashes quicker as a positive feedback to the learners. Conversely, if the learners move the components away from the correct form, the flashing of the character will slow down. In this way, the learners can try out different configurations that they first think possible for arranging the components, and eventually build up a sense of how to configure correctly the components of a character in recovery from other incorrect configurations.

²All learning objects described in this paper are downloadable from www.dragonwise.hku.hk/dragon2/.



Fig. 7 Component positioning game – 嘴

The design of this learning object shares a similar rationale with that of the previous one. It gives the learners an experience to experiment with the variations in certain critical features, in this case, the spatial relation among the components of a character. To further elucidate the specialty of this kind of learning object, we can take on the perspective given by the theory of affordances (Gibson 1977; Norman 1988) to look at how teachers go about learning to use these learning objects. Studies of affordances investigate how the appearance of a physical object signals to the people in what way the object can possibly be used. In view of this, the design of the learning objects here can be described as affording the teachers to deliver their teaching in a way that makes explicit the variations along the dimension of a particular critical aspect. In other words, through forcing the teachers to manipulate only in one specific aspect, the learning objects focus the attention of the teachers on that aspect. Instead of requiring the teachers to understand the intricacy of some pedagogical principles in advance, *the learning objects afford teachers the chance to realize inductively the importance of using variations in instruction as the teachers go along using the learning objects*. To a certain extent, we can expect that no teacher can teach without these variations with the use of these learning objects. This kind of variation affordance is what makes the learning objects described here uniquely different from other instructional soft-

ware. We will continue to elaborate on this with more examples of learning objects in due course.

Learning the functional aspects of the radicals of Chinese characters

The learning objects mentioned above are specifically designed for the learning of the orthographic aspects of the forms of Chinese characters. In what follows, we will turn to another set of learning objects that are specialized in the learning of the functional aspects of the radicals in Chinese characters.

Over 85% of, or in other words, the majority of modern Chinese characters fall into the category of *semantic phonetic compound* 形聲字, which means that the characters are a combination of exactly two parts – one semantic and the other phonetic radicals. As shown in Fig. 8, the *semantic radical* 扌 (which is related to ‘action by hand’) contributes meaning to the characters 推 (push), 拉 (pull), 抄 (copy), 指 (point) and 抓 (grab). Similar to this, the *phonetic radical* 白 (baak6) hints on the sound of the characters 伯 (baak3), 怕 (paa3), 拍 (paak3) and 帕 (paak3).³ The above linguistic terms to talk about the functional aspects of Chinese characters are traditionally regarded as an advanced topic, which is not explicitly taught in the formal curriculum of primary schools. However, the teaching of the characters themselves can actually be carried out in an implicit way by inviting the students to find out on their own the similarity and difference among the characters. In this fashion, the students no longer need to rote memorize the characters one by one in isolation. Rather, the characters can be learned in a way that the students can relate the new characters to what are already known to them. With regard to how well the students have understood these functional aspects, let us see what happens to the writings of the students in the collected samples.

Apparently the nature of the errors is simply a mix-up of similar-looking radicals: in Fig. 9(a), the radical 目 was mistakenly used, instead of 日, for the character 暖; similar to this, in Fig. 9(b), the character 籃 was wrongly written with the radical 艹 on top in place of

³Fuller description of the features of Chinese characters can be found in Lam et al. (2001).

Semantic Phonetic Compounds 形聲字



Fig. 8 Semantic and phonetic radicals of Chinese characters.

and in Fig. 9(c), the radical 今 at the bottom was confused with 令 in the character 琴.

Looking deeper into these errors reveals a lack of awareness on the functional aspects of the radicals. In Fig. 9(a), the character 暖, which means ‘warmth’, is actually more closely related to the radical 日 (sun) in comparison with 目 (eye). Likewise, 籃 (basket) is made of 艹 (bamboo or rattan) rather than 艹 (plant). In like manner, the problem of Fig. 9(c) is in the phonetic radical. The character 琴 (kam4) sounds more adjacent to the radical 今 (gam1), when used as a character on its own, than to 令 (ling6). Putting these together, if the student realized the functions of the radicals, it would be unlikely for them to make the errors as described above. To forefront these functional aspects to the learners, we have designed and developed the following set of learning objects.

Semantic phonetic compound exercise

Figure 10 shows the learning object called the Semantic Phonetic Compound Exercise. Put simply, the task of the learners is to complete a fill-in-the-blank question by substituting characters for the pictures in the given sentence. To choose a character, the learners can explore the options of characters hidden in the squares within the grid of the radar panel. As shown in Fig. 10(a), moving the pointer from top to bottom uncovers a list of semantic radicals: 虫 (bug), 鳥 (bird), 魚 (fish) and 豸 (animal). After having decided on the one best fit for the situation, for example 鳥 (bird) in this example, the learners can check up the characters in the corresponding row as shown in Fig. 10(b). A list of different kinds of birds, namely, 鴉



Fig. 9 Some Students’ writing errors.

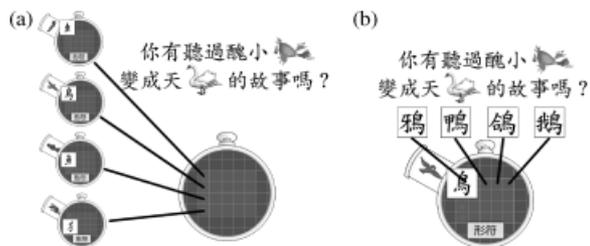


Fig. 10 Semantic phonetic compound exercise – 鴉, 鴨, 鴿 and 鵝.

(crow), 鴨 (duck), 鴿 (pigeon) and 鵝 (goose) is revealed. The learners can freely move around the pointer over each of the squares one by one to hear the sound of each unhidden character. By way of this, the learners can discover the interconnected relations among all of the characters in the panel such as the fact that all characters in a row share similarity in meaning.

Animated semantic phonetic compound

The learning objects are not only explorable by the students as illustrated previously but teachers can also use the learning objects for presentation and exposition purpose in the classrooms. Figure 11(a) shows the use of the learning object Animated Semantic Phonetic Compound in conjunction with a standard text. The text,⁴ provided by a partnership school, is purposely set up to include together several key characters that contain the same phonetic radicals, namely, 白 (baak6), 伯 (baak3), 怕 (paa3), 拍 (paak3) and 帕 (paak3). Using a framed Web page, teachers can link up the key characters in the text to their corresponding Animated Characters. As the teachers go along teaching the whole text, the teachers can explain the key characters with the use of these learning objects. In Fig 11(b), a click on the semantic radical transforms the radical into a picture of the thing that it represents. The purpose of this is to help the learners to relate the

⁴Adapted from the Chapter 9 of 謝錫金編著(2000). 《綜合高效識字(1)》。香港：青田教育基金會。

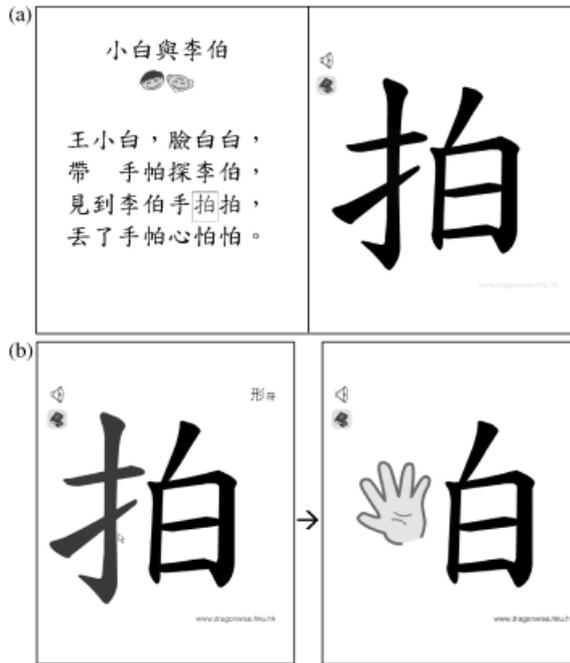


Fig. 11 Animated semantic phonetic compounds – 白 伯 怕 拍 和 帕.

modern script to its pictographic origin. In a similar way, clicking the phonetic radical 白 produces the sound of the radical (baak6), which can be made to compare with the pronunciation of the character 拍 as a whole (paak3).

The design of the Animated Characters is not tied to any specific piece of texts, which makes them easily adaptable to different texts used in the curricula of different schools. In a broader context, *the learning objects should be designed to be simple, re-usable and more generally independent of any pre-determined ways of delivering the instruction.* There should be no presumption about whether the user is a teacher or student, or whether the learning objects are used for exposition, consolidation or exploration. It is similar to the case of using a piece of rock in a Geography lesson. The rock carries with it its various properties that can be subjected to experimentation but does not make any assumption about how it is going to be used by whom in the classrooms. By doing so, the teachers can flexibly select the desirable learning objects necessary to them and use the learning objects jointly together with other existing teaching materials that the teachers are using everyday in their regular teaching.

As such, the cost of the teachers for trying to embrace the use of the learning objects as an innovation in the classroom is reduced to a minimal; thereby more teachers will be willing to try out the learning objects in their classes (Rogers 1962; Carroll 1990).

With the use of the learning objects, the teachers are encouraged to develop new instructional materials adopting the same pedagogical idea of bringing the relations of the characters to the fore, but specific to their own school-based curriculum. Put more generally, the design of the learning objects affords multiple possibilities of usage, such that the teachers can explore how teaching can be carried out differently in different classrooms. In fact, rather than regarding the teachers as merely the ‘operators’ of the learning objects, we truly respect the expertise and the frontline experience of the teachers, especially in handling the unique problems of their schools (Chung et al. 2003). As such, rather than imposing the ‘best’ procedure of teaching to the teachers, we work closely with them, upholding the idea that *the teachers should be empowered with the use of the learning objects to synthesize innovative and realistic ways of carrying out their teachings for their particular classes of students.* By way of this, eventually a variety of different praxes of using the learning objects in the classrooms can be developed alongside with the software.

Putting the learning objects into practice in classrooms

To find out the various possible ways of using the learning objects in classrooms, we have observed a total of 12 lessons given by the teachers of our partnership schools. All the lessons were at grade one to three levels at 12 primary schools in Hong Kong. We found that designing learning objects in this way can indeed provide flexibility to teachers to deliver the lessons in their individual ways. Prior to their use, we had no intention of imposing onto them any conclusive instructional approach with the use of the learning objects. By doing so, we hoped to observe what actually happens in the classrooms when the teachers used the learning objects. The lessons were taped on video and subsequently analysed carefully. In what follows, we will briefly describe four typical types of lessons that came out of the analysis.

獨在異鄉為異客, (Alone in a place away from home)
 每逢佳節倍思親, (Miss my family much on this festival)
 遙知兄弟登高處, (Know my brothers are heading to the hills)
 遍插茱萸少一人。 (Without me with the Cornus leaf pinned on the clothes)

Fig. 12 九月九日憶山東兄弟 (Remembering the brothers at ShanDong on the ninth moon, day 9).

Text-centred lesson

The most common way of using the learning objects is to arrange the lesson to centre on teaching a piece of text. The teachers often use a PowerPoint or an ordinary Web page that shows the content of the entire text and, from time to time, refer to the learning objects to explain the unfamiliar characters in the text. The lesson is often conducted in a conventional classroom setting in which the teachers use the computer in front of the class. For example, a teacher gave such a lesson on the poem 九月九日憶山東兄弟 by 王維 (Wang, Wei) (Fig. 12).

The teacher began the lesson with recalling the memory of the students on the Chung Yeung Festival that had just happened a few days ago. He then asked the students to listen to the reciting of the poem by the computer and then to read aloud the whole poem together. Following this, the teacher led the students to listen carefully and read out each line of the poem one after another. After the students had had a brief idea of the meaning of the poem holistically, the teacher went on to explain in detail some of the characters that the students might find difficult.

For instance, since it may be difficult for the students to write the character 獨 that appeared in the first line of the poem due to its complexity, the teacher demonstrated the correct writing with the Stroke Sequence learning object of the character 獨. Then, to explain the characters 異 and 鄉, the teacher used the Animated Characters to illustrate where the present form of the characters came from and how the meaning of the character 異 had been extended to mean 'away from'. To give an explanation on the second line, the teachers used the Semantic Phonetic Character exercise to draw the attention of the students to the phonetic of the character 倍. In this exercise, the students had to complete the word 數? (several times) in a sentence by selecting a character from 倍, 培 and 陪, all of which share the same phonetic radical 音 and sound similarly. To make clear the distinction between the easily confused characters 思 and 恩, the teacher

used the Characters Identifying Exercise, in which the students had to distinguish between the two characters in an instant manner. Other than using the computer, the teacher had also used real objects such as a picture of Cornus, mentioned in the last line of the poem, to show the students what a Cornus leaf is.

Character-centred lesson

Instead of focusing on a text, another way of using the learning objects is to centre on a few learning object characters. In this case, the teachers usually use a computer lab, in which each student can spend more time directly with the computer for practice. As an example, a teacher gave one such lesson as a revision exercise on the characters that the students had just learned in the previous lesson. To practise the character 落 (down), the teacher first invited the students to make up words orally with the character 落 such as 落下 (get down), 落葉 (falling leaves) and 落雪 (snowing). The teacher also reminded the students that the character 落 could also occur at the second position in a word such as 日落 (sunset).

After finishing this, the teacher and the students began to work on the computer. The teacher first gave a demonstration on the use of the Stroke Sequence learning object⁵ of the character 落. The students then practised on their own computers and were asked to raise their hands after completion.

Towards the end, the teacher asked the students to speak out aloud each stroke of the character in sequence one by one and use their fingers to pretend writing in the air, namely, 豎 (vertical stroke), 橫 (horizontal stroke) and so on and so forth. In the meantime, following the sequence, the teacher wrote the stroke accordingly on the teacher computer. The lesson ended with a big applause to each other for successfully completed the practice.

⁵Refer to Lam *et al.* (2001) for detailed description on the interface of the Stroke Sequence learning object.

Common feature-centred lesson

Instead of a revision of the characters, the learning objects can be used for teaching certain common features of Chinese characters. For example, one of the lessons was set out to focus on the various configurations of the characters. The teacher started the lesson by questioning the students what configuration was common to the characters 四, 同, 疼 and 痛 – enclosed configuration. He followed by asking the sequence for writing characters with such a configuration, namely, from outside to inside. He then repeated with similar questions about other configurations such as the left right and top bottom.

After warming up, the teacher began to demonstrate how to use the Stroke Sequence learning object on the computer. He then asked the students to write a set of characters with the same configuration, three times for each character. Upon completion, the teacher invited some of the students to come to the front of the computer lab to use the teacher's machine to write. Each student wrote a few strokes of the characters and finished the writing of all the characters in a collaborative effort.

Motivation-centred lesson

The final way of using the learning objects reported here is rather unstructured, and the purpose of the lessons is only to motivate the students to learn Chinese characters. For example, in a remedial class, a teacher tried to build up a non-threatening atmosphere in a computer lab, in which the students with reading problems could freely choose to play with any one of the learning objects.

Some students played with the characters 士, 土 and 工 of the Stroke Variation Game, while others moved around the components to form the character 嘴 with the Component Positioning Game, and so on. The teacher came to help each student with care one by one for any problem they had in operating the computer. She also praised them with encouraging comments for any accomplishment they had made.

Taken all together, a diverse variety of different ways of organizing a lesson with the use of the learning objects have been observed. This provides concrete evidence as to the flexibility in the design of this kind of learning objects, as independent of instructional styles, student levels, teaching content and school curriculum. More examples of lesson designs

of our partnership teachers can be found in Dragon-wise (2003).

Conclusion

To sum, there are infinitely many possible ways of seeing something in isolation. Only through systematic variations, the learners can discern the important features of what are to be learned. This paper reports on the design of a remarkable kind of variation-affording learning object that enables the learners to experience the variations in some specific critical features of Chinese characters. Rather than explicitly lecturing about these important features, the learning objects afford the learners to develop awareness on the structures of the language implicitly through exploring and contrasting many different related characters. The learning objects themselves are also designed to be small, self-sufficient and free from any constrained ways of how teaching should be carried out. More importantly, the teachers are thus empowered to invent creative ways of using the learning objects to meet the specific needs of their own classrooms. It is hoped that by means of this, the learners can learn to see not only the characters themselves but also beyond this, the underlying structural regularities that organize the writing of different Chinese characters as a whole. This capability should prepare the learners for the learning of other new characters in the future.

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References

- Carroll J.M. (1990) *The Nurnberg Funnel: Designing Minimalist Instruction for Practical Computer Skill*. The MIT Press, Cambridge, MA.
- Chan L. & Nunes T. (2001) Explicit teaching and implicit learning of Chinese characters. In *Developmental Aspects in Learning to Write* (ed. L. Tolchinsky), pp. 33–53. Kluwer Academic Publishers, Dordrecht, Netherlands.
- Chen Y.P., Allport D.A. & Marshall J.C. (1996) What are the functional orthographic units in Chinese word recognition: the stroke or the stroke pattern? *The Quarterly Journal of Experimental Psychology* **49A**, 1024–1043.

- Chung A.L.S., Ki W.W., Lam H.C., Ko P.Y., Chou P.W.Y., Lau E.C.C., Lai A.C.Y. & Lai S.M.S. (2003) Teacher participation and empowerment: a critical process in developing ICT curriculum materials and classroom practice. *Information Technology, Education and Society* 4(1), 39–54.
- Dragonwise (2003) *Computer-assisted Learning of Chinese Characters – Classroom Examples (in Chinese)*. Dragonwise Team, Faculty of Education, The University of Hong Kong, Hong Kong, 現龍 (2003) 電腦輔助中文識字：課堂實例，香港：香港大學教育學院現龍小組。
- Gibson J.J. (1977) The theory of affordances. In *Perceiving, Acting, and Knowing: Toward an Ecological Psychology* (eds R.E. Shaw & J. Bransford), pp. 67–82. Hillsdale, NJ, Lawrence Erlbaum Associates.
- Gurtwitsch A. (1964) *The Field of Consciousness*. Piquesne University Press, Pittsburgh.
- Ki W., Tse S.K., Law N., Lau F. & Pun K.H. (1994) A knowledge-based multimedia system to support the teaching and learning of Chinese characters. In *Proceedings of ED-MEDIA 94-World Conference on Educational Multimedia and Hypermedia*, 25–30 June 1994, Vancouver, BC, Canada, pp. 323–328.
- Ki W.W., Lam H.C., Chung A.L.S., Tse S.K., Ko P.Y., Lau C.C., Chou W.Y., Lai C.Y. & Lai M.S. (2003) Structural awareness, variation theory, and ICT support. *L1: Educational Studies in Language and Literature, Special Issue: ICT and the Transformation of the L1 Curriculum: Implications for Teacher Educators* 3, 53–78.
- Lam H.C. & Ki W.W. (2003) An observational study on how learners go about using an online database for improving the writing of Chinese. In *Proceedings of the International Conference on Computers in Education*, 2–5 December 2003, Hong Kong.
- Lam H.C., Ki W.W., Chung A.L.S. & Ko P.Y. (2000) Experience in designing databases for learning Chinese characters. *International Journal of Computer Processing of Oriental Languages* 13, 351–375.
- Lam H.C., Ki W.W., Law N., Chung A.L.S., Ko P.Y., Ho A.H.S. & Pun S.W. (2001) Designing CALL for learning Chinese characters. *Journal of Computer Assisted Learning* 17, 115–128.
- Lam H.C., Pun K.H., Leung S.T., Tse S.K. & Ki W.W. (1993) Computer-assisted-learning for learning Chinese characters. *Communications of COLIPS: An International Journal of Chinese and Oriental Languages Information Processing Society* 3, 31–44.
- Marion F. & Booth S. (1997) *Learning and Awareness*. Lawrence Erlbaum Associates, Mahwah, New Jersey.
- Marion F. & Tsui A.B.M. (2003) *Classroom Discourse and the Space of Learning*. Lawrence Erlbaum Associates, Mahwah, New Jersey.
- Norman D.A. (1988) *Psychology (Design) of Everyday Things*. Basic Books, New York.
- Rogers E.M. (1962) Characteristics of the Innovation. In *Diffusion of Innovations* Chapter V, pp. 121–147. The Free Press, New York.
- Tsao C.Y. & Shen Y. (1965a) Developmental studies on the recognition and generalization of Chinese characters in primary school children: I. development of recognition under tachistoscopic condition (in Chinese). *Acta Psychologica Sinica* 30, 1–9. (曹傳詠、沈曄 (1965a) 小學兒童分析、概括和辨認漢字字形能力的發展研究 I 在速示條件下辨認字形能力的發展。《心理學報》第1期，總第30期，1–9頁。)
- Tsao C.Y. & Shen Y. (1965b) Developmental studies on the recognition and generalization of Chinese characters in primary school children. II. Development of generalization and its relation to recognition (in Chinese). *Acta Psychologica Sinica* 31, 121–134. (曹傳詠、沈曄 (1965b) 小學兒童分析、概括和辨認漢字字形能力的發展研究 II 分析概括字形能力的發展與其辨認發展的關係。《心理學報》第2期，總第31期，121–134頁。)
- Tzeng O.J.L., Hung D.L., Chen S., Wu J. & His M.S. (1986) Processing Chinese logographs by Chinese brain damaged patients. In *Graphonomics: Contemporary Research in Handwriting* (H.S.R. Kao, G.P. Van Galan & R. Hoosain, eds), Elsevier Science, The Netherlands, pp. 357–374.