CONCRETE THINKING ABILITIES AMONG HONG KONG JUNIOR SECONDARY SCHOOL PUPULS

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Introduction

According to Jean Piaget, intellectual development in children proceeds in a number of stages. One of these stages – the 'concrete thinking' stage – begins at about 7 years of age and continues to about age 12. This is the principal mode of thinking used by primary school children and is characterised by thought which is limited to real objects encountered in direct experience. The children also think about the properties of these objects, for example, weight, colour, shape, and the actions that can be done with these objects.

The final stage in intellectual development – the 'abstract or formal thinking' stage develops from about the age of 12 to the age of 15 or 16. Pupils who have fully developed this type of thinking are capable of dealing with the hypothetical, generalizations, theories, and the manipulation of symbols in formulas and equations commonly met with in subjects such as Mathematics and Science.

The change from concrete to abstract thought is not as sudden as Piaget's age classification would indicate. Many pupils, especially those of lower ability, do not appear to reach full development in their concrete thinking abilities until later than the age of 12. This paper reports on research done with Hong Kong Junior Secondary science pupils to determine the extent to which certain concrete thinking tasks are mastered.

Some Characteristics of Concrete Thought

Piaget and other researchers have been able to identity a number of cognitive achievements that a child shows by the end of the concrete thinking stage.[1] Three of these are described below.

1. *Conservation* Concrete thinkers realize that when an object is changed physically, the amount of it present is not changed. Thus the shape or length of a piece of rubber can change without altering the amount of rubber. There are several types of conservation, attainment of which occurs at different ages in the concrete thinking stage. Among these are:
   - Conservation of substance (achieved at age 6–7). The child realizes that the amount of substance does not change. Thus a ball of plasticine still contains the same amount of substance when rolled into a sausage shape.
   - Conservation of volume (age 6–7). Pouring a liquid from one container into a container of differing shape does not change the volume.
   - Conservation of weight (age 9–12). A child understands that the weight of a ball of plasticine does not change even though the shape of the plasticine may change.
   - Conservation of displacement volume (age $11–12^{+}$). The child realizes that a divided object will occupy the same volume as a whole object when immersed in water.
2. *Time, distance, speed relationships* Up to the age of 9, children have difficulty comparing the time taken and the distance covered of two (or more) moving objects/ persons. They think that going further always takes more time, irrespective of speed.

3. *Classification* Being able to classify objects is essential to intellectual development. As with conservation, there are a number of progressive steps in the development of classification, beginning at about age 3 of Piaget's pre-operational stage and continuing through the abstract thinking stage. Among these steps are:

   - Class inclusion (age 5–6). The child forms subclasses and can include these in larger classes, for example, that coins belong to the larger class 'money'.
   - Ascending hierarchies (age 7–8). The child is now able to make ascending hierarchies. He is aware of subgroups and major groups and can group these subgroups into major groups, for example, that coins and paper notes are two subgroups that can be put into one group 'money'.
   - Descending hierarchies (age 9–10). The ability to do this is more difficult than for ascending hierarchies and does not show itself for an additional one or two years. To do this, the child must reverse his thinking, another important characteristic of the concrete thinking stage.
   - Classification using several criteria (age 11–14). This ability completes the classification sequence and occurs during the abstract thinking stage. Classification systems as used in libraries and in Biology can be understood and constructed.

Attainment of Concrete Concepts

There is evidence that many pupils of secondary school age – even senior pupils who are well into the abstract thinking stage – do not achieve success on tasks characteristic of the concrete thinking stage until several years later than those indicated by Piaget. Elkind[2] tested 369 pupils in American junior and senior high schools (ages 12.6 to 17.7) and found that 87 percent achieved conservation of substance while only 47 percent achieved conservation of displacement volume. He also found that boys achieved greater success than girls in the attainment of conservation.

To what extent do Hong Kong pupils attain concrete concepts?

In an attempt to answer this question, an investigation was carried out in 3 areas of concrete thought:

1. Conservation of displacement volume.
2. Time, distance, speed relationships.
3. Classification – ascending and descending hierarchies.

The remainder of this paper describes the research that was undertaken.

The Design of a test of Concrete Thinking

To assess each of these areas, a pencil-and-paper multiple-choice test in Chinese was prepared. For conservation of displacement volume, three items were used, one of which involved a simple calculation. Two items were used to assess time, distance and speed relationships. To assess classification abilities, three items were prepared – two to test an understanding of ascending hierarchies and one for descending hierarchies. It was felt that these items would provide sufficient evidence of a pupil's understanding of the three concrete thinking tasks.

A trial test was carried out first with 120 pupils in Forms 1–3 in one secondary school. Based on the results, some modifications were made. For example, the original items used to assess classification referred to ducks. In Chinese however, there tends to be confusion in distinguishing 'duck' from 'bird'. Therefore parrots were substituted for ducks in the final test.

The final version of the test which was in Chinese, is shown in Appendix I. Each correct item scored I mark. A full score in each of the three areas was thought necessary as evidence of concrete thinking ability.

Research Method

A total of 2121 pupils were given the test. They ranged from Form 1 to Form 3 and came from 54 classes in 13 secondary schools. Table 1 shows the distribution of classes and pupils.

Table 1 The distribution of classes and pupils used for the administration of the Piagetian test of concrete thinking

Type of School	No. of Schools	No. of Classes		
		Form 1	Form 2	Form 3
Govt./subsidized	9	14	15	8
Private	4	6	6	5
No. of pupils	Boys Mean age (years)	416 13.2	407 14.3	226 15.6
	Girls Mean age (years)	400 13.0	402 14.2	270 15.5

A frequency analysis was carried out to determine the percentage of concrete thinkers in each of the three areas. This was done for boys and girls in Forms 1, 2, and 3. Statistical anlayses using the chi-square test were performed with decisions taken at the 0.05 level of significance or less.

Results and Discussion

(a) **For each concrete thinking area**

The percentage of boys and girls who achieved success on each of the 3 concrete thinking tasks was determined. The results are summarized in Table 2.

Table 2 The percentages of concrete thinkers among boys and girls in Hong Kong Junior secondary classes on each of 3 characteristics of concrete thought

Characteristic	Sex	Percentage of concrete thinkers				X^2 Forms 1–3	X^2 girls / boys Forms 1–3
		Form 1	Form 2	Form 3	Total		
Conservation of displacement volume	B	31.7	36.5	31.6	33.5	1.33	23.5***
	G	27.4	24.3	22.0	24.9	0.91	
	B+G	29.6	30.4	26.3	29.2	1.29	
Distance, time, speed relationships	B	21.0	30.7	27.0	26.0	5.06	16.7***
	G	15.6	19.8	20.9	18.5	2.24	
	B+G	18.3	24.2	23.7	22.2	4.96	
Concrete Classification	B	67.6	73.1	73.0	70.9	0.71	8.76***
	G	59.6	61.6	67.0	62.2	0.99	
	B+G	63.7	67.5	69.8	66.6	1.26	

*$p<0.05$; **$p<0.01$; ***$p<0.001$

Fewer than 30% of junior secondary school pupils fully understand the concept of displacement volume. The differences in percentages between the three forms for each sex separately are not significant, although the results indicate clearly that boys are achieving significantly greater success in this area than girls. These findings tend to confirm those from the United States study mentioned earlier in the article.

The relationships of time, distance, and speed are also poorly understood by pupils with only about 22% achieving success. Once again, the level of comprehension does not differ significantly from form 1 to Form 3 within each sex grouping, though boys outperform girls. It is interesting to note that 23% of boys and 29% of girls obtained a score of zero (out of a maximum of 2) in this area. Perhaps these relationships are more abstract than indicated by Piaget. If this were the case, an increase in the number of pupils achieving success would be expected from Form 1 to Form 3 as abstract thinking capabilities develop. Although Table 1 does indicate a gradual improvement, the differences are not significant with the sample size and level of significance used ($p \leqslant 0.05$).

By the time pupils enter Form 1, a substantial proportion have achieved the ability to ascend and descend classification hierarchies. This tends to confirm Piaget's hypothesis that these abilities are achieved by age 10 in children of average intellectual ability. Although boys still show a significantly higher ability than girls, the differences are less marked than for the other two concrete thinking areas.

In order to explain the observations for the first two areas, two possible hypotheses can be made:

1. The maturation of certain concrete thinking abilities takes longer than suggested by Piaget. If this were so, then an increase in the proportion of pupils achieving success should occur at some age or class level. Because Table 1 indicates that the proportion of pupils achieving success in the junior secondary years is constant, further research is needed with pupils in senior classes to test the hypothesis (though this would be hampered in Hong Kong by the selection process whereby only about 60% of the Form 3 population enter Form 4).

2. Pupils have had insufficient experiences of the type needed for these abilities to mature. (Piaget himself came to believe that the development of cognitive abilities was not purely a question of the maturation of the nervous system but was also dependent on interaction with the social environment and with expereince in general[3]). Therefore the exposure to learning experiences for pupils in Forms 1–3 which allow them to discover the concepts and relationships for themselves should increase the success rate.

Investigations are underway to test these hypotheses.

(b) **A comparison of concrete and abstract thinking ability in the area of classification**

The performance of each pupil in the concrete thinking aspects of classification described in this article was then compared with the performance in classification tasks requiring abstract thinking. The design of the test used for this latter task is described elsewhere.[4] The test itself – in Chinese – appears in Appendix II. Frequencies of boys and girls in Forms 1–3 were obtained for three groups – those successful at both the concrete and abstract levels (the 'abstract thinkers' group), those successful on the concrete but not the abstract tasks (the 'concrete thinkers' group), and those not achieving success at the concrete level (the 'not fully concrete thinkers' group). Table 3 shows the results of the analysis. Figure 1 shows graphically the cummulative proportion of pupils at different Piagetian stages in the development of classification abilities.

The percentage of abstract thinkers increases from Form 1 to Form 3. The differences in the pattern of performance between boys and girls is significant, with boys generally performing better. Just over 40% of the Form 3 population has reached the Piagetian level of cognitive maturity in this ability.

As the percentage of abstract thinkers increases, there is a corresponding significant drop in the percentage of concrete thinkers. However, about 30% of Form 3 pupils are still in this category.

Table 3 The proportion of Hong Kong Junior Secondary Schools pupils at different Piagetian stages in the development of Classificational abilities

Level of Achievement	Sex	Percentages			X^2 Forms 1–3	X^2 boys/girls
		Form 1	Form 2	Form 3		
3: Abstract thinkers	B	18.5	33.6	42.4	26.5***	6.9*
	G	20.1	26.5	40.0	19.9***	
	B+G	19.4	30.1	41.3	37.3***	
2: Concrete thinkers	B	49.1	39.5	30.6	12.2**	9.1*
	G	39.5	35.1	27.0	6.3*	
	B+G	44.3	37.4	28.5	19.7***	
1: Not fully concrete thinkers	B	32.4	26.9	27.0	2.3	28.7***
	G	40.4	38.4	33.0	1.8	
	B+G	36.3	32.5	30.2	3.2	

*p<0.05; **p<0.01; ***p<0.001

It appears from these results that about one-third of the pupils in Forms 1–3 do not fully achieve the stage of concrete thought in the area of classification (and probably in other areas as well). Although the figures in Table 3 indicate a gradual drop in percentages from Form 1 to Form 3, the differences are not statistically significant. This group consists of the low ability pupils and, it Piaget is correct, will not progress to a higher cognitive level when they complete their junior secondary education at Form 3.

Summary

1. Only a minority of junior secondary school pupils (less than 30%) achieve success on the Piagetian concrete tasks dealing with conservation of displacement volume, and time-distance-speed relationships.
2. Two-thirds or more of these pupils achieve success on the concrete classification tasks of ascending and descending a hierarchy.
3. In all three tasks, the percentage of pupils achieving success does not vary significantly from Form 1 to Form 3 though the proportion of boys is greater than for girls at all class levels.
4. The findings for classification abilities confirm Piaget's view that the majority of children master these tasks prior to secondary education. The results for the other two tasks would indicate that success is not achieved until several years later than those indicated by Piaget, if indeed they are ever achieved by the majority of pupils.
5. As pupils proceed from Form 1 to Form 3, the proportion capable of abstract thought in the area of classification increases, while the proportion still at the concrete level correspondingly decreases. The proportion of pupils failing to fully achieve the concrete thinking stage remains almost constant from Form 1 to Form 3.

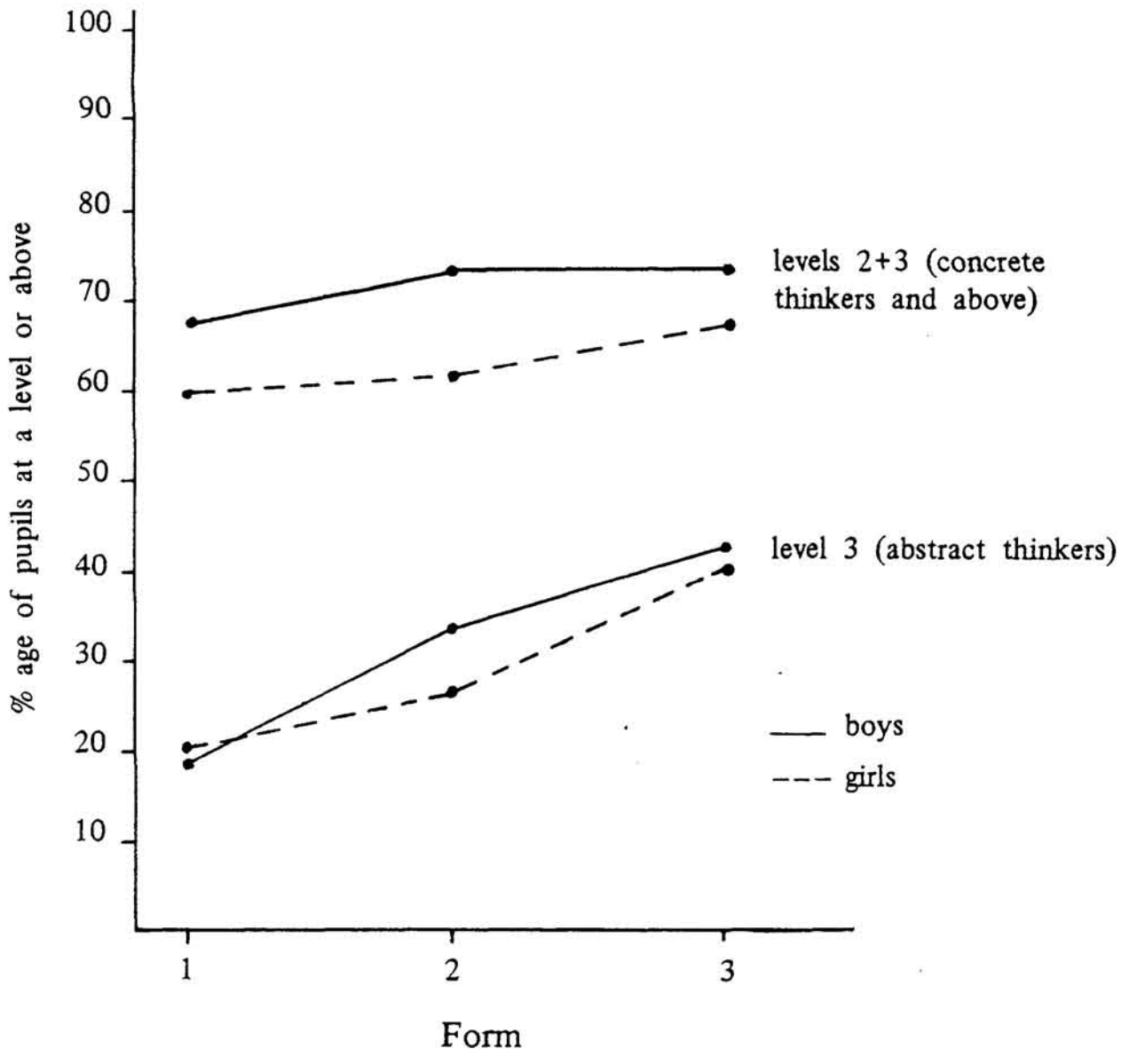


Figure 1: The cumulative percentage of Hong Kong Junior Secondary School pupils at various Piagetian stages of cognitive development in the area of classification.

References

1. Phillips, J.L.,Jr. *The Origins of Intellect: Piaget's Theory*, San Francisco, W.H. Freeman, 1969.

2. Elkind, David, 'Quantity Conceptions in Junior and Senior High School Students', *Child Development*, Vol. 32, 1961.

3. Piaget, Jean "The Theory of Stages in Cognitive Development", in *Measurement and Piaget*, Donald R. Green et. al (Eds.), New York, McGraw-Hill, 1971.

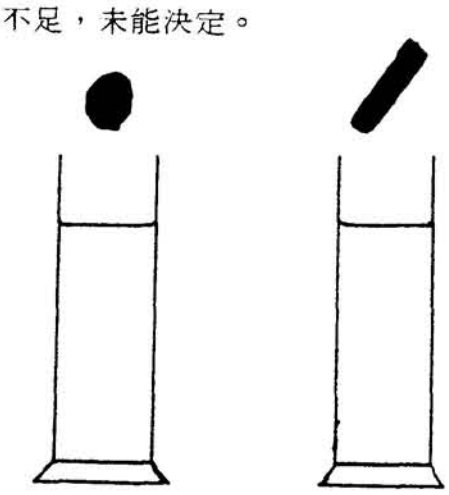
4. Heyworth, Rex,'Piagetian Cognitive Development in Hong Kong Junior Secondary School Pupils,' *H.K. Science Teachers' Journal*, Vol. 10, No. 2.

Appendix I

The items used in the Piagetian-type test to assess pupils' abilities in three areas of concrete thinking.

1. 偉明和美芬都有一個大小相同的黏土球，但是，偉明把他的黏土球捏成長條狀。然後，他們分別將黏土放進圖中的量筒，量筒內盛着同等份量的水，試問誰者的量筒水位將會上升較高呢？

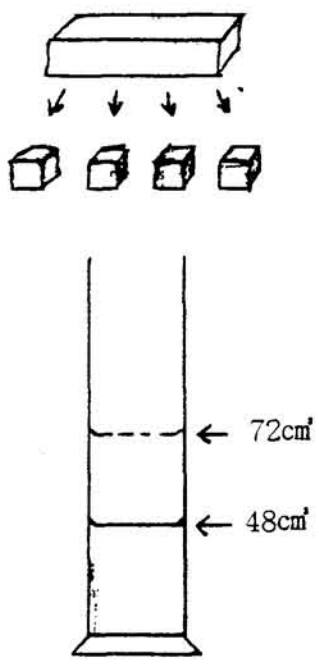
   A. 美芬的量筒水位會較高。
   B. 偉明的量筒水位會較高。
   C. 兩人的量筒水位會等高。
   D. 資料不足，未能決定。



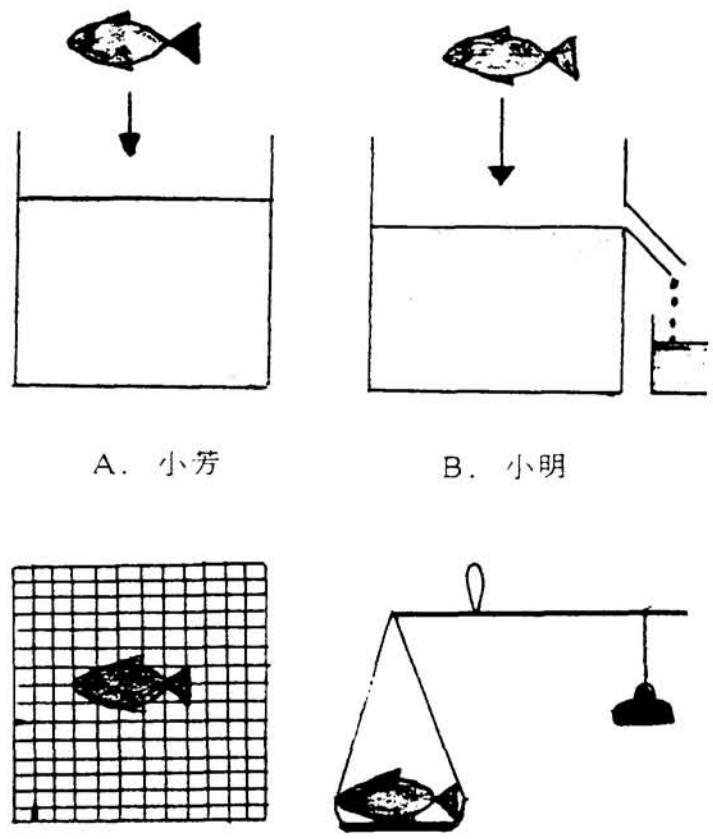
美芬　　偉明

2. 將一木塊分成四個體積相等的小木塊，然後把它們全部放進量筒之中，量筒水位因此由48cm³升到72cm³，請問小木塊的體積該是多少？

   A. 6 cm³
   B. 8 cm³
   C. 12cm³
   D. 24cm³



3. 四個學生用不同的方法量度一條魚的體積：誰人的方法正確呢？

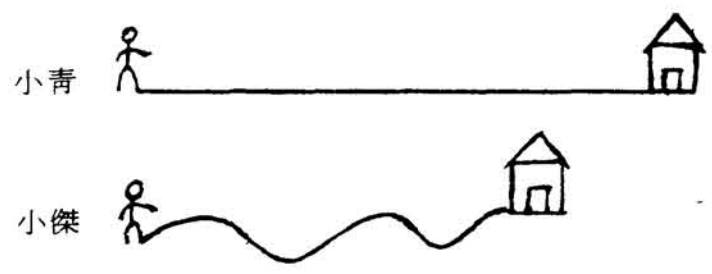


A. 小芳　　B. 小明

C. 小清　　D. 小輝

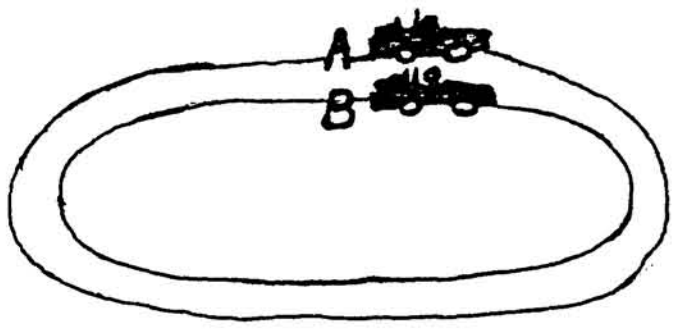
4. 小青和小傑以相同速度同時起步行向小屋，他們離開小屋的路程是一樣的，但小傑走的路是彎曲的。誰人首先到達他的小屋呢？

   A. 小青首先到達。
   B. 小傑首先到達。
   C. 兩人同時到達。
   D. 資料不足，未能決定。



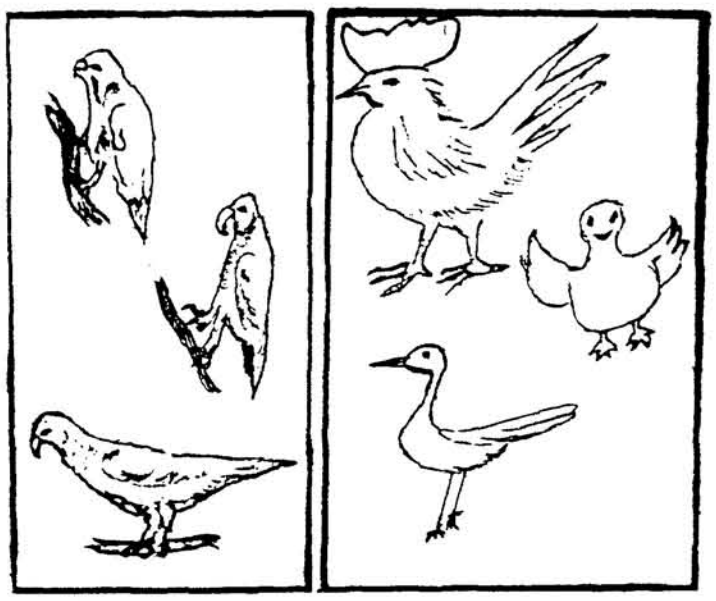
5. 兩部跑車沿圖中不同路徑比賽，若它們分別從A 和B 同時出發，而繞一匝所需時間相同，則下列敍述何者是正確？

   A. 跑車A 之速度較高。
   B. 跑車B 之速度較高。
   C. 兩部跑車之速度相同。
   D. 兩部跑車行走路程相等。

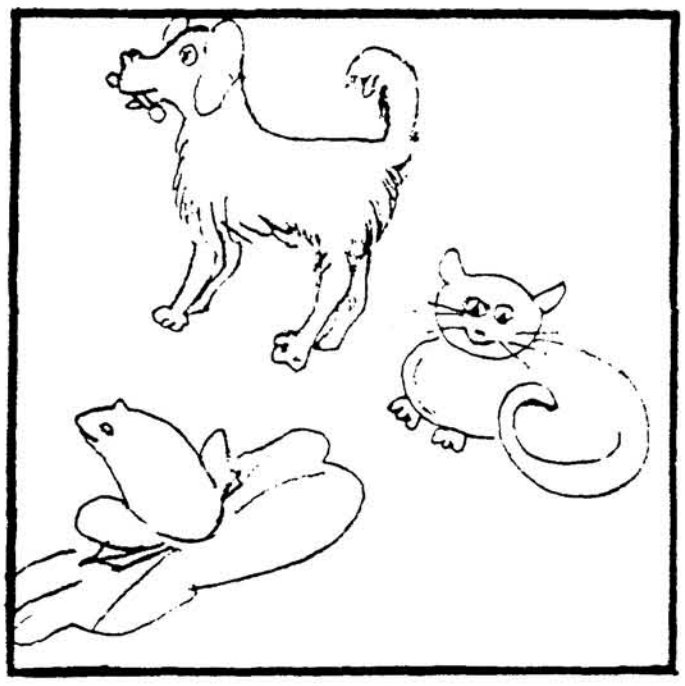


6—8 某學生有三組圖片，第一組定名爲"鸚鵡"第二組定名爲"鳥類"；第三組定名爲"動物"。

第一組："鸚鵡"　　第二組："鳥類"



第三組："動物"

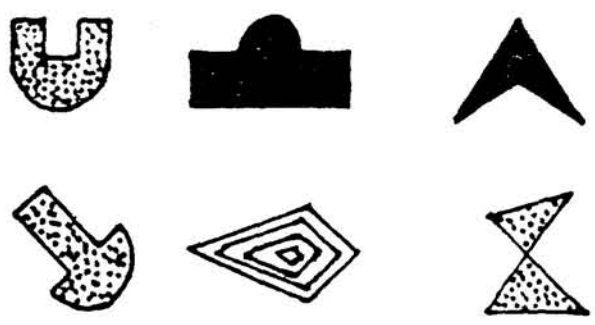


6. 該學生把第一組和第二組合併成爲一組，這個合併而成的組應該定名爲：
   A. 鸚鵡　　B. 鳥類
   C. 動物　　D. 鸚鵡及鳥類
7. 該學生把第一、第二及第三組合併成爲一組，這個合併而成的組應該定名爲：
   A. 鸚鵡　　B. 鳥類
   C. 動物　　D. 鸚鵡及鳥類
8. 假設全世界的動物都死掉，請問還有鸚鵡存在嗎？
   A. 有，因爲鸚鵡不是動物。
   B. 有，因爲鸚鵡跟動物屬於不同的組。
   C. 沒有，因爲該學生已把三組合併爲一組了。
   D. 沒有，因爲鸚鵡也是動物。

Appendix II

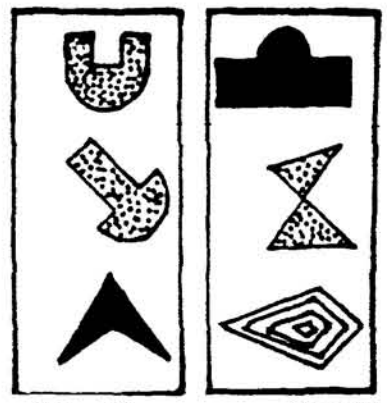
The items used in the Piagetian-type test of abstract reasoning in the area of classification.

1. 下面是六個不同的圖形：



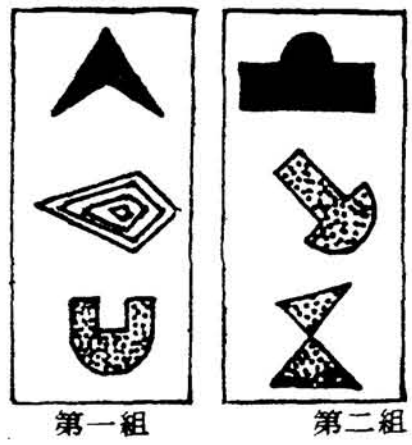
有四位學生把六個圖形分成兩組，每組三個，每組之內各圖形需要有共通的地方。那位學生分組辦法正確呢？

A.



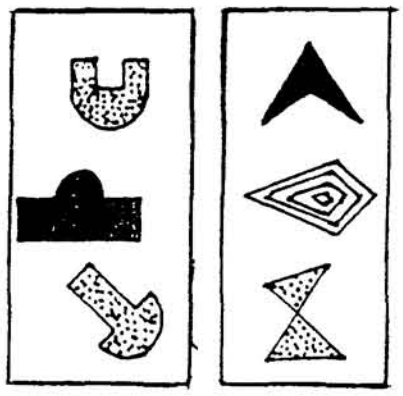
第一組　　第二組

B.



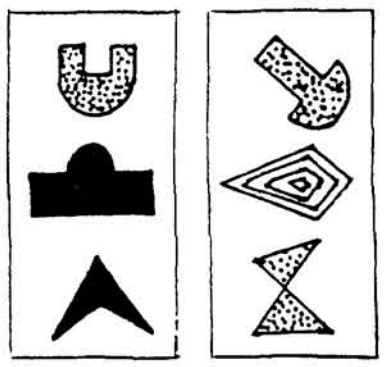
第一組　　第二組

C.



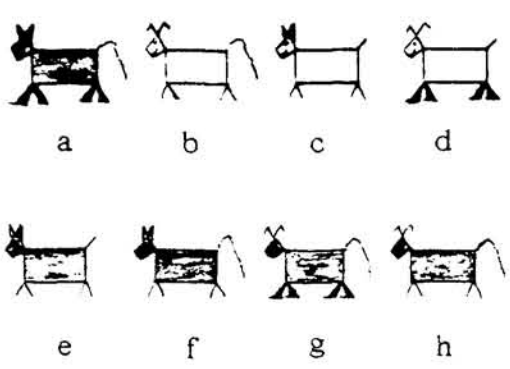
第一組　　第二組

D.



第一組　　第二組

2—3 下圖中有八隻狗，根據牠們的相同和相異的地方，可以把牠們分成兩組，第一組及第二組，每組有四隻狗。



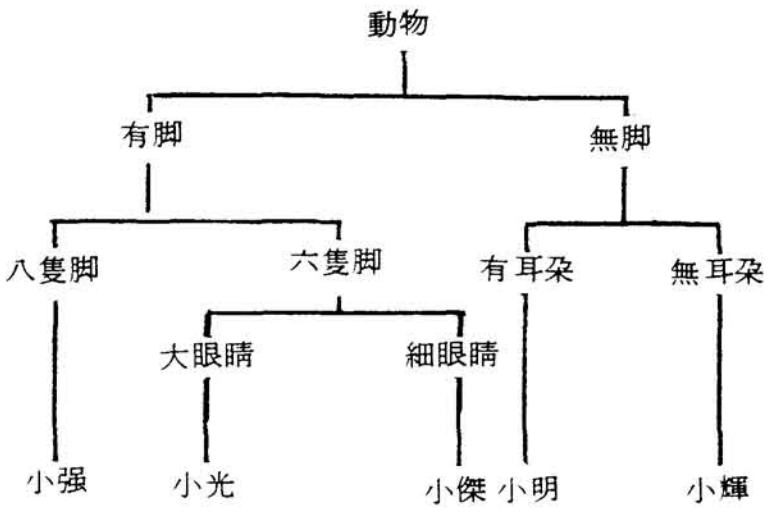
a　　b　　c　　d

e　　f　　g　　h

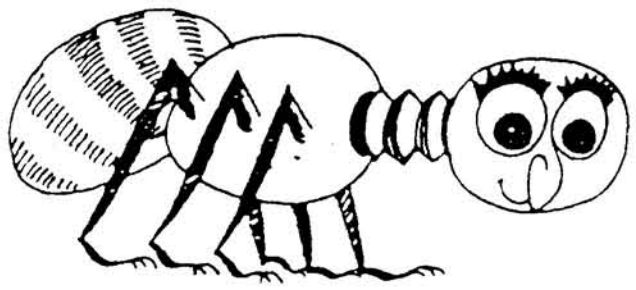
2. 下列是四位同學分出來的兩組狗隻，請問誰人的分法是正確的呢？

	第一組		第二組
A.	a，b，e，f	；	c，d，g，h
B.	a，c，e，f	；	b，d，g，h
C.	d，e，g，h	；	a，b，c，f
D.	b，c，d，h	；	a，e，f，g

3. 現在要將第一組的狗隻再分開成兩小組，每組有兩隻，請問需要用下面何種差異來分開牠們？
   A. 顏色的差異
   B. 腿部的差異
   C. 尾巴的差異
   D. 不能用上面的差異來分開牠們
4. 請根據下面圖表及右面圖片作答。

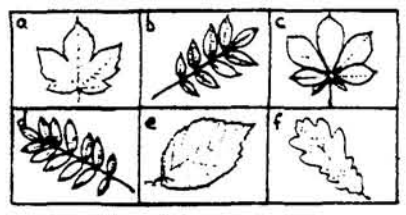


右面圖片中的動物名字應該是：



A. 小强　B. 小光　C. 小傑　D. 小輝

5—7 圖中有六片不同的樹葉，我們希望同一些準則來把它們分組。



5. 首先，我們需要將它們分成兩組，第一組及第二組，每組三片。現在有四位同學把其中三片樹葉分在第一組，誰人的分法是正確的呢？　A. b，e，f　B. a，b，c　C. a，b，e　D. b，c，d
6. 現要再把第一組的樹葉分成兩個小組，那兩片樹葉應該分在同一組呢？
   A. b，d　B. b，c　C. b，e　D. a，b
7. 在解答 6 題時，我們用了何種標準來把第一組分開成兩個小組呢？
   A. 葉緣圓滑的兩片分在同一組
   B. 葉片較細的兩片分在同一組
   C. 葉緣粗糙的兩片分在同一組
   D. 扇形葉面的兩片分在同一組

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