

Chapter 2

Practices of Innovative Exploration in Language Teaching: Questioning the “Stage Theory of Children’s Cognitive Development”

As early as 1952, the famous Swiss educational psychologist Jean Piaget had proposed the important perspective that “children’s cognitive development” is divided into stages, which children must go through in order without skipping any of them (Piaget 1952). Further writings were published subsequently to elaborate this view. In 1970, he published his masterpiece *The Principles of Genetic Epistemology* (Piaget 1972), in which he delivered an in-depth and systematic discussion on the matter, forming his unique “Stage Theory of Children’s Cognitive Development”, making a seminal contribution to researches in this area.

2.1 Summary of Piaget’s “Stage Theory of Children’s Cognitive Development”

Piaget’s “Stage Theory of Children’s Cognitive Development” believes that if determined by “operation”, children’s cognitive development can be divided into two large stages, “pre-operational” and “operational”. The pre-operational stage can be further divided into “sensori-motor level” and “pre-operational level”, and the operational stage can be divided into “the stage of concrete operations” and “the stage of formal operations”. Thus, there are four stages in total. Here, operation does not refer to operation in formal logic or in mathematics. It means psychological operations: they operate psychologically and internally through images, representations or symbols; for example, “pouring the water in a bottle into a cup” is originally an external and perceptual behavioural act, its result is observed with the eyes. However, for adults or senior grade students, the result of this act can be foreseen merely by imagining the whole process with representations in mind. There is no need to carry it out in actual behaviour. This process of imagining the

process of pouring water in mind is an interiorized psychological operation. These psychological operations have two basic characteristics:

- ① **Reversibility**—Things can be done in one direction and in the opposite direction. Taking the “pouring water” operation mentioned before as an example, not only can the water be poured from a bottle to a cup in the mind, but it can be poured back to the bottle and returned to its original state as well. This is referred to as “reversibility” or “reversible operation”. Reversibility is divided into inversion (aka “reversibility”) and reciprocity, such as $+A$ is the inversion of $-A$ and $A > B$ is the reciprocal of $B < A$.
- ② **Conservation**—The operation will cause changes in the external appearance of the object while its original property remains constant. This immutability is called conservation, for example, “narrow \times high” equals to “broad \times short” (area unchanged).

Using operations as determination, Piaget divided children’s cognitive development from birth to adolescence into “sensori-motor level”, “pre-operational level”, “the stage of concrete operations” and “the stage of formal operations” as mentioned above. The characteristics of these four stages can be summarized as follows.

2.1.1 Sensori-Motor Level (Piaget 1952; Pi 1977; Li 1999)

This stage ranges from infancy to 2 years of age. During this stage, children’s cognitive development is focused on differentiation of sensory perceptions and motions. At birth, infants only have innate inherited unconditioned reflex. Then, they gradually acquired the ability to cope with external stimulations by organizing their sensory perceptions and motions. The latter part of this stage is the germ of thinking, and there emerges a clear distinction between sensory perceptions and motions, and gradual differentiation of methods and goals. In reference (Piaget 1952), Piaget provided a detail description of the observational study on this stage and further divided it into six sub-stages:

- (1) **Sub-stage 1** (birth–1 month old)—“Exercising of Reflexes”. This stage is characterized using innate unconditioned reflexes to adapt to the external environment, such as sucking a nipple whenever there is one and crying whenever feeling hungry or thirsty.
- (2) **Sub-stage 2** (1–4.5 months old)—“Formation of Primary Circular Reactions”. During this stage, combination of several behaviours to form circular reactions based on innate unconditioned reflexes occurs, which helps infants to adapt to external environment more effectively, for example, by seeking the origin of a sound as soon as they hear it and tracing an object with the eyes immediately when movement occurs.

- (3) **Sub-stage 3** (4.5–9 months old)—“Formation of Purposeful Reactions”. As infants always touch and play with various equipments and articles around them with their hands, their activities move beyond self-preoccupation. The infants, as the agents, are able to influence objects around them as well. After the surrounding object is influenced by the agent, it will attract more attention from the agent and trigger influence from the agent again. In this way, there is a gradual differentiation between the infant's behaviour (that is, the infant's method) and the result of the infant's behaviour (that is, the infant's goal), which allows the infant to start realizing that certain behaviour could be taken to achieve certain goals.
- (4) **Sub-stage 4** (9–11, 12 months old)—“Coordination of Methods and Goals”. With the differentiation of methods and goals, some schemata are formed as the specific methods to achieve certain goals. For example, infants will stretch their hands to places beyond their reach. This reveals that they aimed at reaching an object before stretching their hands. With increasing amount of daily activities, infants are able to learn more and more methods (that means schemata, such as, grasping, pushing, knocking, hitting, and shouting) to cope with the surroundings in order to achieve their goals. The connection between schemata becomes more flexible and diversified, and there is also better coordination and clearer distinction between methods and goals.
- (5) **Sub-stage 5** (11, 12 months old–1.5 years old)—“Accidental Discoveries”. With increasingly frequent use of different schemata, infants will also make some changes instead of merely repeating the original behaviour. That means they learn to solve new problems through trial and error. For example, there is a doll on the bed, but the infant is not able to reach it, so it grasps whatever nearby in a random manner. Eventually, it grasps a corner of the bed sheet and discovers that the movement of the sheet is connected to the location of the doll. Then, it pulls the sheet slowly and gets the doll. This way of discovering solutions to problems seems simple, but it is a great advancement in infants' cognitive development. However, these are accidental discoveries. At this stage, infants still have not acquired the ability to discover solutions to pre-determined goals.
- (6) **Sub-stage 6** (1.5–2 years old)—“Purposeful Discoveries”. Infants begin to discover solutions to problems according to specific goals and directions. For example, there is a transparent plastic box containing chocolates. At first the infant turns the box around and looks. Then it attempts to put its little finger through the crack on the box to get the chocolates, but fails. After that, it stops and looks at the box, opening and closing its mouth before forcefully pulling open the box with its hands. At last, the box is opened and it gets the chocolates. Such opening and closing of mouth symbolize the infant's “imagination” of opening the box in its mind. This shows that infants have already acquired the most basic of interiorized psychological operations. It is only that the subjects of such psychological operations are still not abstract symbolic representations or representations of some specific objects, but the image of the concrete object (the chocolate box) at the present moment.

During the first 3 of the above 6 sub-stages, infants still do not have the concept of permanent objects, but only flickering sensory images. They find that the agents seem to be the centre of the world, but still have not realized the existence of self. With the enrichment and development of schemata, infants gradually distinguish the agent and objects, and begin to view themselves as one of the numerous objects that form the world. Piaget appreciated this emergence of detachment from egocentrism in infants' consciousness very much, and thought that it is the "Copernican revolution" (Piaget 1972) in children's cognitive development and the greatest achievement in the whole "sensori-motor level". He believed that this Copernican revolution marked by "**detachment from egocentrism**" is generally attained progressively after sub-stage 4.

2.1.2 Pre-operational Level (Piaget and Inhelder 1964, 1954)

During the pre-operational level, the sensori-motor schemata of children are gradually interiorized into representational schemata or image schemata. Intensified by the emergence and development of language, children use increasingly more representations and words to depict external objects. Yet, at this stage, they are still not able to represent abstract concepts with representations, words or other symbols. These can only be applied with the presence of concrete objects and in actual scenarios, which means that cognition is still bounded by the visual images of concrete objects. In reference (Piaget 1972), Piaget divided children's cognitive development in this level into two sub-stages:

2.1.2.1 Pre-operational Sub-stage 1 (2–4 years old)—“Formation of Representation System”

During this stage, children start to establish and use representative system, which means a system of indications and symbols. Piaget (1972) pointed out that during this period, with further development in children's intelligence, "the series of successive physical actions, each given momentarily, is completed by representative systems capable of evoking in the form of an almost simultaneous whole, past or future actions or events as well as present ones and spatially distant as well as near ones". Obviously, when Piaget talked about representative systems here, what he actually meant is a representation system, and he did not include other representative systems (such as language) in it. This is because the only way to reproduce activities and events in the past and future "simultaneously" is by a three-dimensional visual representation system. Yet, the linguistic symbol system is one dimensional and can only be shown in a linear and sequential manner. Apart from that, the interiorized representation of actual activities is equivalent to "internalization" (turning external behaviours and activities into interiorized

psychological operations) mentioned before, which is the "conceptualization" of activities. However, Piaget clearly stated that "conceptualization" at this stage is still not equal to the establishment of real concepts. It can only be called "pre-concept" (Piaget 1972) as it is established with representation system (rather than linguistic symbol system).

Children are able to establish representation representative systems in this sub-stage because there is separation of "signifiers" and "referents". To understand this issue, Piaget stated that special attention should be paid to distinguishing between symbols and signs.

In an ordinary representative system, the relationship between symbols themselves (signifiers) and matters denoted or represented by symbols (referents) does not exist in the objective matters themselves, but in the subjective consciousness of the cognitive subjects (i.e. the minds of the children). For example, in children's games, they use bamboo rods as horses and wooden stools as cars. Here, the bamboo rods and wooden stools are "signifiers" and horses and cars are "referents" (things being signified). In this situation (that is, when representations are used as symbols to denote objective matters), "signifiers" and "referents" are connected by children's subjective imagination. However, that is not the case for signs. Signs are a part of the properties or components of objective matters. They indicate the appearance of the objective matters; for example, footsteps indicate that someone is coming and a sinking float indicates that a fish is biting the bait. Footsteps and sinking float are signs. In this case, the "signifiers" (footsteps and sinking float) become one of the properties or components of the "referents" (someone and the fish that bite the bait). The connection between "signifiers" and "referents" existed in the objective matters themselves rather than in the subjective consciousness of the cognitive subjects.

The development of children's representative system relies mostly on the creation and mastery of the symbolic representative system (especially that of the linguistic symbol system). Language is a symbolic representative system that is generated and established by society. It is the most important types of symbolic representative system. Piaget believed that in this sub-stage, children are still not good at using language to express matters that catch their attention and interest. Although they have already acquired the ability to use words, nevertheless concepts are still unformed (they cannot capture the common properties between matters). Children are only using words as a symbol to denote the image of a particular matter rather than the intrinsic property of that matter.

2.1.2.2 Pre-operational Sub-stage 2 (5–6 years old)—"Elimination of Egocentrism"

As stated before, in between the first half and the second half of the sensori-motor level, there is a Copernican revolution marked by "detachment from egocentrism". In sub-stage 2 of the pre-operational level, a similar phenomenon occurs with further advancement in the representation system. There is a gradual elimination

of egocentric cognition (this elimination commences in the middle of the pre-operational level, that is, when sub-stage 2 starts). There exist differences between “detachment from egocentrism” and “elimination of egocentrism”. The former points to the separation between cognitive subjects and objects, which means that the children no longer view themselves as the centre of the world, but rather as one of the objects that form the world. The latter means that the subjects give up or eliminate egocentric cognition while comprehending objective matters. Piaget thought that before 5 years old, children are egocentric. They understand objective matters only from their own viewpoint, and are unable to think in others’ perspectives and points of views. Piaget reached this conclusion with the following experiment: Let a child sit on one side of a model mountain and put a doll on the other side. Then, asked the child to describe the scenery that the doll see. The result of the experiment proved that most children under 5 described the scenery according to what they saw in their own location (they were unable to describe it according to what the doll saw in its location).

2.1.2.3 Major Characteristics of the Pre-operational Level (Piaget 1972; Pi 1977; Zhu and Lin 1991)

Piaget believed that children in the pre-operational level exhibit the following characteristics in their cognitive development:

- ① **They mainly Reflects objective matters with a representation representative system** (representation system) **rather than a linguistic symbol representative system** (linguistic symbol system). As concepts are still unformed (as Piaget put it, there is only pre-concepts), there is no logical thinking based on verbal concept, but only thinking based on representation (that means imagery thinking and intuitive thinking).
- ② **Mostly egocentric cognitive style.** It is not until the later stage of this level that this kind of cognitive style is gradually given up or eliminated.
- ③ **Lack of reversibility in thinking.** Reversibility means that the cognitive subject can alter the direction of thinking, that is, to apply mental processing in both positive and negative directions. In general, children in the pre-operational level do not possess such reversibility. That is why they always understand relationships in a single direction only. For example, when a 4-year-old children was asked, “Do you have any brothers?”, he answered, “Yes”. And when asked further, “What is your brother’s name?”, he said, “Jim”. But when he was asked in the other way round, “Does Jim have any brothers?”, the boy then answered, “No”.
- ④ **Lack of conservation in thinking.** Conservation refers to the awareness that certain original properties (such as, length, area, volume, weight) remain constant in spite of changes in the objects’ appearance. Usually, children in the pre-operational level do not possess conservation, and thus their understanding of volume is always single dimensional. For example, a group of 4–5-year-old

children were given two cups, A and A', of same size and shape. Let the children put the same numbers of wooden beads into the cups with their own hands. The children knew at this moment that the two cups had the same numbers of beads. Then, the experimenter poured the beads in A' into a tall and narrow cup B, and asked them if cup A and B had the same numbers of beads. This time, some children said cup B had more beads than A while some said cup A had more beads than B. Why would there be two different answers? Piaget believed that this is because children in the pre-operational level have not acquired conservation in their thinking. When they thought about the height, they missed the width, and vice versa. In psychology, this phenomenon is called "unidimensionality".

- ⑤ **Lack of transitivity in thinking.** Transitivity refers to the cognitive subject's ability to recognize that causal relation produced by interplay of matters is sometimes transferred through an intermediary. Normally, children at the pre-operation level do not recognize this transitivity. For example, children of 6 years old were given three glasses of different shapes, A, B and C. A contained red liquid, C contained blue liquid, and B was empty. Then, behind a curtain, the liquid in A was poured into B, then C's into A, and lastly B's into C (so as to swap the liquid in A and C). After that, the curtain was drawn to let the children observe the result after the swap. In general, they did not recognize B's role as the intermediary in this transference process. Thus, they said that the liquid in A was poured directly into C, and that in C was also poured directly into A.

2.1.3 The Stage of Concrete Operations (Piaget 1953, 1950)

During this stage, abstract concepts start to form in the cognitive structure of children. Piaget (1972) pointed out that "The age of 7–8 years, on average, marks a decisive turning point in the development of conceptual tools". Children begin to possess basic logical reasoning ability, and their thinking start to show an awareness of reversibility and conservations. In reference (Piaget 1972), Piaget divided the cognitive development of children at this stage into two sub-stages:

2.1.3.1 Concrete Operational Sub-stage 1 (7–8 years old)—"Formation of Reversibility and Conservations"

Piaget believed that reversibility in children's thinking does not emerge from nowhere. It is rooted in the process of cognitive development, during which children integrates the cognitive activities of "anticipation" and "retrospection" into one single activity. For example, when a child at this stage was asked to put rods of various lengths in order, he would not search for the correct sequence through continuous trial and error as when he was in the pre-operational level. He would

first pick out the shortest rod, and then pick out the shortest again in the remaining rods, and continue this process until all rods were lined up. In this way, “anticipation” (picking out the shortest rod in sequence, making it possible to get the correct order in the shortest time) is integrated with “retrospection” (after every step, the child will look back to check if the actual result is in accord with the “anticipation”). This avoids performing trial and error blindly, and greatly improves efficiency in sequencing the rods. In the process of interiorized psychological operations, anticipation is equivalent to direct operation, and retrospection is equivalent to inverse operation. Their integration produces reversible operation.

The formation of conservation in children’s thinking is far more complex, and Piaget (1972) believed that three conditions are needed:

- ① **Reflective abstraction**—It means that the subject’s abstraction of the object’s properties is gained through his action and influence on that object, rather than by direct perception.
- ② **Coordination**—Such coordination combined the various pieces of scattered and partial understandings into an integrated whole
- ③ **Self-regulation**—This enables understandings to convert in two directions (addition and subtraction, positive and negative) and to reach an equilibrium, which ensure conservation in thinking

The formation of these three conditions (that is, the formation of conservation) is the major hallmark of children’s cognitive development at the concrete operational sub-stage 1. As conservation and transitivity in thinking are closely connected (detail discussion can be found in reference Piaget 1972), **the formation of conservations in thinking inevitably means the formation of transitivity**. In other words, conservation and transitivity in children’s thinking are formed at the same stage.

2.1.3.2 Concrete Operational Sub-stage 2 (9–10 years old)—“Exploration of Causality”

This sub-stage is hallmarked by children’s development in exploring the reasons for movements and changes in things, which means the development in searching for causal explanations. Piaget (1972) pointed out that such development indicates “a clear advance over the first sub-stage (from 7 to 8 years), leads the subject to raise a group of kinematic and dynamic problems, which he is as yet unable to solve with the operational means at his disposal. There then occurs a series of fruitful disequilibrium states, and it is these that we would characterize as novel”. Piaget went on to say that the development in logical mathematical operation is the major factor that enhances children’s active search for causality, and logical mathematical operation is an ability gained through the aforementioned “reflective abstraction” (which means it is attained through the subject’s direct act and influence on the object). Obviously, such ability founded on the subject’s practice does not only act to enhance children’s exploration in causality, but is also significant in fostering the whole formation and development of children’s cognitive structure.

2.1.3.3 Major Characteristics of the Stage of Concrete Operations (Piaget 1972; Li 1999)

- ① **The major characteristic of the stage of concrete operations is its concreteness.** As mentioned earlier, with the formation of abstract concepts during this stage, children begin to possess basic logical reasoning ability. This ability is said to be at the basic level because logical reasoning at this stage is still relying on the support of concrete matters, in the absence of which children will have difficulties. For example, if an inference question based on transitive relations was asked, e.g. "If $A > B$, $B > C$, which is larger, A or C?" Most children at the stage of concrete operations are not able to come up with the correct answer. Yet, if asked in another way, "Miss Zhang is taller than Miss Li, and Miss Li is taller than Miss Wang; who is taller, Miss Zhang or Miss Wang?" (Zhang, Li and Wang are all teachers with whom the subjects are familiar), the children were able to answer it. This shows the concreteness of such an operation and that the logical reasoning ability at this stage is thus still at a basic or rudimentary level.
- ② **Possess conservations in thinking.** According to the research by the Piagetian school, awareness of conservation of different properties is attained at different ages, for example, the conservation of liquid is learned at 7–8, conservation of weight at 9–10, and conservation of volume at 11–12.
- ③ **Possess reversibility in thinking.** As there is still no interaction between the two types of reversibility, "inversion" and "reciprocity", the two of them can only control class and relation separately, and the logic in concrete operations concerns only the logic of class and the logic of relation. Children can only apply such logic to concrete objects, and the class and relation system in concrete operation have not been combined into an integrated whole.
- ④ **Possess transitivity in thinking.**
- ⑤ **Frequent disequilibrium in cognition.** As mentioned before, such disequilibrium is caused by children's active search for causality between matters. It is indeed the actual driving force of children intellectual development, because it triggers the two important cognitive activities of "assimilation" and "accommodation", and enhances expansion and development in children's cognitive structures in both quality and quantity, which allows them to reach new cognitive equilibrium.

2.1.4 The Stage of Formal Operations (Piaget 1941, 1946–1969, 1946–1970, 1948)

Piaget believed that children enter the stage of formal operation at around 11–12. The major characteristics of this stage are as follows:

① Commencement of separation of form of thinking and content of thinking

The major characteristic of formal operations is that thinking is no longer restricted to concrete objects. There is a separation of the content and form of

thinking, and thinking starts to take its role and function in formal reasoning. Before that, all operations are directly related to the objects (concrete matters), which means that the content of form of thinking are still not separated. For example, for some concrete operations that can be applied to various objects, there is no difference between the content of their psychological processing, but they differ only on the sequence of processing. In other words, before entering into the stage of formal operations, the objects of children's psychological processing can only be concrete objects, not abstract concepts. Yet, after entering into the stage of formal operations, as Piaget pointed out (Piaget 1972), children's knowledge "transcends reality itself, relating it within the possible and the necessary; thus dispensing with the concrete as intermediary".

Piaget believed that formal operations are formed by the logical relations (such as conjunction, disjunction and implication) between the propositions of interiorized psychological operations, namely classification and seriation. As formal operations, which are not limited by concrete matters, are carried out in the form of propositions, it is thus also commonly referred to as propositional operations.

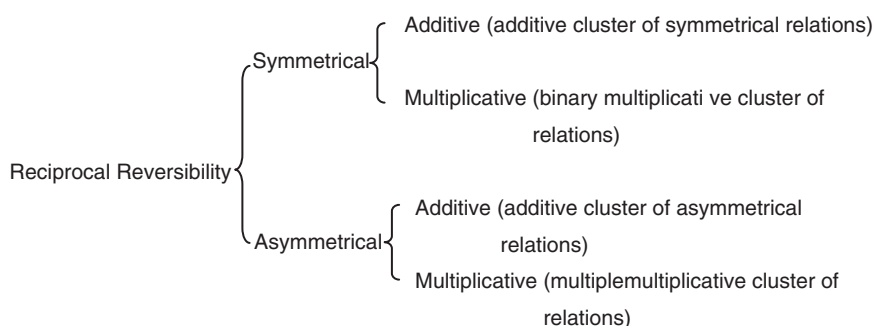
② Capable of carrying out various acts of logical reasoning with hypothetical propositions

The capability to deal with hypothetical propositions is another major characteristic of children at the stage of formal operations. Children are no longer only capable of dealing with propositions about actual objects. Piaget pointed out in reference (Piaget 1972) that "The chief characteristic of formal operations is their capacity to deal with hypotheses". The hypotheses children raise during this stage are not about objects, but propositions. The content of these hypotheses consists of "intrapositional operations" which can be verified directly, such as class and relation. However, deductive operations (such operations enable a hypothesis to reach its conclusion) are a totally different type. They are operations on operations, and so Piaget named them "interpropositional operations" or "second-order operations". Piaget believed that (Piaget 1972), "It is this power of forming operations of operations which enables knowledge to transcend reality, and which by means of a combinatorial system makes available to it an infinite range of possibilities".

③ Specified structure of operation

Piaget thought that formal operations carry structural integrity. He pinpointed the combinatorial system based on bi-propositional operations and INRC quaternary conversion group as the actual practical structures of formal operations.

A binary proposition is a compound proposition with two sub-propositions (p and q). Each sub-proposition carries two values, true and false, thus forming four possible combinations:



To the subjects of formal operations, the structures of propositions are $((p \wedge q) (p \neg \wedge q) (\neg p \wedge q) (\neg p \neg \wedge q))$ rather than a "class—product" one. These structures represent a hypothetical judgment (proposition), and thus, further combination based on the above four combinations are possible, and it will produce the following 16 combinations, which is Piaget's bi-propositional operations-based combinatorial system.

Disjunctive Forms	Numbers and names given by Piaget
(o)	(2) complete negation
$(p \wedge q)$	(3) disjunction
$(p \neg \wedge q)$	(8) nonconditional
$(\neg p \wedge q)$	(10) inverse nonconditional
$(\neg p \neg \wedge q)$	(6) conjunction
$(p \wedge q) \vee (p \neg \wedge q)$	(13) affirmation of p
$(p \wedge q) \vee (\neg p \wedge q)$	(15) affirmation of q
$(p \wedge q) \vee (\neg p \neg \wedge q)$	(11) biconditional
$(p \neg \wedge q) \vee (\neg p \wedge q)$	(12) exclusion
$(p \neg \wedge q) \vee (\neg p \neg \wedge q)$	(16) negation of q
$(\neg p \wedge q) \vee (\neg p \neg \wedge q)$	(14) negation of p
$(p \wedge q) \vee (p \neg \wedge q) \vee (\neg p \wedge q)$	(5) incompatibility
$(p \wedge q) \vee (p \neg \wedge q) \vee (\neg p \neg \wedge q)$	(9) inverse conditional
$(p \wedge q) \vee (\neg p \wedge q) (\neg p \neg \wedge q)$	(7) condition
$(p \neg \wedge q) \vee (\neg p \wedge q) (\neg p \neg \wedge q)$	(4) conjoint negation
$(p \wedge q) \vee (p \neg \wedge q) \vee (\neg p \wedge q) \vee (\neg p \neg \wedge q)$	(1) complete affirmation

The INRC quaternary conversion group is founded as there is convertibility between different formal operations. As stated before, both concrete operations and formal operations carry the characteristics of reversibility, conservations and transitivity (as mentioned, reversibility is divided into inversion and reciprocity), and these characteristics imply convertibility. Thus, based on the different natures involved in the transformations, these conversions can be categorized into four types: inversive conversion (N), reciprocal conversion (R), correlative conversion (C) and identical conversion (I). A complete transformation structure, the INRC conversion group, is then formed.

The INRC conversion group is an actualization of the Klein four-group in mathematic. It is Piaget's innovation to apply it in reflecting the rules of conversion in formal operations.

2.2 Contributions of Piaget to Theories of Children's Cognitive Development

The summary of Piaget's "Stage Theory of Children's cognitive development" presented above shows that Piaget has made important and outstanding contributions to the study of the area. His contributions mainly concern the followings aspects:

2.2.1 Insisting on a Dialectical Materialism View on Cognitive Development, Opposing the Idealist and Mechanical View

Regarding the fundamental issues of the origin and development of cognition, there has been continuous debate between two schools of thought and two world views for a long time. One side takes the idealist apriorism view and insists, like innatism and various apriorisms, that "the subject possesses from the start endogenous structures which it imposes on objects" (Piaget 1972). The other side believes in mechanical materialism and, like the empiricists, thinks that "the subject is instructed by what is outside him". Piaget took the viewpoint of dialectical materialism and strongly criticized both of these sides. Regarding the origin of knowledge, he firmly believed that (Piaget 1972), "knowledge arises neither from a self-conscious subject, nor from objects already constituted (from the point of view of the subject) which would impress themselves on him; it arises from interactions that take place mid-way between the two and thus involve both at the same time". Concerning the development of cognition, he provides the following clear exposition (Piaget 1972), "the problem stated by genetic epistemology is whether the genesis of cognitive structures only represents the totality of presuppositions for the achievement of knowledge, or whether it provides the constitutive conditions of knowledge. In other words: does genesis correspond to a hierarchy or even a natural interdependency of structures; or does it merely describe the temporal process by which the subject discovers these structures as pre-existing realities? The latter alternative involves the view that theses structures are preformed; either in the objects of physical reality, or as a priori in the subject himself, or in the ideal world of possibility in a Platonic sense. Now, through its analysis of genesis itself, genetic psychology has tried to show the inadequacy of these three hypotheses, and to make a case for the view that genetic construction in its wider sense is an effectively constitutive construction". Piaget also had his own unique and

brilliant idea on how cognitive structures are actually constructed, "The achievement of knowledge is thus to be explained in terms of a theory indissolubly linking structuralism with constructivism, every structure being the resultant of a genesis and every genesis being the transition from a more to a less elementary (or more complex) structure".

Through such brilliant philosophy, Piaget clearly indicated his dialectical materialism standpoint on children's cognitive development, and sharply differentiated his view from the idealist and mechanical materialism viewpoints of cognitive development. He showed the right direction for researches on cognitive development and led them onto the right track.

2.2.2 Pioneering in the Introduction of Researches in Children's Psychogenesis into Epistemology, Giving a Seminal Contribution to the Establishment of "Genetic Epistemology"

Piaget believed that (Piaget 1972), "the study of the psychogenesis of knowledge is an indispensable part of epistemological analysis". This is just the same as how "anthropogenesis" is studied. With a lack of information about prehistoric man, seeking help from biologists is the only way. Biological knowledge about embryogenesis is then used to patch the missing parts in anthropogenesis. To researches on epistemology, especially those on the origin of human cognition, this bears the implication that the targets of the researches can be reached through studying infants' psychogenesis. This analogical method arose in Piaget's mind because he had been a zoologist, and it was natural for him to compare his research with that of an embryologist. He thought that just as researches on embryology are able to reveal the structural similarities among animals and the early development of mankind, researches on infants' psychogenesis and development would also help to clarify the origin and structure of human cognition. He believed that careful study of the most elementary intellectual activities of humans (that of children and even infants) would aid deeper understanding of adults' thinking. However, this is just the opposite way of the traditional epistemology. The traditional ignored the lower level cognition, but studied only the higher level cognition of adults. That is to say, it only focused on part of the eventual development of cognition. Thus, the results always went awry. Thus researches in epistemology remained stagnated and without any breakthroughs for a long time.

By introducing the psychogenesis and development of infants and children into researches on epistemology, Piaget sought to engage in an in-depth study of the origin of cognition and psychogenesis of infants by going through the primal form of cognition. He also sought to investigate the relationship between such primal cognition and the development of child psychology at later stages and levels (including the stage at which comprehensive advanced thinking ability,

that is, advanced cognition level, is attained). Piaget put all these thoughts into action, and at last achieved his aim; he established a blank new subject—"Genetic Epistemology", which is just as what Piaget said (Piaget 1972), "an epistemology that is naturalist without being positivist; that draws attention to the activity of the subject without being idealist; that equally bases itself on the object, which it considers as a limit (therefore existing independently of us, but never completely reached; that the above all sees knowledge as a continuous construction".

Piaget contributed seminal research to "Genetic Epistemology", and his name will forever be linked with "Genetic Epistemology". To honour his outstanding contribution to the area, the American Psychology Association specially presented him with a citation. On it was stated, "He has approached questions up to now exclusively philosophical in a resolutely empirical manner, and has made epistemology into a science separate from philosophy, but related to all human sciences". Piaget is worthy of such praise.

2.2.3 Pioneering in Revealing the Existence of Stratification in Children's Cognitive Development, and Providing Precise Descriptions to the Development of Some Stages

Considerable researches and practical observations have proved that Piaget's notion that "there is stratification in children's cognitive development" is scientific and ubiquitous. From the outset of children's cognitive ability to its maturity, there exist some stages that children go through from a lower level to a higher level. The order of these developmental stages cannot be changed and there is no skipping. For example, children in the pre-operation stage cannot skip the stage of concrete operations and arrive directly at the cognitive ability attained at the stage of formal operations. This is a general rule of cognitive development. Knowing and mastering this rule provides an important guide to reform in basic education and to the improvement of the quality of education.

Piaget had made in-depth studies on the characteristics of every stage of children's cognitive development, and his analysis on the sensori-motor stage is especially brilliant. He divided the cognition of infants of 0–2 years of age into six stages, ranging from the outset of cognition to the preliminary formation of "interiorized psychological operations". Careful and detail observations were made on each of the sub-stages, which formed the basis of his comprehensive and brilliant analysis. Apart from that, making "elimination of egocentrism" the hallmark of pre-operational sub-stage 2 and drawing an analogy between this hallmark and the "Copernican revolution" at sensori-motor stage are as well one of his impressive achievements, which combined fertile imagination with thorough and profound theoretical analysis.

2.2.4 Creating a Complete and Unique Research Method for Children's Cognitive Development

Exactly as Professor Lin Chong De, famous psychologist of our country, pointed out (Zhu and Lin 1991), Piaget devoted his whole life to researches on children's cognitive development and his contributions were not restricted to what has been outlined above. He not only established a new theory of children's cognitive or thinking development, but also created a whole new set of unique research methods for child psychology, namely the "clinical method" (a method that combines both interview and experiment). "Clinical method" is the major research method of the Piagetian school. To avoid redundancy, it will not be repeated here. Interested readers may refer to related references (such as reference Zhu and Lin 1991; Flavell 1963).

2.3 Thinking Theory Researches: Challenges to Piaget's Criteria for Dividing "Children's Cognitive Development Stages"

The above discussion shows that many of Piaget's thoughts and ideas connected with his founding of genetic epistemology are prominent and brilliant, and that they acted as a huge driving force to the advancement of researches on children's cognitive development. All these we sincerely admire and adore. However, through our theoretical researches on creative thinking in recent years and from years of explorations in primary school language teaching reform, we have found that there are still some problems in Piaget's theory, and some of his basic viewpoints even show an obvious discrepancy with the outcomes of our teaching reform experiment. At first, we were puzzled, and then became doubtful, about Piaget's authoritative viewpoints. After serious reflection for a longer time, and especially after re-examining the theory of cognitive development, we finally came to the conclusion that there is a need to critique the "bases" and "criteria" Piaget applied in dividing the stages of children's cognitive development (for they are the foundation of Piaget's theory), and to raise our own viewpoints.

2.3.1 Piaget's Criteria in Dividing "Children's Cognitive Development Stages"

As stated at the beginning of Sect. 2.1 of this chapter, Piaget used "operation" as the basis or criterion in dividing children's cognitive development into stages. Although operation is a concept Piaget introduced from the science of logic, as

mentioned above, it does not refer to logical operation in formal logic or operation in general mathematics. It refers instead to an interiorized psychological operation, in which explicit behaviours and actions are transformed into interiorized action performed psychologically through some kind of representative system. According to Piaget's definition, two more basic properties (reversibility and conservation) are needed for such interiorized psychological operations to become an "operation". That means

Operation = Interiorized Psychological Operation + Reversibility + Conservation

Applying operation according to this definition as his basis or criterion, Piaget divided children's cognitive development into the following stages:

0–2 years old: As mentioned, basic interiorized psychological operations appear only at the end of this stage. Before that, there is no interiorized psychological operation, indeed no operation at all (that means no sign of thinking). Thus, cognitive development at this stage can only be marked by explicit behaviours and actions that are not interiorized and can be directly perceived only through sensory organs. This stage is thus named the "sensori-motor stage". Actually, according to the original ideas of Piaget, it would be more precise to name this stage "non-thinking stage" (a stage when thinking ability has not been acquired).

2–6 years old: There are already interiorized psychological operations at the beginning of this stage. However, these interiorized psychological operations do not have reversibility or conservation, and are neither perfect nor of more advanced level. That is to say they have not reached the level of "operation", but can only be regarded as "pre-operation" (or "quasi-operation"). Thus, naturally, this children's cognitive development stage is named the "pre-operational stage".

7–10 years old: Interiorized psychological operations have started to acquire reversibility and conservations at this stage, which means that they have reached the level of operation. Yet, operations at this stage still rely on concrete objects, and the contents and forms of psychological operations are still inseparable. As operations are still of a lower level, this stage of children's cognitive development is named the "stage of concrete operations".

11 or 12–15 years old: Interiorized psychological operations have further developed on the foundation of the former stage. Operations are no longer restricted by concrete objects, and their contents and forms have completely separated. Operations have reached an advanced level in which they can be carried out through propositions and hypotheses. Thus, this stage is named the "stage of formal operations" or "stage of propositional operations".

Through the above analyses, it is not difficult to note that "operation", as Piaget's basis or criterion in dividing children's cognitive development stages, is of the nature of what is generally referred to as "thinking". More precisely, it is equal to "abstract logical thinking", which uses language concepts as the processing materials of thinking. This view of Piaget is clearly revealed in the above division of children's cognitive development, and more prominently in the

concrete analysis of these stages in Sect. 2.1 of this chapter. For example, during the 2–6-year-old stage, although a representative system based on representations has already been established, Piaget still thought that children's ability to interiorize psychological operations had not reached the level of operation. As reversibility and conservation have not been acquired in children's interiorized psychological operations, and since a representative system based on language concepts has not been established (which means they still cannot conduct logical thinking), this stage can only be called the "pre-operational stage" (that is, the stage of pre-logical thinking). When children are 7–11 or 12 years old, their interiorized psychological operations have reached the level of operation, but still require the support of concrete objects (which equals basic logical thinking). Thus, this stage can only be named the "stage of concrete operations" (that is, the stage of basic logical thinking). During the 12–15-year-old stage, with further advancement in their abilities to interiorize psychological operations, the cognition (thinking) of children is no longer restricted by concrete objects. They are capable of carrying out formal operations or propositional operations through propositions, hypotheses, judgments and inferences. It is the stage of advanced abstract logical thinking.

2.3.2 Major Principles for Setting the Division Criteria of Children's Cognitive Development Stages

To determine the rationality of the above division criteria, we should first discuss and set out the principles upon which the division criteria of children's cognitive development stages should be based.

It is well known that issues of cognitive development are equivalent to those of thinking development, and researches on the division of children's cognitive development stages are equivalent to those on the division of children's thinking development stages. Thinking ability concerns at least two factors: mental processing ability and mental processing materials. Mental processing ability is the manifestation of integrated abilities, namely, application of mental processing modes and strategies, and storage of mental processing materials (that means memory). It is the aforementioned ability to interiorize psychological operations. Mental processing materials refer to the various symbolic representative systems, such as representations and concepts. Thus, in dividing children's cognitive (thinking) development into stages, "mental processing ability" and "mental processing materials" should be considered at the same time. They are the major principles upon which the division criteria of children's cognitive development stages should be based. Violating this principle by only considering one of the factors will create one-sided division criteria, thus failing to guarantee rationality and scientificity.

2.3.3 Comments on Piaget's Division Criteria of "Children's Cognitive Development Stages"

Returning to Piaget's division criteria, the problem now becomes very obvious: Piaget depended solely on "operation ability" (that is, "interiorized psychological operation ability" with reversibility and conservations) to divide children's cognitive development into stages. He completely ignored the effect of the other factor ("mental processing materials") and even further restricted the first factor with reversibility and conservations. Piaget employed such restrictions to turn "operations" into a real criterion that determines the existence of logical thinking ability in children. But this also introduced irreparable defects into his division, in the following ways:

2.3.3.1 Determining the Development of Cognition (Thinking) with "Operations" Puts the "Sensory-Motor Level" Completely Out of the Scope of Thinking

Piaget's operation has not yet emerged at the sensory-motor level, and that level is thus a "non-operational stage". As stated, in Piaget's perspective, "operations" share the same nature with what is generally called "thinking", and the existence of operations represent the existence of thinking. In this way, the sensory-motor level is a stage when there is no real thinking, and therefore Piaget put it completely out of the scope of thinking. However, such a view is open to discussion. In fact, many experts in academic circles have recognized that there is thinking in some higher animals, and this is especially obvious in primates (such as chimpanzees) which have already acquired the ability to solve problems with simple tools (for example, they get fruits in high places by connecting bamboo rods) (He 2000). This kind of ability is actually similar to the thinking ability of infants of about 1-year old (i.e. infants in the fourth or fifth sub-stage of the sensory-motor level. As mentioned above, infants at the fifth sub-stage can, for example, get a doll which is out of reach by pulling the bed sheet). Why is it, then, that thinking ability in animals is recognized, but similar intelligence in human infants is not? Humans actually evolved from animals. Although thinking in humans is essentially different from that of animals, but this does not mean that there is an insuperable gap between them. Indeed, infants gradually develop animalistic thinking from the start of the third sub-stage (the emergence of the Copernican revolution) of the sensory-motor level. Such animalistic thinking shares the same characteristics with the general thinking of humans. It also includes "interiorized psychological operations" and "mental processing materials".

As mentioned, the third sub-stage of the sensory-motor level is also called "Formation of Purposeful Reactions". During this sub-stage, there is a gradual differentiation between infants' behaviour (method) and the result of the behaviour

(goal), which at last allows infants to acquire the ability to reach a certain goal by performing a particular behaviour—at first, there is a certain goal in mind, and then execution by the four limbs is commanded (to perform a particular behaviour). Without doubt, before executing such behaviour, the cognitive subject must first complete the related procedures psychologically (that is, interiorized psychological operations), or else he would not be able to command the movements of the limbs. In other words, basic interiorized psychological operations do not emerge, as Piaget proposed, at the end of the sensori-motor level (Sub-stage 6), but already exist at the third sub-stage. As for mental processing materials, though the more advanced representative systems based on **representations** and **concepts** have not yet been formed at the sensori-motor stage, the concrete image of objects can still be used as materials for mental processing. This is the **common ground** of human and animal thinking. Both animals and humans are capable of using “concrete image of objects” as the mental processing material for thinking.

The **differences** between human and animal thinking are as follows: “Concrete images of objects” constitute the only mental processing material used by animals, but for humans, mental processing materials include not only “concrete images of objects”, but also various representative systems, including, “representations of objects”, “language-based concepts” and “other symbol-based representations” (for example, gestures, postures, semaphore). More importantly, humans basically use only the two representative systems of representation and concept (“concrete images of objects” are rarely used) as the processing materials of thinking. This is the fundamental difference between human thinking and animal thinking.

Here, the two different concepts of “concrete images of objects” and “representations of objects” should be clearly distinguished. The former (**concrete images of objects**) refers to the impression that the now perceiving object has left in the mind of the perceiving subject. Although such impression can continue to exist without the presence of the concrete object, it reflects the total impression of the particular object at the moment, and it cannot be decomposed or integrated. Thus, the concrete images of objects do not embrace generality, but only concreteness and intuitiveness. The latter (**representations of objects**) refers to the impression that a formerly perceived object, which is not perceived currently, has left in the mind of the perceiving subject. These impressions exist even after being detached from concrete objects, and can be decomposed or integrated. Thus, representations of objects comprise not only concreteness and intuitiveness, but also generality (Zhu and Lin 1991). This is what enables humans to perform advanced thinking activities, such as analysis, integration, abstraction, generalization, association and imagination, through representations. Animal thinking based on “concrete images of objects” can never carry out such activities.

Thus, it can be seen that excluding the sensori-motor level from the scope of thinking is unreasonable. Scientifically, the sensori-motor level should be named

the “stage of animal thinking” (that is, a “lower stage of thinking development” when the mental processing materials are concrete images of objects). This would make possible a clearer recognition of the relations and differences between humans and animals, and a deeper understanding of the nature of thinking, which in turn would direct us towards a more conscious effort to enhance development in human thinking.

2.3.3.2 Determining the Level of Cognitive (Thinking) Development with only the Level of “Operations” Downplays the “Pre-thinking Stage” or “Quasi-thinking Stage”, Which Does Not Consist of Logical Thinking, but only of Representational Thinking

As stated in Sect. 2.1 part 2 of this chapter, the representative system based on representations has already been established during the “pre-operational level”, and children at that level are able to use representations as the mental processing materials for thinking, which means that they have already acquired representation-based imagery thinking and intuitive thinking. However, as their interiorized psychological operations have not acquired reversibility and conservation, and in particular, as the representative system based on language concepts has not been established (they are not able to carry out logical thinking), they are still unable to perform operations. Thus, this stage of children’s cognitive (thinking) development is named “pre-operational”. As mentioned above, Piaget equated “operations” with general “thinking” (more precisely, “abstract logical thinking”), and by defining this stage as the “pre-operational level”, he implied that, during this stage, children’s cognitive development is still at the level of “pre-thinking” or “quasi-thinking”, which means that there is still no real thinking during this stage. Downplaying or even denying representation-based thinking means downplaying or even denying imagery thinking and intuitive thinking as well (because both these kinds of thinking employ representations as mental processing materials). This is precisely one of the most serious academic flaws in Piaget’s stage theory of children’s cognitive development and even in his “genetic epistemology”. In the twenty-first century, no one would ever doubt the importance of imagery thinking and intuitive thinking, not to mention denying them. In fact, during the previous century, long before Piaget published his “genetic epistemology” (1970), lots of famous artists and scientists had already discussed the importance of representational thinking. For example, the world-famous aesthetics master and founder of art psychology, R. Arnheim, had published a monograph of 500-odd pages in the 1960s. This monograph provides a thorough and detailed discussion on the nature, characteristics and importance of representation-based thinking (Arnheim 1969). With lots of convincing facts, Arnheim

proved that representational thinking is not of a low level, but conversely, it is the most basic form of human thinking. Early in 1945, the greatest physicist of the Twentieth century, Albert Einstein, had already given a very precise description on two important stages of thinking processes during creative activities: at the first stage, imagery thinking and intuitive thinking are employed to grasp the nature and properties of objects or the implicit relationships between complicated matters; then, one would proceed to the second-stage selecting the suitable conceptual terms for logical analyses and inferences (that means logical thinking), so as to prove and examine the correctness of imagery thinking and intuitive thinking. Obviously, Einstein focused more on the effect of the first stage during creative activities, i.e. the effect of intuitive thinking and imagery thinking. Because of this, he clearly claimed, "I believe in intuitions and insights". Thus, it makes one extremely sorry to see that, as the arbiter of psychology, Piaget was still stubbornly downplaying and even denying representation-based thinking in the 1970s in his researches on children's cognitive development. It is easy to imagine what a negative impact it will result from dividing children's cognitive (thinking) development on the basis of such a perspective and employing it as the theoretical basis for cultivating and educating children.

2.3.3.3 Determining the Level of Cognitive (Thinking) Development with only the Level of "Operations" Involves Merely the General Development of Logical Thinking at "The Stage of Concrete Operations" While that of Imagery Thinking and Intuitive Thinking is Excluded

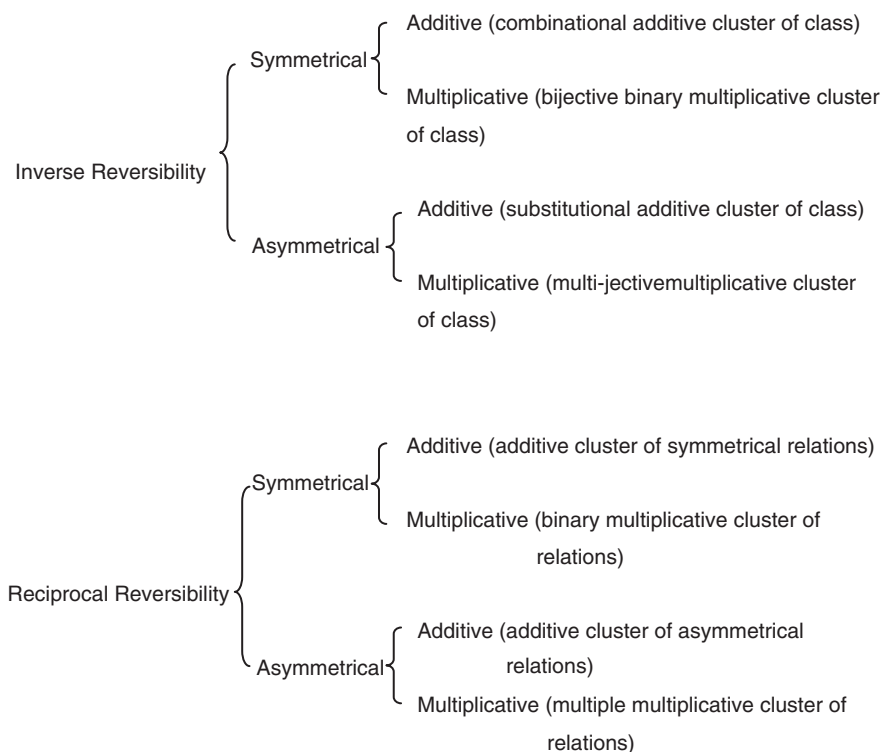
As mentioned in Sect. 2.1 part 3 of this chapter, Piaget further divided the stage of concrete operations into two sub-stages. The major hallmark of sub-stage 1 is the formation of reversibility and conservations in children's thinking (as transitivity and conservations are closely related, the formation of conservations implies also that of transitivity). Sub-stage 2 is mainly hallmarked by the gradual increase in children's interest in exploring causal relationships.

Here, reversibility, conservations and causal relationships are the basic properties and relations of formal logic. As mentioned, there are two forms of reversibility, "inversion" and "reciprocity", and their logical expressions are as follows:

$+A - A = 0$ (Inversion)

$A = B, B = A$ (reciprocity)

Piaget believed that children at the stage of concrete operations should be able to master the eight cluster structures formed by three layers, which comprise the two types of reversibility mentioned above, symmetrical and asymmetrical, additive and multiplicative (Piaget 1950; Li 1999):



Based on the above, Piaget thought that children at the stage of concrete operations, who have attained reversibility and conservations in thinking, should be able to perform logical operations of the following five groups (Zhu and Lin 1991):

- ① **Combinability** (For example, $A < B$, $B < C$ can be combined into a new relationship $A < C$)
- ② **Reversibility** (For example, $A + B = C$, $C - B = A$)
- ③ **Associativity** [For example $(A + B) + C = A + (B + C)$]
- ④ **Identity** (Any operation has an opposite operation that can combine with it to form “zero operation”, such as $A - B = 0$)
- ⑤ **Tautology** (Repetition of quality without changing the property, that means $A + A = A$)

The above analysis shows that at the stage of concrete operations, nearly all contents of operations are directly imported from formal logic and are related to the general development of logical thinking. (This is closely related to the fact that the concept of “operations” itself is introduced directly from formal logic.) None of the content is related to the development of imagery thinking or intuitive thinking, not even the most basic one. As an extremely important stage of children’s cognitive (thinking) development, the stage of concrete operations (children at this stage are of 7–11 or 12 years of age, still in their primary school years) comprises merely the development of logical thinking, but without the development of

imagery thinking and intuitive thinking. Is it not then very strange and ridiculous? If such a theory is employed to guide the education of the whole primary school stage, can we really train talents with real creative minds? Unfortunately, until now, the majority of secondary and primary schools in the world, including those in China, still regard Piaget's stage theory of children's cognitive development as the golden rule.

2.3.3.4 Determining the Level of Cognitive (Thinking) Development with only the Level of "Operations" Involves Merely the Advanced Development of Logical Thinking at "The Stage of Formal Operations" While that of Imagery Thinking and Intuitive Thinking is Excluded

As mentioned in Sect. 2.1 part 4 of this chapter, the stage of formal operations has several basic characteristics, which include separation of the forms and contents of thinking; ability to perform various kinds of logical reasoning with hypothetical propositions; and attainment of another two typical formal operation structures (combinatorial system based on bi-propositional operations and INRC quaternary conversion group). Everyone who have studied logic and mathematical logic would be able to spot at a single glance that nearly all of Piaget's discussion in this part is directly related to logic (for example, propositions, hypotheses, judgments, inferences, conjunction, disjunction and implication) or mathematics (such as the various combinatorial systems of operation and the INRC quaternary conversion group or other conversion group), and there is little about psychology. Thus, many readers come up with the doubt: "Is this part related to the issues of thinking and psychology?" We can certainly view that part as meaning to be the method of cultivating the necessary capability of advanced abstract logical thinking, which means regarding it as a necessity for the advanced developmental stage of logical thinking. If this be so, we can demand, with equal reason, the introduction of the necessary capabilities for the advanced developmental stages in imagery thinking and intuitive thinking. This is because, for a person of real talent with genuine creative thinking ability, advanced abilities in logical thinking, imagery thinking and intuitive thinking are equally important, and none is dispensable. (As mentioned above, masters such as Einstein and Arnheim even put more focus on the latter two.) It is really unfortunate that such an important issue was once again neglected by Piaget.

What then is the reason for this repeated neglect of imagery thinking and intuitive thinking? Is it because, when compared with logical thinking, imagery thinking and intuitive thinking are not divided into two stages with a basic level and an advanced level, but are more primitive with only one single level? No. Logical thinking can be divided into a lower "empirical logical thinking" and an advanced "theoretical logical thinking" (theoretical logical thinking is just the same as abstract logical thinking, which children should master and do master during the stage of formal operations) by considering whether the cognitive subject relies on

concrete objects when he makes judgments and inferences with language concepts (mental processing materials). Similarly, imagery thinking can be divided into “reconstructed imaginations” (general imagery thinking) and “creative imaginations” (advanced imagery thinking) by considering whether the cognitive subject creates original and unique property representations of new objects as a result of his reconstruction and processing of different objects’ property representations with association and imagination. Intuitive thinking can also be divided into “general intuitive thinking” and “complex intuitive thinking” (that is, advanced intuitive thinking) by considering whether the cognitive subject employs simple relation representations of objects (such as relation representations concerned only with flat surface or spatial locations) or complex relation representations of objects (for example, relation representations that concern human relationships or logical and semantic relationships between objects) as their mental processing materials in carrying out intuitive thinking.

This proves that it is not by accident that imagery thinking and intuitive thinking are neglected once again at the stage of formal operations. Their repeated neglect is the result of Piaget’s deep-rooted academic bias of focusing on logical thinking and downplaying representational thinking. As stated, this is the greatest flaw and error in his academic thought. This error has introduced an irreparable defect into Piaget’s stage theory of children’s cognitive development, and it is a pity to see that his “stage theory of children’s cognitive development” is equivalent to a “stage theory of children’s logical thinking development”. To recapture the true colour of Piaget’s stage theory of children’s cognitive development and prevent it from giving the public (and even the psychology circle) the faulty belief that it is how children’s cognition (thinking) should develop, I sincerely hope that Piaget’s stage theory of cognitive development can be renamed by such a term (or at least to understand its true meaning in this way). The above analyses prove that the new name (that is, stage theory of children’s logical thinking development) is the most faithful way of capturing the original and true meaning of Piaget’s stage theory of children’s cognitive development.

2.4 Practices of Education Reform: Questioning Piaget’s Division of “Children’s Cognitive Development Stages”

In the section above, the research outcomes of modern thinking theories (especially those of creative thinking theories) were used to make a serious and detailed analysis of “operations”, which is Piaget’s division criterion for dividing or distinguishing children’s cognitive development stages. The previous section also pointed out the theoretical lopsidedness of this division criterion and the irrationality and unscientific nature of its resulting division. In the following, our more than 5-year experience in the innovative experiment on leapfrogging development approach in language teaching will be used to examine the gap between Piaget’s stage division and practices of the current education reform.

The overview, outcomes and important experiences of the Leapfrogging Development Experiment have been recounted in Chap. 1 of this book, and so they will not be repeated here. It should be emphasized that this innovative experiment is web-based and that it achieved progress acceleration through a dynamic integration of character recognition, reading and writing (rather than separating them as in traditional teaching) by information technology. The experiment is named “Leapfrogging Development Experiment” because the teaching effect and efficiency required to attain the targets of the experiment are at least double those needed in reaching the traditional targets.

As mentioned, the experiment aims mainly at students in primary 1 and 2. The experiment commenced at the beginning of the new term in September 2002, and the students were all about 6 years old at that time. Tests and assessments were made near the end of the first and second academic year (the end of the second and fourth semester) to examine the effect and outcomes of the experiment. At the end of the second academic year, most students had just turned 8 years old. That is to say, students in the experimental classes were around 6–8 years old at the time of the experiment. They were at the end of Piaget's pre-operational stage or at the beginning of the stage of concrete operations. Originally, when the students were at that stage (which also means at the end of stage 2 and the beginning of stage 3), it might seem that a comparative analysis should have been made between Piaget's children's cognitive development level and the actual level attained by the experimental class students at this stage, so as to find out if there were any problem and to gather experience. Yet, as the actual cognitive development level of the students enrolled in our experimental classes with leapfrogging development was generally higher than that of the control classes, we postponed the comparative analysis to the next cognitive development period—that is, to the end of stage 3 and beginning of stage 4, rather than the original end of stage 2 and beginning of stage 3 period. This also meant comparing the cognitive development level of children at the end of the stage of concrete operations and the beginning of the stage of formal operations (this is equivalent to the expected cognitive development level of 10-year-old children) with that actually attained by students in our experimental classes. As mentioned above, students in our experimental classes were only 6–8 during the experiment. This means that, according to Piaget's theory, the expected cognitive development level of 10-year-old children was used to make a comparison with that of our experimental class students.

As stated in Sect. 2.1 part 3 of this chapter, children at the stage of concrete operations have five basic characteristics in their cognitive development:

- ① **Concreteness.** This is the major basic characteristic of the stage of concrete operations (with the formation of abstract concepts at this stage, children have acquired the ability of logical thinking. However, this ability is still at its preliminary stage and needs the support of concrete objects).
- ② **Possess conservations in thinking** (But some conservations can only be attained at the later stage of this stage)
- ③ **Possess reversibility in thinking**

④ **Possess transitivity in thinking**

- ⑤ **Frequent disequilibrium in cognition.** This shows that at this stage (especially at the latter half of the stage), children have a stronger interest and need in exploring the causal relationships between objects.

As mentioned in Sect. 2.1 part 4 of this chapter, children at the stage of formal operations have the following three basic characteristics in their cognitive development:

- ① **Commencement of separation of form of thinking and content of thinking**
- ② **Capable of carrying out various kinds of logical reasoning with hypothetical propositions**
- ③ **Possess specified structure of operation**

In these three characteristics, ① involves the forms of operations, ② involves the contents of operations, and ③ involves the structures of operations. This shows that by focusing on the development of children's cognitive ability, the major characteristic of the stage of formal operations can be summarized in one phrase: **“Logical reasoning based on hypothetical propositions with separation of form and content”**.

Piaget's theory states that children's cognitions develop in a lower to higher level sequence. Children must go through the developmental stages one by one without skipping any. This clearly points out that in children's cognitive development, the expected highest requirement of one stage is the expected basic requirement of its following stage. For the stage of concrete operations, its highest requirement is the basic requirement for the stage of formal operations. The above analysis of the “major characteristics of the stage of formal operations” clearly reveals that the basic requirement of the stage of formal operations (which is also the highest requirement of the stage of concrete operations) must be “logical reasoning based on hypothetical propositions with separation of form and content”.

It has been pointed out that the highest requirement in the latter stage of concrete operations is equivalent to the expected cognitive development of a 10-year-old child. “Highest requirement” refers to the greatest extent which the cognitive ability of children can reach at this cognitive development stage (or at this age group). This clearly shows that **“logical reasoning based on hypothetical propositions with separation of form and content” is the highest cognitive development requirement which can only be attained by 10-year-old children**. This is a completely logical conclusion deduced in strict accordance with Piaget's theory. However, is this conclusion scientific? That is to say, is this resulting conclusion of Piaget's criterion for dividing children's cognition development stages really objective and realistic?

In order to make a comparison between the actual cognitive development level acquired by the experimental class students and the result of Piaget's theoretical analysis, a method for collecting related information that can realistically reflect the thinking achievements of students must first be found. There are various methods: conversation, experiment, test, clinical method, etc and Piaget chose to use

his own unique “clinical method”. This clinical method depends mainly on verbal conversations and is supplemented by direct observation and physical operations. It can also be carried out on a basis mostly on physical operations supplemented with observation and questions. Whichever of these two methods is employed, the best outcome can only be gained with the dynamic integration of physical operations, verbal questioning and direct observation.

Piaget's clinical method has both pros and cons. For example, some questions may put pressure on the testee or do not interest him, so he refuses to answer it or just muddles through it, which results in a failure to gather realistic test data. Other than that, some questions may be implying and suggesting, which would also affect the authenticity of the test result. In light of all these, we hope to collect the thinking achievements that children produced consciously and willingly in an environment without any external pressure and restriction. These thinking achievements will be used as the basis for finding out the students' development in cognitive ability and in conducting a comparative analysis with the theoretical “highest requirement” (“Highest requirement” here refers to the aforementioned **“highest cognitive development requirement which can only be attained by 10-year-old children”**, which is deduced in accordance with Piaget's division of children's cognitive development stages). After consideration and comparison of many different aspects, it is firmly believed that “the selected pieces of online exercises by experimental class students” best suit our requirements as mentioned above. This is because these online exercises were posted consciously and willingly by the students as they would like to communicate with the teachers or tell the teachers their innermost feelings (rather than controlled composition writing). These exercises were collected and published by teachers without any change in the wordings, and thus can reflect most faithfully the students' ideas and cognitive development status.

Following are the exercises of some of the experimental class students and our comments. (On the first line is the name of the student, and from the second line onward are extracts from the exercises. Words in brackets are added by the author to facilitate reading.)

Student 1: Xian Meng Jia

Extract of the exercise: “Through lots of games, I learnt to understand forest signs and how to deal with enemies, how to take care of the wounded, this is actually a military training to me¹”.

Explanations and comments: The school had arranged a spring outing to Nan Ao (a tourist spot near Shenzhen) and played games there. The composition of Xian Meng Jia describes the whole course of this activity, and the above extract is its last paragraph. In this paragraph, Xian induced the general conclusion, “this is actually a military training to me” through the military training-related examples of “learnt to understand forest signs”, “how to deal with enemies” and “how to

¹The student made a grammatical mistake in his original Chinese composition here concerning the usage of “我” (literally means “me”) and “我的” (literally means “mine”).

take care of the wounded”. This shows that Xian had already mastered inductive reasoning, which moves from specific facts to general conclusion.

Student 2: Li You Xin

Extract of the exercise: “My favourite people are: Father and mother.....Although they are usually very strict to me, but I know that it is for my own good. Under their guidance, I get known to lots of logic, learnt lots of knowledge, in future, I should show even more respect to them, and be a good child who obeys her parents”.

Explanations and comments: The extract actually involves three examples of categorical deductive reasoning based on a proposition.

[Reasoning 1]: All strict demands urge people to improve,
(Proposition 1, universal categorical judgment, major premise)

My parents have strict demands on me,
(Proposition 2, singular categorical judgment, minor premise)

Thus, my parents urge me to improve. (Conclusion)

[Reasoning 2]: All people who urge me to improve cherish me and care for my well-being.

(Proposition 1, universal categorical judgment, major premise)

My parents urge me to improve.

(According to the conclusion of reasoning 1)

(Proposition 2, singular categorical judgment, minor premise)

Thus, my parents cherish me and care for my well-being. (Conclusion)

[Reasoning 3]: Anyone who wants to get known to logic must obey their parents.

(Proposition 1, universal categorical judgment, major premise)

I want to get known to lots of logic.

(Proposition 2, particular categorical judgment, minor premise)

Thus, I must obey my parents (be a good child who obeys her parents).
(Conclusion)

Student 3: Chen Yao

Extract of the exercise: “The annual “May 1” Festival has come, my father had already planned a trip back to the hometown Chaozhou in these 7 consecutive public holidays, because the shrine festival, which is held every 20 years, of their hometown will be held this year, so we must rush back to the hometown on April 30 of the solar calendar. I feel very unhappy, originally I would be participating in the ancient poem recitation competition today, I had prepared for it for a long time, and it is also a rare chance for me to be a little hostess! But my father must have me take a leave, or else I am unfilial. Succumbing to my father’s authority, I could only agree with his (opinion) and took a leave, but I feel very bad”.

Explanations and comments: This paragraph involves two types of reasoning, hypothetical reasoning and categorical reasoning.

[Hypothetical reasoning]: Not attending the shrine festival means unfilial,

(Proposition 1, hypothetical reasoning with sufficient condition, major premise)

I am not an unfilial person,

(Proposition 2, singular categorical judgment, minor premise)
Thus, I should attend the shrine festival. (Conclusion)
[Categorical reasoning]: All trivial matters must submit to important matters,
(Proposition 1, universal categorical judgment, major premise)
Comparing with the shrine festival, participating in ancient poem recitation and
be a little hostess are trivial matters,
(Proposition 2, singular categorical judgment, minor premise)
Thus, I can only let the former submit to the latter. (Conclusion)
Even though the little author Chen Yao (6 years old) was not happy, she recog-
nized the correctness of the result of logical reasoning. So she acted rationally and
was able to control her emotions rather than letting them affect her. This is diffi-
cult even for adults.

Student 4: Yuan Bo

Extract of the exercise: “My eyesight becomes poorer, I must do more eye exer-
cises, and pay attention to protect my eyes....In future, I must protect my eyes
better, use my eyes scientifically, and lay a good foundation to my future studies”.
Explanations and comments: This extract involves one example of hypothetical
reasoning and one of categorical reasoning.

[Reasoning 1]: If we lack eye exercise and care,
our eyesight will become poorer,
My eyesight becomes poorer,
Thus, my poorer eyesight may
have resulted from a lack of
exercise and care.

(hypothetical reasoning)

[Reasoning 2]: In order to protect our eyes
well, we need to use our eyes
scientifically and do more eye
exercises,
I want to protect my eyes well,
Thus, in future, I must use my
eyes scientifically and do more
eye exercises.

(categorical reasoning)

[Reasoning 1]:	If we lack eye exercise and care, our eyesight will become poorer, My eyesight becomes poorer, Thus, my poorer eyesight may have resulted from a lack of exercise and care.	(hypothetical reasoning)
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[Reasoning 2]:	In order to protect our eyes well, we need to use our eyes scientifically and do more eye exercises, I want to protect my eyes well, Thus, in future, I must use my eyes scientifically and do more eye exercises.	(categorical reasoning)
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Student 5: Zhang Jun Hao

Extract of the exercise: “My little brother was playing beside me. Suddenly, my little brother let out “wow” and started crying, the whole family rushed to see him. May be my little brother wanted us to pay attention to him, he had reached his goal, and thus he laughed. Don’t you think he was cunning? My little brother used crying as a method to get others’ attention and to reach his goal, he was really quite cunning”.

Explanations and comments: This extract involves an example of two-limbed hypothetical reasoning (its major premise is a two-limbed hypothetical judgment) and an example of categorical reasoning).

[Reasoning 1]: Pretending or using a not
rightful strategy means playing
a trick,
My little brother pretended to
be crying,
Thus, my little brother was
playing a trick.

}

(two-limbed hypothetical
reasoning)

[Reasoning 2]: Using tricks to achieve any
particular goal is cunning,
My little brother used trick to
get others’ attention,
Thus, my little brother was
rather cunning.

}

(categorical reasoning)

Student 6: Tang Tian

Extract of the exercise: “Eastern Wu had ordered Commander-in-Chief Lu Xun to lead a large army of a hundred thousand soldiers to attack Shu, Liu Bei asked for a strategy to defeat the enemy. Zhuge Liang said, “Sun Quan has a senior general Zhou Tai, who is extremely brave and fierce, but, he dislikes Lu Xun the most, and also has an unyielding character. He will definitely attack (in a hurry), and Lu Xun will definitely failed to stop him, thus, we can lay an ambush to annihilate him”.

Explanations and comments: This is the beginning paragraph of the first chapter, “Strive for Supremacy: Shu and Wu”, of Tang Tian’s novel, “*New Romance of the Three Kingdoms*”. From 9 April, 2001 to the end of May that year, in just

1-month time, Tang had written five chapters for his *New Romance of the Three Kingdoms*, amounting to more than 9500 words. At the end of primary one, he had composed seven chapters which amounted to more than 17, 000 words. His work displays rich imagination and higher level logical thinking. This paragraph involves the following complex logical reasoning (the first two are categorical reasoning, and the third one is a two-limbed hypothetical reasoning).

- | | | |
|--|---|--|
| <p>[Reasoning 1]: All brave and fierce generals
press for victory and will attack
in a hurry,
Zhou Tai is a brave and fierce
senior general,
Thus, Zhou Tai will definitely
attack in a hurry.</p> | } | (categorical reasoning) |
| <p>[Reasoning 2]: Anyone who dislike a particular
person will refuse to listen to
the advice of that particular
person,
Zhou Tai dislikes Lu Xun the
most,
Thus, Zhou Tai will certainly
refuse to listen to Lu Xun's
advice (definitely failed to stop
him).</p> | } | (categorical reasoning) |
| <p>[Reasoning 3]: If we lay an ambush and the
enemy comes in a hurry, we
can annihilate the enemy,
Zhou Tai will definitely come in
a hurry, (according to the
conclusions of reasoning 1 and
2)
Thus, the Shu army can surely
annihilate the Wu army by
laying an ambush.</p> | } | (two-limbed
hypothetical reasoning) |

Student 7: Huang Xu

Extract of the exercise: "The cunning fox caught the cock as soon as it jumped up, as it was trying to eat the cock, the cock said, "Bro fox, you break your words. But, it's good if you eat me, I have bird flu anyway, it will prevent me from suffering then". The fox heard it, believed it, and put down the cock and rushed to the

river to wash its hands, it was afraid that it would be infected, and never dare to come for the cock again. The clever cock used wisdom² to defeat its enemy”.

Explanations and comments: When Huang was writing this piece, there was bird flu near Shenzhen in Hong Kong. Huang Xu used this instance to compose this creative and good work to “give some ideas to the cock”. The above extract involves the following three examples of reasoning (two of categorical reasoning and one of hypothetical reasoning).

[Reasoning 1]: All kinds of flu are infectious, I had bird flu, Thus, I will infect it to others.	} (categorical reasoning)
[Reasoning 2]: Infectious diseases will endanger the lives of others, I will infect others, Thus, I can endanger the lives of others.	} (categorical reasoning)
[Reasoning 3]: If I tell the fox that I have infectious disease, it will stay away from me because it is afraid, Now, I tell the fox that I have infectious disease, Thus, the fox will stay away.	} (hypothetical reasoning)

Student 8: Xiao Feng

Extract of the exercise: “My little cousin is only one, he wears two pigtails, round eyes, has a face like a red apple, white and neat teeth, and has sweet voice when speaking. She is very politely, she will address female as aunt when she meets them, and male as uncle. When she came to my home to play last time, I taught him to recognize the characters “大” [literally means “big”] and “太” [literally means “excessive”], she remembered immediately that “大” has one dot less. We all said that she is a clever child”.

Explanations and comments: The author of this piece was only six, and the cousin in the writing was only about one. Children do not tell lies and Xiao Feng’s description of his 1-year-old cousin’s behaviour is real and believable. This reveals that (at least some) infants of about 1-year old who can speak have already acquired the basic ability to use language concepts for abstraction and generalization, because the cousin “will address female as aunt when she meets them, and male as uncle”. Although it is rather rare for children of about one to acquire

²The student made a vocabulary mistake in his original Chinese composition here, misplacing “智慧” (literally means “wisdom”) with “知慧”.

such language generalization ability like Xiao Feng's cousin, such ability is not rare in children who are a little bit older. In fact, many children of 2–3 years old will address young men as “big bro”, young ladies as “big sis”, and old people as “grandpa or grandma”. This shows that these children of two or three have already mastered the basic ability to use language concepts for abstraction and generalization, and that they have also acquired the basic ability to make judgments for he (she) knows that:

If a person is a male and young, we should use “bro” to address him, If a person is a female and young, we should use “sis” to address her, If a person is a male and old, we should use “grandpa” to address him, ...	}	(hypothetical reasoning with sufficient necessary conditions)
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An even more surprising example was experienced personally by the author of this book. I have a granddaughter who is now 11 years old. When she was 3.5-year old, an unforgettable incident happened. It was a Sunday. My son (who is also the uncle of my granddaughter) joked with my granddaughter. He held a big piece of chocolate in his hand and said, “Call me papa and I’ll give you the chocolate”. At the beginning, my granddaughter refused to do so, but eventually she could not refrain from the temptation of the chocolate and called him “papa” once. As soon as she finished the chocolate, she gazed at her uncle and said, “You are my uncle, not papa. There is only one papa in one home, not two”. (Author’s note: “There is only one papa in one home, not two” is an abstract judgment that this child of three and a half made.) Her uncle was unhappy to hear that and thought that she was too crafty in changing her words just as she finished the chocolate, and returned, “I’ll never buy you chocolate anymore”. My granddaughter heard it and immediately rebutted, “If you really want to be a papa so much, why don’t you find a girlfriend and have a child”. I was sitting by their side at that time and was greatly surprised to hear her words. They seemed simple, but they involved a rather complex piece of hypothetical reasoning: “If you want to be a father, you have to have your own child; If you want to have your own child, you need to have your own wife first; If you want to have a wife, you need to get a girlfriend first”. This is a complex reasoning process which involves several hypothetical propositions. I was too surprised to believe that a child of three and a half had voiced them. This shows that in our age, some pre-school children not only master the basic ability to employ language concepts in making generalization and judgments, but also have a certain capability in logical reasoning based on hypothetical propositions.

There are still numerous online exercises and daily examples like the above. The case of a 3.5-year-old child possessing basic capability of generalization,

judgments and reasoning may be viewed by some as an individual case or exceptional case. However, the pieces of selected online exercises produced by the experimental class students in primary one and two should be sufficient to prove that with appropriate education, children of 6–8 are fully able to master this capability—including the ability of logical reasoning based on hypothetical propositions. Yet, according to Piaget’s theory, such **“logical reasoning based on hypothetical propositions with separation of form and content”** is regarded as **“the highest cognitive development requirement which can only be attained by 10-year-old children”**. But the reality is an embarrassment to that authoritative theory.

The above daily examples and online exercises which faithfully reflect the inner voice and wisdom of students are intended to show that in Piaget’s children’s cognitive development theory and especially in the resulting stage division of his division criterion, there are at least three defects:

1. Imposing a Mechanical Fixed Division of Children’s Cognitive Development Stages. Putting Too Much Emphasis on Innate Genetic Factors while Neglecting the Influence of Language Environment and Effect of Education

This view is especially harmful in the Information Era. It is common sense that with the popularization of television, multimedia and Internet, people acquire information and knowledge quicker and easier. The quality and quantity of the acquired information and knowledge greatly improved. There is also an obvious acceleration in the progress of children’s cognitive development. Piaget failed to recognize that although the stages and order of this development are unchangeable, they can be greatly compressed and started much earlier with the support of appropriate education and in an information technology environment. Development stages are not unchangeable in length of time. If children’s cognitive development is viewed within Piaget’s mechanically divided fixed age groups (0–2, 2–6, 7–10, 11 or 12 onwards), great restriction and limits will be imposed on our basic education, especially primary education.

2. Believing that at the pre-operational stage (2–6 years old), there is only representation-based thinking but no language concept-based logical thinking. Believing that there is no hypothetical proposition-based abstract logical thinking at the stage of concrete operations (7–10 years old), but only representation-based thinking and basic logical thinking that relies on concrete objects

That is to say, the language foundations of pre-school children aged 5–6 are still very weak, and consequently these children do not have sufficient language concepts to support abstract logical thinking. A direct conclusion from this is—in teaching language subjects (and other subjects) in junior and middle primary grades (primary 1–4), emphasis should only be put on visualized teaching with images and cultivation of imagery thinking based on representation rather than cultivation of abstract logical thinking. Even when it is in the senior primary

grades (primary 5–6), cultivation can still only be focused on basic concrete object-dependent logical thinking rather than advanced abstract logical thinking. Such a viewpoint is extremely harmful to language teaching in primary schools and the development of language ability in primary school students. It is well known that language and thinking are inseparable. On the one hand, language is the material shell of thinking. Humans cannot perform advanced logical thinking without language. On the other hand, thinking ability has a decisive effect and restriction on the formation and development of language ability. If primary school students are still at the stage of basic concrete object-dependent logical thinking in their senior primary grades (primary 5–6), then their reading and writing abilities will surely be poor. (In the following, the research outcomes of modern child psychology and child linguistics will be used to prove that that viewpoint of Piaget is completely inconsistent with the reality.)

3. Being concerned only with the development of logical thinking ability in the process of children's cognitive thinking while completely neglecting that of representation-based thinking ability. Factitiously separated logical thinking and representational thinking, which is detrimental to the cultivation of creative thinking in children

It has been pointed out in Sect. 2.3 of this chapter that when Piaget used “operations” as the criterion for dividing children's cognitive development stages, he was actually employing “logical thinking” as the criterion while not taking into consideration any representation-based thinking. (Representation-based thinking includes imagery thinking and intuitive thinking.) In fact, human's language concept-based logical thinking and representation-based thinking are interdependent and inseparable, and they develop concurrently. The above online exercises of the experimental class students also show that the outstanding pieces among them are usually the products of a better integration of logical thinking and representational thinking. Separating these two types of thinking factitiously (or even making them hostile to each other) is not only harmful to the development of representational thinking, but also to that of logical thinking. Without sufficient development in logical thinking and representational thinking (that means imagery thinking and intuitive thinking), creative thinking and creative talent are completely out of the question. Thus, it is vital for us to drop Piaget's viewpoint which focused on logical thinking but neglected representational thinking, and abandon using “operations” as the standard for dividing children's cognitive development stages. A dynamic integration of logical thinking and representational thinking (or more precisely, a dynamic integration of logical thinking, imagery thinking and intuitive thinking) should commence seriously from the very beginning of primary school (and even since the junior primary grades) in language teaching and also in the teachings of other subjects. It is only in this way that basic education can act as a foundation for the cultivation of a large group of innovative talents with extremely creative minds.

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