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Understanding and facilitating the development of intellect

*by Andreas Demetriou
and Constantinos Christou*

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Series Preface

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The International Academy of Education is grateful to Professor Andreas Demetriou for writing the present booklet. Andreas Demetriou is currently Professor of Psychology and President of the University of Nicosia Research Foundation. Prior to his present position, he was a professor of psychology at Aristotle University of Thessaloniki, Greece (1975-1996), and the University of Cyprus (1996-2008). He has served in high-level academic and administrative positions, such as Vice-Rector of the University of Cyprus, President of the Cyprus University of Technology, President of the Conference of Rectors of the Universities of Cyprus and also Minister of Education and Culture of Cyprus. He is a fellow of Academia Europaea and the International Academy of Education, an Honorary Doctor of Middlesex University, London, an Honorary Visiting Professor of the Northeastern Normal University, China, and an Honorary Professor of Durham University, UK. He has developed a theory of intellectual development integrating the developmental, psychometric, and cognitive traditions and he is currently working along several lines, including basic processes underlying different cognitive domains and the educational implications of the theory. This work is published in more than 180 books and articles.

The officers of the International Academy of Education are aware that this booklet is based on research carried out primarily in economically advanced countries and that the recommendations of this booklet need to be assessed with reference to local conditions and adapted accordingly. In any educational setting, guidelines for practice require sensitive and sensible applications and continuing evaluation of their effectiveness.

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21. Principles of instruction *by Barak Rosenshine.* 31 p.
22. Teaching fractions *by Lisa Fazio and Robert Siegler.* 25 p.
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25. Nurturing creative thinking *by Panagiotis Kampylis and Eleni Berki.* 26 p.
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Table of Contents

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Introduction

Information flows continuously in the environment. As we attempt to do something, our senses receive large volumes of information. In any conversation, messages are exchanged rapidly. To understand meaning, we have to focus, record, choose and process relevant information at every moment, before it is displaced by other information. Often, information is incomplete or masked by other information or the problems to be solved are new to us. Thus, we must compare different aspects of information or other messages, and use deduction to fill in the gaps in the information, connect it with what we already know or invent solutions to new problems.

Children at school learn new concepts every day. Reading, arithmetic or science are very demanding for them. To learn, children must hold information in their heads, use previously acquired concepts to interpret new information and then change their understanding as required. These tasks are possible because we can focus on information and process it before it disappears, alternate between stimuli or concepts according goals, and make decisions based on an understanding and evaluation of information through reasoning. At the same time, we adjust our strategies according to what we already know or depending on our strengths and weaknesses.

To understand human intelligence, psychological and cognitive sciences try to specify what cognitive processes are involved in dealing with the above-mentioned tasks, how these processes change during learning, why individuals have different capacities, and how biology and culture may influence them. Any systematic attempt to improve intelligence through education would have to build on the knowledge assembled by research since the end of the nineteenth century. In this booklet we outline how the sciences of the mind view intelligence and suggest a programme for instruction that may build upon its various processes.

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1. The organization and development of intelligence

Intelligence involves multiple processes and develops along a number of fronts. To be successful, education must cater for all processes, support development and capitalize on achievements.

Research findings

Organization. Intelligence involves both general and specialized processes. They are as follows:

- *Representational capacity;* i.e. how much information we can handle and process at any given moment.
- *Abstraction and inference* involve processes enabling the student to identify patterns in information, inter-relate them, and to draw conclusions and decisions based on consistency/contradiction so that they follow logically from one another. For example, if you take it for granted that "birds fly" and "cats are birds", it follows logically that "cats fly", even if we know that this is not true. This is so because in logical inference we connect statements as given regardless of their correspondence to reality.
- *Domain-specific processes* specializing in the recognition, recording and processing of specific types of information and relationships (e.g. verbal, spatial, quantitative).
- *Cognizance,* a special part of consciousness concerned with being aware of mental processes (e.g. knowing that memory and inference are different sources of knowledge, the first drawing upon past experience and the second upon the comprehension of current information); *executive control* (i.e. knowing how to regulate different mental processes); and *meta-representation* [i.e. the production of new representations (e.g. the mental images, signs or token objects used in understanding) building upon prior representations].

Development. All four of the above-mentioned types of processes are always present in mental functioning, but their efficiency, importance or inter-relations change during learning and development. Through their own development, students can gradually deal with more representations. They become increasingly adept at using inference to connect representations and evaluate conclusions. They also invent new representations to stand for the relations between representations (e.g. the name of a class, such as "mammal", can stand for very different animals) and they can alternate flexibly between them according to the needs of the moment. Thus, the concepts or problems that children can master develop exponentially. Development transforms the dominant worldview prevailing during successive phases of life.

The infant's worldview is like a sea where separate islands are visible but are not connected. Infants possess all sorts of representations, mainly mental images of objects and events, as well as language, but they are not explicitly aware of them. Representations are not yet systematically interlinked and inference connects representational islets of understanding according to personal experience. This is the reason why in early childhood infants have very special, strongly personal, views about the world and they make logical mistakes in their inferences (e.g. they infer that a cat on a wall will fall because it previously fell off the edge of the bed). Later, at 5 to 6 years of age, representations are recognized as mental images, signs or tokens of reality that are not identical to what they represent. As a result, children start to search systematically for relationships, aligning them and inter-defining their meaning. For instance, they can identify the picture that represents an object or the digit that stands for the quantity of a particular set of objects. However, placing things in groups is still guided by personal experience and the way they are encountered in the environment rather than reality as such. Thus, for instance, stories may be made up according to the communication needs of the moment rather than truth or consistency. In terms of the islands analogy, at this age bridges start to be made between them according to experience, but no general overview is yet available to guide travelling from one to the other.

In early primary school, children begin to work out relationships between representations guided by their origin (e.g. how did I learn this or that?), their nature (e.g. numbers *versus* words) and their conceptual consistency (e.g. If I see three objects when I count, I must say "three"). This provides coherence to primary children's worldview, which becomes obvious in their conceptual networks (e.g. concepts about the animate world or the natural environment) and their relations (e.g. recognition that membership in a particular class of animals implies properties beyond those that can actually be seen). In the island analogy, maps are now available about connections between the islands, although a general overview allowing the child to choose between destinations is still missing.

In adolescence, concepts cohere within and across domains according to general principles of truth and validity, permitting an "if … then" approach that is typical in this period. Thus, an overview is in place showing how to choose and use the links connecting the islands.

Implications for educators

The nature of developing intelligence as described above suggests a number of general implications for education:

- Education must develop programmes that address each of the four types of processes involved.
- The complexity/simplicity of concepts taught at successive school grades must be aligned with the representational possibilities typically associated with the abilities of children at each grade.
- The pace of teaching of any concept must be aligned with the typical representational and processing ability of the grade concerned. Anyone may operate at a level lower than his or her optimum ability when first confronted with a new task. Thus, teaching must always start with examples demanding less than the students' optimum ability.
- The worldview associated with each major educational level (pre-school, primary and secondary) must be consolidated at the beginning of the level and then used to prepare the transition to the worldview of the next level. Pre-school children must acquire awareness of age-specific representations and build links between them. For example, they should look at a set of objects, name them, choose representations appropriate for each, and make up a story about them arranging the objects so that they match the story. Primary schoolchildren must acquire an insight into the mental processes that determine linkages. For example, teachers should explain the object/word/image connections, conceive of alternative connections and specify their similarities and differences. Adolescents must grasp the formal principles influencing these processes. For instance, they should understand how the sequences of a story necessarily follow on from one another.

Specific programmes implementing all of these general educational principles will be described in the following sections.

Suggested readings: Anderson et al., 2001; Demetriou, Mouyi & Spanoudis, 2010; Demetriou, Spanoudis & Mouyi, 2011; Demetriou et al., 2013, 2014; [Hunt, 2011; Piaget, 1970.

2. Individual differences in intelligence

Individuals differ in intelligence at any age according to their rate of learning, intellectual development and socio-economic background. Education must cater for the different needs and possibilities of different children.

Research findings

The origin of individual differences. Individuals differ in their ability to learn new knowledge and skills, and to solve new problems by appropriately modifying previous knowledge and skills. These differences may come from any of the processes mentioned in the previous section:

- Understanding often suffers in slow individuals because they fall behind the flow of events in the educational environment.
- Limited representational capacity is a disadvantage when large volumes of information must be processed.
- Limited command of the inferential processes may lead to wrong interpretations.
- Lack of domain-specific knowledge may hinder the assimilation and processing of new information.
- Limited awareness about mental processes and about one's own strengths and weaknesses may cause wrong choices.

Intelligence tests include tasks that involve all of these processes. Moreover, tasks are systematically structured in levels of difficulty that match the ability of children at different ages. Thus, the score obtained on these tests, such as intelligence quotient (IQ), is a general index reflecting the overall standing of an individual relative to other individuals, primarily of the same age. Levels of intelligence reflected in IQ are distributed in a normal manner throughout the population. That is to say, the majority of people (i.e. two-thirds of the population) have average intelligence (i.e. from 85 to 115 IQ points). In other words, they are able to solve the problems appropriate for their age. The rest are equally distributed between people with low intelligence (less than 85, because they can solve only problems that are appropriate for younger children) or high intelligence (higher than 115, because they can solve problems that are appropriate for older children), with proportions decreasing with distance from the mean of 100. Thus, the same IQ score (e.g. 120) obtained by a 5-year-old pre-schooler and a 15-year-old adolescent conveys the same information about the relative standing of these individuals: they both score higher than about 87% of their cohort. However, they would not be solving the same kind of problems. The 5-year-old child can find a solution to the problems solved by the average 6-year-old child and the 15-year-old adolescent can find a solution to the problems normally solved by adults.

Individual differences in intelligence are partly the result of heredity, but the effect of the environment is also very important, particularly during childhood.

The influence of social and cultural factors on intelligence. There are three factors that have a major impact on intelligence: social class, culture and education.

It is well established that children growing up in poor families with low levels of education have lower intelligence and slower development than children of educated or affluent parents.

There may even be specific cultural practices that relate to the overall intellectual achievements of different cultures. A good example here is the learning of the logographic system of writing in several Eastern cultures, such as Chinese. Learning this system is extremely demanding for representational efficiency from early in life, because children must learn to recognize and produce thousands of complicated visual patterns. There is evidence showing that Chinese children are faster in visual pattern recognition and have a larger capacity of working memory. This enhances general cognitive ability, providing a general advantage in information processing and problem-solving.

Education is also an important factor for intellectual development, because it improves the functioning of all of the above-mentioned processes: it strengthens the students' ability to handle information in their memory; it fosters an analytical attitude to information that facilitates abstraction and reasoning; and it sharpens students' knowledge of themselves, facilitating better learning management. These influences are reflected in both individual differences and the rate of intellectual development: there is an increase of about two to three IQ points for each extra year of schooling and a faster transition to the next development level.

In fact, access to education for an increasing numbers of people throughout the twentieth century, together with the fact that the environment has become increasingly abstract and symbolic, is associated with the so-called "Flynn effect". Flynn discovered that IQ increased by about 10 IQ points every thirty years since the beginning of the twentieth century, totalling about 30 points over the century. Interestingly, this effect came to a halt in the educationally advanced nations of northern Europe, but it is just starting in developing nations where education has only recently become widely available, thus lessening the gap in IQ between developed and developing countries.

Implications for educators

At any grade children with lower intelligence may be left behind if the demands of teaching exceed the children's current level of understanding. This effect is cumulative and, when extended over a long period of time, may result in illiteracy. This is a major educational setback affecting up to 30% of children in various countries, even in developed countries. To minimize these problems, education systems must employ the following techniques:

- Develop and use diagnostic tools able to specify the discordance between understanding capabilities, the developmental tempo of students, and teaching demands and pace.
- Develop flexible curricula in the various school subjects that would allow individualization of the teaching rate according to the abilities of individual students.
- Develop special remediation programmes to enable students who have been left behind to catch up and progress apace with their classmates.
- Pay special attention to students at risk at major developmental/educational turning points to ensure that new teaching demands proceed apace with their developmental transitions.

In the following pages we will outline programmes aiming to enhance the beneficial influence of education on each of the underlying processes of intelligence.

Suggested readings: Ceci, 1991; Demetriou et al., 2005; Demetriou et al., 2011; Gustafsson, 2008; Flynn, 2009; Hunt, 2011; Kazi et al., in press; Kyriakides & Luyten, 2009; McBride-Chang et al., 2011; Rindermann & Thomson, 2013; Winship & Korenman 1997.

3. Representational capacity

Representational capacity may be enhanced, become more durable over time, and more flexible in representing and understanding information.

Research findings

Representational capacity defines how much information a person's brain can deal with in understanding and problem-solving. "Working memory" is the technical name for representational capacity. A common measure of working memory is the maximum amount of information (e.g. number digits, words, sentences, mental images) and mental acts (e.g. numerical operations, grammatical rules, mental rotation) that the mind can efficiently hold and process simultaneously. It is widely accepted that working memory includes both specialized storage and general information management processes. Specialized storage deals with information delivered by the senses, such as phonological storage for acoustic information and visuo-spatial storage for visual information. General management processes, such as rehearsal, promote the executive control of specialized storage systems. For example, rehearsal may be used to update information until this information is used. Furthermore, the sorting of information according to special characteristics (e.g. it concerns plants and animals) may facilitate storage and recall.

Obviously, if a student cannot represent the sentences that the teacher has just spoken he/she will not be able to follow the teaching. We are all familiar with lapses in concentration when we experience moments of absent-mindedness during a presentation. With age, our ability to digest information increases from about one piece of information at 1/2 years to about five to seven pieces at 15/16 years of age. As a result, individuals can handle more representations and deal with more complex situations. Also mental processing becomes faster, better focused and increasingly controllable, so that it can shift across concepts or actions, if needed. In this way, improved control of representational capacity enhances learning and problem-solving at any age.

Implications for educators

To strengthen working memory, education must aim at three main goals:

- *To familiarize children with representational limits.* For instance, recalling an increasing quantity of numbers or words and recording the cut-off point when one is no longer able to deal with them would demonstrate what one is able to store and recall at any time. Recalling information in different ways (e.g. words presented individually or arranged into meaningful sentences) or recall strategies (e.g. in the correct order or in the reverse order) would show that different approaches influence how much information we can handle.
- *To familiarize children with its role in learning.* For example, using distracters — responding to an interruption, diverting attention from the current mental task (such as a complicated problem in mathematics) — would demonstrate that when target material is out of representational focus the solution cannot be achieved and thus understanding is not possible.
- *To increase personal control.* For example, children must be trained to manage more than one task simultaneously by alternating between blocks or types of information and inter-relate items according to type and time of presentation. Counting and naming the number of several items on one side of a computer screen and matching them with the appropriate number digit on the other side helps bring together three alternative ways of representing numbers into a general number concept. Presenting visual information on one side of a screen and a verbal description on the other side, and asking children to unite them into a complete story would help them integrate information according to the flow of events in time. Also, carrying out practice in re-organization and re-distribution would enable children to trade-off an increasing volume of information with greater semantic density of representations to be held in focus. For instance, using a generic representation, such as "fruit" as a recall marker for several objects (e.g. apple, banana, pear, etc.).

Suggested readings: Baddeley, 2012; Buschkuehl & Jaeggi, 2010; Demetriou, 2013; Demetriou et al., 2013, 2014; Pascual-Leone, 1970.

4. Abstraction and inference

Abstraction unifies experience. Inference ensures that unification is valid according to earlier knowledge or based on reason and enables children to choose between reasoning schemes.

Research findings

Relations are recognized by comparisons that can specify *similarities and differences* between objects or concepts (e.g. colour may appear to unite very diverse objects simply because they have the same colour) or their interactions in space and time (e.g. when object or event A happens, another object or event B follows). *Inference* carries properties from one situation or concept to another on the basis of similarity or their possible interactions. Information that is missing in a target situation (e.g. "Is this an animal?") is *inferred* because the two situations are similar in some respects (e.g. "They move"), so that characteristics of the known situation (e.g. "Animals move on their own") are ascribed to the new situation on the basis of their similarities ("It moves on its own, so it is an animal"). Equally, when there is correlated change with two events appearing in sequence, a causal relation may, where appropriate, be inferred (e.g. "When it gets cloudy, it rains").

Inductive, analogical and deductive reasoning are the main types of inference.

- *Inductive reasoning* may involve any kind of representation, such as perceptions, mental images or propositions. On the hand, this form is very powerful in generating concepts because it generalizes from particular observations to general conclusions. For example, one may conclude that "all swans are white" because "all swans she saw so far were white". However, on the other hand, it is limited by the fact that these conclusions are only likely and may be mistaken: for example, because there is always the possibility that there are black swans as well that were never seen.
- *Analogical reasoning* is inductive reasoning applied to relationships as such (e.g. "Wings are to pigeons as feet are to cats"—they enable them to move). It is worth noting that analogical reasoning is frequently erroneous because the analogy drawn is not appropriate or relevantly similar.
- *Deductive reasoning* is applied to propositions (or statements) and transfers meaning from the general to the specific, given the

statements already accepted. For example, if one accepts that "Birds fly" and that "Guzy [an imaginary bird] is a bird", one must also necessarily accept that "Guzy flies": the property of flying is transferred to it because it is a member of the class of birds. Thus, if the initial statements are true, and the reasoning is valid, then the conclusion is necessarily sound, even though one might never have seen Guzy. Thus, inference in deductive reasoning transfers meaning from one set of propositions (the premises) to other propositions (the conclusion), and it always proceeds from the general (the premise) to the specific (the conclusion), which follows necessarily from the premises (Guzy necessarily flies).

At the age of 2 to 3 years, inference is automatic, based on the experiential associations projected in global representations (e.g. "The cat is standing on the edge; she will fall" — I fall when I am standing on the edge). Conflicting conclusions may be drawn at this phase, depending upon the global representation activated ("the cat will jump" — cats jump when on the edge). At 4 to 6 years binary variants of representations ("eat/no eat", "playing outside/not playing outside") may be aligned according to a goal (e.g. "I ate, so I can play outside"), allowing pragmatic inferences and deals. Experientially based analogical relations may also be grasped if prompted (e.g. "You are big, you have a big brain; I am small, I have a small brain"). Representational alignments generate an insight about representations enabling children to search for and focus on them according to current knowledge or communication needs (e.g. searching for an answer from memory), thus facilitating transition to the next stage. This insight is reflected in the fact that children start to differentiate between mental processes.

In the next period, at 7 to 8 years, children first master simple inferential schemes such as *modus ponens*[1] (If it is a bird, it flies; it is a bird, thus, it flies) and disjunction (it is either blue or square; it is square; thus, it is not blue). Also they construct analogies involving familiar relations (e.g. table is to eating as bed is to sleep). At the next phase, they may systematically envision alternative forms of an inferential scheme and handle alternative expressions of it, as when they are stated in negative forms (If it is a bird, it flies; it does not fly; thus, it not a bird). In analogical reasoning, they can grasp relations between different types of relations, implying that they can construct a relation between seemingly different relations (e.g. "speaking is to silence as water is to fire" is acceptable, because they are both opposite). In this period they differentiate between mental processes;

1. If one statement or proposition implies a second one, and the first statement or proposition is true, then the second one is also true. If *P* implies *Q* and *P* is true, then *Q* is true.

thus they regulate processing according to task demands (e.g. they slow down processing according to task complexity).

Adolescents understand that seemingly different inferential relations yield the same results if they are formally identical, indicating that they grasp the principles underlying them. The "if … then" sequence appearing in early adolescence is possible because different principles may be taken as starting points for alternative lines of reasoning. By middle adolescence, principles are aligned yielding general criteria of truth, validity, and soundness, enabling them to recognize non-decidable arguments (e.g. in the argument, "If it is a bird, it flies; it is a bird; thus, it flies", they understand that refuting that something is a bird cannot lead to any conclusion about flying; or ascertaining that something does fly cannot lead to any conclusion about its identity [whether it is a bird or otherwise] because "flying" may be caused by many other factors in addition to being a bird). Also, adolescents grasp metaphorical analogies (e.g. "a drop is to the ocean as a grain is to sand"), indicating that they align alternative mental spaces according to the principle chosen.

Implications for educators

Educating reasoning must enable students to acquire command of the abstraction and inferential process. Specifically, instruction must enable children to do the following:

- Differentiate between inferential processes and logical forms, such as inductive, analogical and deductive reasoning. Thus, they must understand that in inductive reasoning inference is based on similarity between objects and similarity of relations between objects, but in deductive reasoning inference is based on relations imposed by the structure of the argument. Specifically, students must understand that inference in inductive and analogical reasoning proceeds upwards, generalizing a common property observed across many instances (e.g. that each swan one has seen is white) to a general principle (therefore, all swans are white). Deductive reasoning, on the other hand, proceeds from general, already accepted principles (e.g. all birds fly) to conclusions about particular cases, given a statement that the cases share one or more properties specified by the general principle (if Guzy is a bird, Guzy must fly). Thus, children must understand that an argument involves a network of relationships systematically arranged. Connectives, such as "is", "if ... then", "either ... or", etc., signify this arrangement and the type of logical relation or scheme involved. For example, "is" usually indicates a class relation (i.e., this entity belongs to this class), which may be useful both for inductive and deductive inference. "If … then" indicates relations of implication dominating in deductive reasoning (i.e., "If this is true that must also be true"). "Either … or" indicates disjunction in deductive reasoning. Thus, they may be used to break down the argument into the premises involved, and focus on their logical relationships independent of content. (Educators should understand that teaching abstract inference is generally more difficult at the abstract level. Teaching abstract inference by way of concrete examples with familiar content, and then moving to an abstract level, will probably be more successful.)

- Decontextualize inference by recognizing that inference obeys rules that may not always coincide with common sense or existing knowledge. This may be rather easily shown if teachers use examples that pit common knowledge against the logical necessity of the inferential process: for example, the argument, "all fish live in trees; this salmon is a fish; therefore it lives in a tree", makes it clear that statements not true in the real world (no fish lives in a tree) may produce conclusions consistent with the premises if the reasoning is valid.
- Use self-initiated representations (mental models) to validate conclusions and make use of reflection (meta-representation) to lift reasoning from the search for relations between mental models to the grasp of underlying logical relations.

We will explain how these aims may be attained with reference to the examples presented in Table 1. The first set of examples addresses inductive reasoning. They refer to the familiar case of flying birds. They aim to show that recognizing that an object is a member of a class allows one to transfer other class properties to this object – for example, they have wings, they fly, they lay eggs, etc. (e.g. imaginary *nigles*). Children must also grasp that having one class property (*nappows* fly) *may* indicate class membership, but they must be aware that there may be other hitherto unrecognized properties that may show that the assumption was wrong.

At pre-school, instruction should expand on the comparison of objects and the identification of their similarities. For example, children must understand that distinct objects may be reduced to a single class based on a common crucial property (e.g. they fly), despite their differences (e.g. in size, colour, etc.). Pointing to the common property *and* the differences to be ignored given the common property of interest brings the abstraction process itself into focus. Symbols standing for the defining classification property may be used to symbolize the connection between reality and representation (e.g. the symbol ^^ looks like wings and stands for flying). Thus, symbolization brings the meta-representational process into focus. At primary school, emphasis may shift to class specification on the basis of underlying hidden general properties present in all particular classes (e.g. ways of reproduction — birds lay eggs). This will bring into focus the underlying induction process that connects seemingly unrelated properties, given some constraints. At secondary school, emphasis must shift to the nature of inductive generalization as such. In other words, it is likely but not necessary. Thus, belief in inductive generalizations must always remain open to future falsification (e.g. there are birds, such as ostriches, that do not fly, and mammals, such as bats, that do fly). This brings into focus logical principles constraining the operation of induction – that is, that however strong our inductively derived beliefs may be, especially if they are based on repeated observations which make them highly likely, they are never necessary, because a deviating case is always possible, however small the likelihood. An example may show these limitations: “Nappows fly; are they birds?” Once the teacher lets the children express their views, she informs them that nappows are a type of helicopter on an imaginary planet. They do fly, but they are not birds.

The second set of examples addresses analogical reasoning. The emphasis of instruction here shifts from object similarity to relational similarity. Horizontal examples involve analogical relations in the same order, namely between (1) specific elements, (2) classes and (3) general functions. Thus, children may be instructed to pinpoint and elaborate on the relations within and across pairs, within and across analogies. In pre-school, teaching may start from studying actual animals and objects, and specifying their relations within and across pairs within each analogy. For example, they both have parts enabling them to move. Observations may then be encoded into verbal statements with the explicit aim of showing how one kind of representation may be expressed as another kind of representation. In this way, observations or their action or visual models are meta-represented into language. At primary school, the relations may be pursued through analogies with the aim of showing the relationships between relations (i.e. that flying and walking are motion). By the end of primary school or the beginning of adolescence relations may be formalized in abstract representations, as above. Eventually, during high school, the relations may be discussed from the context of different knowledge domains, such as biology (motion is needed for survival), physics (wings and feet make use of similar principles to ensure motion—friction), and technology (artificial parts, such as wheels, make use of the same physical principles).

The examples given in Table 1 show the difference between induction (actual information is relevant and essential), analogical reasoning (a general property, such as motion, describes relations between apparently differing elements or properties), and deductive reasoning (form constrains inference, while knowledge about

Table 1. Examples of tasks that can be used in learning-to-reason programmes

Example 1: Inductive reasoning

Pigeons are birds: they have wings and they fly.
Hawks are birds: they have wings and they fly.
Nigles are birds. Do they have wings? Do they fly?
Nappows fly. Are they birds? Do they have wings?

Example 2: Analogical reasoning

Wings are to pigeons as feet are to cats.	Wings are to aeroplanes as wheels are to cars.
Wings are to birds as feet are to animals.	Wings are to flying machines as wheels are to vehicles.
Flying is to birds as walking is to animals.	Flying is to flying machines as rolling is to vehicles.

Flying, walking and rolling enable motion, given the constrains of each living being or vehicle: A (flying); B (birds); C (walking); D (animals); E (flying); F (aeroplanes); G (rolling); H (cars) –> motion.

Example 3: Deductive reasoning

Birds fly	Birds fly	Birds fly	Animals and birds either walk or fly
Nigles are birds	Cats are birds	*Nappows* fly	Ligies (an imaginary creature) are animals
Nigles fly	Cats fly	*Nappows* are birds	Ligies walk

properties is irrelevant). The first two arguments stand for easy *modus ponens*. Given the premises, the conclusion is true in both cases, although the conclusion is not sound in the second example. The last two arguments are inconclusive. *Nappows* may or may not be birds and ligies may or may not walk, given the premises. These arguments may be compared with each other and with the inductive and analogical problems presented above from a number of respects, to highlight their similarities and differences.

At pre-school, children must realize that the information in the premises is connected by inference. Actual models of the organisms involved and visual representations of the line of inference going from one to the other are obviously useful. For example, the teacher may show several birds flying with their wings wide open, all connected by a line to a symbol such as ^^ on top to highlight the induction of the property of flying from each different case. At primary school, directed comparisons across the various arguments would enable children to differentiate the form of the argument from the content of the premises and to understand that logic governs inference. That is, when children understand that the conclusion “cats fly” necessarily follows from the premises, given that we accept that “cats are birds” and that “birds fly”, they already know that logical structure underlies inference and this overrides actual knowledge about reality.

In adolescence, they must be introduced to the conditional and suppositional nature of reasoning and the role of form in constraining inference.

Suggested readings: Demetriou, 2013; Demetriou et al., 2011; Demetriou et al., 2014 ; Moshman, 2011.

5. Domains of the mind

There are domains of mind involving special strategies for knowledge extraction and problem-solving. Education must specifically address each of them to develop facility in dealing with problems.

Research findings

The general mechanisms mentioned above coexist with a number of specialized domains. Specialized domains are primary knowledge extraction mechanisms that provide fast access to important aspects of the natural and physical environment. There are automatic ones, such as: recognition of small sets of up to four elements, which is a basis of arithmetic; and colour recognition, which is a basis of categorical thought. Discussion about the various domains of intelligence has been going on for decades. In the classical psychology of intelligence, there is general agreement about three domains of thought: *verbal* (command of language), *spatial* (mental orientation in space), and *numerical* (command of numbers and their relations). Another one is the *categorical* domain, which may be a separate domain generating concepts about standard phenomena of the world, such as the differentiation between living and inanimate beings, the day/night cycle, etc. *Causality* has been recently recognized as another domain — the ability to grasp how and when objects or persons cause changes in each other. In recent years, understanding and dealing with one's own and other persons' emotions, feelings and thoughts is regarded as a separate domain of *psychological/social intelligence*.

Implications for educators

Educating in these domains must be tuned to their particular mental characteristics at each phase. Students must acquire model templates for the various domains aligned with understanding the priorities for each phase. For example, in the *categorical* domain teaching must consolidate the fundamental processes and relations enabling reliable and flexible categorization. To illustrate how this may be done we draw on the movement example used above (see Table 1). In kindergarten children must practice sorting according to rules clearly exemplified by obvious physical characteristics (e.g. put together animals that move in the same way—birds fly, animals walk, fish swim). In pre-school, children must learn that there may be complementary rules justifying sorting into sub-classes (e.g. flying and non-flying birds, walking and non-walking animals). Changing the way we sort the same set of objects according to different properties or a combination of them would increase flexibility and executive control. Also, naming classes and sub-classes helps to grasp relations between concepts and symbols.

Later, in primary school, a mental (or actual) template for classification, such as the matrix in Table 2 below, may enable students to focus on the categorization processes as such. Students are asked to put animals and objects in the cells according to the two intersecting rules underlying the table (i.e. the type of movement and the type of animal). At the beginning attention must be drawn to the similarities and differences between various combinations of classes and sub-classes, within and across cells. Later, in primary school the inferential schemes discussed for the teaching of inductive, analogical and deductive reasoning (e.g. "it has wings, so …"; "wings are to … as feet are to …"; "it does not fly, so it is not an …") may be used to show how domain-specific activities and relations may be handled by reasoning. When these relations are understood, teaching in adolescence must focus on biological and physical mechanisms underlying the organization of the table, and the similarities and differences between different types of logical relations and schemes. In conclusion, teaching of categorical thought starts from observables and activities, and ends in scientific concepts, reasoning and logic. In other words, it is worth noting, good teaching frequently proceeds inductively, from observation of familiar examples upwards to the establishment of general principles.

Table 2. A matrix for teaching categorical thought.

Type of creature	***Medium where movement takes place***		
	Air	Land	Water
Birds	Eagle, pigeon, sparrow, bee, fly	Ostrich, chicken	Penguin, duck
Mammals	Bat	Elephant, lion, dog, snake, ant	Whale, dolphin, seal
Man-made	Aeroplane, helicopter, rocket	Car, motorcycle, bicycle, robot	Ship, submarine, sailing boat

Note: Very different animals are put together (such as eagles, sparrows and bees moving through the air [flying] or elephants, lions and snakes moving on earth) to stress the similarity in the principle underlying each type of movement, despite huge differences in structure and appearance.

In the quantitative domain, teaching would have to capitalize on the developmental milestones of quantitative thought. Early in kindergarten children must grasp the concept of whole numbers. Generic quantitative concepts, such as "few" and "many", may be the start. Associating them with specific quantities, such as 2 or 3 *versus* 5 or 6 is conducive to this aim. Associating these sets with their name and written digits in early pre-school years is important to build accurate representations for numbers. Using these concepts in comparative terms (i.e. "less" and "more") and associating with quantitative transformations standing for numerical operations (taking away and adding) would allow the construction of a model of the mental number line by the end of pre-school. Relating different versions of the mental number line in early primary school would allow the teaching of mathematics as needed in the school curriculum. Exploring the relations between different measurement systems, such as expressing weight in kilos and pounds or temperature in Celsius and Fahrenheit, facilitates a general conception of number as variable and of world attributes as quantifiable variables. Finally, at the end of primary school the teacher may introduce different types of numbers, such as natural or rational numbers, fractions and decimals, and associate them with the symbol systems used to express and operate on them. This is useful for moving from arithmetic to algebra.

Pre-algebraic activities are very appropriate in the early primary grades, because they can facilitate transition from plain arithmetic operations to algebraic rules, and from algebraic rules to more general logical rules. For instance, asking students to specify the n^{th} term of a number pattern (e.g. the number coming three positions after the last one) makes it easier for them to shift attention from the particular numbers to their relations. Later in primary school, missing number equations contribute to the transition from arithmetic to algebraic reasoning. For example, in the equation $56 + 47 = \square + 48$, instead of executing the calculations, students might first investigate the relation among the numbers involved and reach a solution by utilizing the identified abstractions (given that 48 is larger than 47 by 1, the number missing must be 1 less than 56). This abstraction may then be transferred to a more abstract algebraic example, such as $a + b = \square + (b + 1)$, where they can manipulate variables $(a - 1)$ rather than specific numbers. Later, in adolescence, students may solve problems that require algebraic reasoning proper, such as specifying the value of x when it is known that $x = y + z$ and $x + y + z = 20$ (i.e. $x = 10$) or specifying when the equation $L + M + N = L + P + N$ is valid (i.e. when $M = P$). These problems require an abstract conception of number such that it leads to the understanding that any number can be expressed by alternative symbols, that symbols can be reciprocally defined in reference to each other, depending upon the particular relation that connects them, and these definitions obey the rules of reasoning discussed in the previous section.

In a similar vein, it would be useful for the understanding of causal relations to have a template for their representation and manipulation. Specifically, the basic principles of the manipulation of causal relations, such as techniques and methods for the isolation of variables in different contexts and different knowledge domains, may be associated with the template: for instance, systematic trial-and-error and pairing of actions with their results at pre-school, systematic and planned variation of factors at primary school, and pairing of hypotheses with experimental design and conclusions at secondary school. This template would also involve the basic relations of causality (i.e. necessary and sufficient, necessary but not sufficient, sufficient but not necessary, neither necessary nor sufficient, and incompatible). Moreover, it would flesh out the basic tenet of causal modelling in science that correlation does not necessarily signify a causal relation.

In adolescence, education should build and enhance the suppositional stance that is possible at this phase. A useful framework for the strengthening of this stance is the systematic exploration of important phenomena from the point of view of different disciplines or different theories within a discipline. Motion is a good example. In physics it is described with reference to speed and space and it is explained in reference to causal factors, such as energy, force and work. In chemistry it is described with reference to the structural and molecular characteristics of objects. In biology it is described with reference to its function (e.g. survival), the structural enabling mechanisms (e.g. feet in walking animals, wings in flying animals), and the biological enabling mechanisms (e.g. eating, digestion, photosynthesis, metabolism). Adolescents may be acquainted with different models for motion in each of the disciplines mentioned above, explore their similarities and differences in relation to the methods used to construct them, the data invoked to support them, the language or symbol systems used to represent them, and their functional role in each discipline as a system of knowledge. Moreover, they may run experiments specially designed to demonstrate specific models in different disciplines.

Suggested readings: Carey, 2009; Demetriou, Spanoudis & Mouyi, 2011; Gardner, 1983.

6. Cognizance and self-regulation

Know thyself. Students must understand the organization and functioning of their own mind, their own strengths and weakness, and adjust their actions accordingly.

Research findings

Under normal conditions, all aspects of cognizance develop systematically from birth to maturity. In the first year of life there is implicit awareness of one's own actions and bodily sensations. In the second year infants recognize themselves in the mirror. However, they are still not aware of their own mental processes. In the period from 3 to 5 years children acquire an intuitive understanding that cognitive processes are affected by the environment. For example, they stare at the point where an object disappeared to remember its location, indicating an understanding that external cues may activate mental processes. At the age of 6 to 7 years children recognize that pairs of tasks belonging to different domains (e.g. categorical vs. mathematical thought) and require different mental processes, and they can recognize the mental operation needed (e.g. classification *versus* counting) regardless of external object characteristics. In adolescence individuals are sensitive to delicate variations between mental operations according to their complexity and the special requirements of the problem concerned (e.g. different types of arithmetic or mathematical procedures). They also build an accurate self-concept about their personal strengths and weakness. Overall, with development, cognitive processes and mental operations are increasingly differentiated from each other and this differentiation guides intellectual development because it allows the generation of increasingly inter-connected, abstract and flexible inferential processes and knowledge structures.

Implications for educators

Learning to learn requires awareness and control of the learning process so that it: (a) takes place at the right pace; (b) is geared to the demands of the task at hand; (c) can bypass possible processing and representational limitations by properly arranging the material to be learned; (d) judiciously uses relevant prior knowledge to enhance new learning; and (e) ensures that learning will endure. For the purpose of the above aims, students must be encouraged to map their own mental functioning as follows:

- Understand the organization and functioning of the mind. For example, mental images are more easily represented and preserved in working memory than abstract expressions in mathematics. Therefore, more rehearsal may be needed to process and remember mathematical representations as compared to mental images.
- All domains deliver their representations to a common limited representational space. Thus, managing representational capacity as specified above is important for learning to learn.
- Understand their own strengths and weaknesses in relation to different domains and processes. This would enable them to capitalize on their strengths and compensate for their weakness.
- Understand that the mind does not like gaps or incoherencies in representations. When gaps exist, they are filled in or "fixed". For example, gaps in knowledge (memory) may be filled in by inference (based on what is known); difficulties in making reliable inferences (e.g. when there are many premises connected by complex relations) may be bypassed by recalling a seemingly relevant answer from memory. In the first case, inference may generate plausible but wrong information; in the second case, memory may provide a true but invalid inference. Thus, students must be educated to differentiate between mental processes and their role in knowledge acquisition or problem-solving.

Education for learning to learn should be adapted to the needs of different developmental phases. Therefore, it must have different priorities at different phases of development (and schooling). Some examples are:

- Infants are not explicitly aware of learning and mental processing. Therefore, educating for learning to learn in pre-school must be indirect, aiming to make the infant realize that different approaches to solving a problem may lead to different information. Mindfulness training at this age would involve raising awareness of the self by systematically shifting attention to different sensory experiences, such as visual and auditory, and examining how they affect thought. For example, when a child looks at apples she thinks about apples; when she looks at pears she thinks about pears; however, when thinking about something else while looking at apples this child may not "see" changes in the number of apples occurring in front of her eyes.
- Pre-schoolers have a limited representational capacity, a limited understanding of representation as a means for bypassing their representational capacity limitations, and a limited command of representational aids, such as using hints to facilitate recall from memory. This contributes to the difficulty of pre-schoolers in learning complex tasks. Some of the difficulties may be overcome

if children know that using representational aids is useful. For example, when trying alternative solutions to a task, pre-schoolers may be instructed to use specific signs on a paper or real objects as tokens for each solution. This approach brings meta-representation into focus as the representation (e.g. the signs or token objects used) of representations (each solution). Describing one's own experiences in alternate ways is conducive to representational alignment and meta-representation.

- Primary school children still do not clearly differentiate between cognitive functions, nor do they understand their possible contribution to learning. Therefore, at primary school, education must focus on building awareness of the differences between mental functions and of their differential impact on learning. For instance, children must realize that recalling information from memory and connecting it with what they see in front of their eyes facilitates understanding of new information. In turn, they must practice rehearsal to realize that it facilitates storage of new information in long-term memory for later use. Also they must understand that associating and relating with prior knowledge helps learning, but varying and changing helps originality.
- In adolescence, education for learning to learn should focus on awareness of the differences between cognitive processes in different cognitive domains. For example, they must grasp the differences between formal disciplines, such as mathematics, and empirical disciplines, such as physics, in knowledge construction: that is, formal relations between constructs in the first case and consistency between a model and reality in the second case. Therefore, planning requires different approaches in the two cases. In the first case, it requires exhaustive search of the logical relations between premises and presuppositions. In the second case, it requires a conception of the world as suggested by a model, the specification of the steps needed to produce crucial evidence, and the realization of these steps through the necessary process.

Suggested readings: Demetriou, 2013; Demetriou & Kazi, 2001; Demetriou & Kazi, 2006; Demetriou, Spanoudis & Mouyi, 2013; Kazi et al., in press; Zelazo, 2011; Zelazo, Qu & Müller, 2005.

Conclusion

The human mind is a complex system involving general and specialized processes. The development of each of their relations is long and dynamic, and occurs on several fronts at the same time. It can be described in terms of complexity, abstraction, analytical attitude, long-term planning, and ingenuity in organizing and using knowledge for the sake of personal and collective good and development. For children, this process always takes place in a particular culture at a particular era. However, the level of all processes can be improved by properly designed instructional methods. This may have wide-ranging effects on the functioning of the individual both in the school and in the society at large. However, it should be noted that to become an expert in a particular subject requires special, extended, systematically organized practice, which was beyond our present concerns in this publication.

At any age, education must enable students to develop and refine the following cognitive skills:

- focus on relevant information;
- scan, compare and choose according to goal;
- ignore irrelevant information;
- represent what is chosen and associate it with prior knowledge;
- assemble information into models and rehearse if necessary;
- evaluate models with reference to the evidence;
- reason by deduction to evaluate truth and validity of models and conclusions;
- prefer solutions that are better or more accurate than earlier solutions;
- and estimate consistency with beliefs, existing theories, dominant views, etc.

Being aware of epistemological issues concerning the similarities and differences between disciplines is an important part of education for critical intelligence.

References

Anderson, L.W. et al. (2001). A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives. New York, NY: Longman.

Baddeley, A. (2012). Working memory: Theories, models, and controversies. *Annual review of psychology*, 63, 1–29.

Buschkuehl, M.; Jaeggi, S.M. (2010). Improving intelligence: a literature review. *Swiss medical weekly*, 140, 266–272.

Carey, S. (2009). *The origins of concepts*. Oxford, UK: Oxford University Press.

Ceci, S. (1991). How much does schooling influence general intelligence and its cognitive components? *Developmental psychology*, 27, 703–722.

Demetriou, A. (2013). Learning to learn, know and reason. *In:* R. Deakin Crick & C. Stringher (Eds.), *Learning to learn*. London: Routledge

Demetriou, A.; Kazi, S. (2001). *Unity and modularity in the mind and the self: Studies on the relationships between self-awareness, personality, and intellectual development from childhood to adolescence*. London: Routledge.

Demetriou, A.; Kazi, S. (2006). Self-awareness in g (with processing efficiency and reasoning). *Intelligence*, 34, 297–317.

Demetriou, A. et al. (2005). The architecture, dynamics, and development of mental processing: Greek, Chinese, or Universal? *Intelligence*, 33, 109–141.

Demetriou, A.; Mouyi, A.; Spanoudis, G. (2010). The development of mental processing. *In:* W.F. Overton (Ed.), *Biology, cognition and methods across the life-span. Vol. 1: Handbook of life-span development*, pp. 306–343. Hoboken, NJ: Wiley.

Demetriou, A.; Spanoudis, G.; Mouyi, A. (2011). Educating the developing mind: Towards an overarching paradigm. *Educational psychology review*, 23(4), 601–663.

Demetriou, A. et al. (2013). Cycles in speed-working memory-G relations: Towards a developmental-differential theory of the mind. *Intelligence*, 41, 34–50. [doi: 10.1016/j.intell.2012.10.010.]

Demetriou, A., Spanoudis, G., & Shayer, M. (2014). Inference, reconceptualization, isight, and efficiency along intellectual growth: A general theory. Enfance, issue 3, 365–396 [doi: /10.4074/S0013754514003097.]

Flynn, J.R. (2009). *What is intelligence: Beyond the Flynn effect*. Cambridge, UK: Cambridge University Press.

Gardner, H. (1983). *Frames of mind: The theory of multiple intelligences*. New York, NY: Basic Books.

Gustafsson, J.-E. (2008). Schooling and intelligence: Effects of track of study on level and profile of cognitive abilities. *In:* P.C. Kyllonen, R.D. Roberts & L. Stankov (Eds.), *Extending intelligence: Enhancement and new constructs*, pp. 37–59. New York, NY: Lawrence Erlbaum Associates.

Hunt, E.B. (2011). *Human intelligence*. New York, NY: Cambridge University Press.

Kazi, S. et al. (In press). Mind-culture interactions: How writing molds mental fluidity in early development. *Intelligence*. <dx.doi.org/10.1016/j.intell.2012.07.001>

Kyriakides, L.; Luyten, H. (2009). The contribution of schooling to the cognitive development of secondary education students in Cyprus: an application of regression discontinuity with multiple cut-off points. *School effectiveness and school improvement*, 20, 167–186.

McBride-Chang, C. et al. (2011). Visual spatial skills: A consequence of learning to read? *Journal of experimental child psychology*, 109, 256–262.

Moshman, D. (2011). *Adolescent rationality and development: Cognition, morality, and identity*. New York, NY: Psychology Press. (3rd ed.)

Pascual-Leone, J. (1970). A mathematical model for the transition rule in Piaget's developmental stages. *Acta psychologica*, 63, 301–345.

Piaget, J. (1970). Piaget's theory. *In:* P.H. Mussen, (Ed.), *Carmichael's handbook of child development* (pp. 703–732). New York, NY: Wiley.

Rindermann, H.; Thomson, J. (2013). Ability rise in NAEP and narrowing ethnic gaps? *Intelligence*, <dx.doi.org/10.1016/j.intell.2013.06.016>

Weil, G.L. et al. (2013). The development of metacognitive ability in adolescence. *Consciousnes and cognition*, 22(1), 264–271.

Winship, C.; Korenman, S. (1997). Does staying in school make you smarter? The effect of education on IQ in The Bell Curve. *In:* B. Devlin et al. (Eds.), *Intelligence, genes, and success. Scientists respond to the Bell Curve*, pp. 215–234. New York, NY: Springer-Verlag.

Zelazo, P.D. (2011). Mindfulness training in childhood. *Human development*, 54, 61–65.

Zelazo, P.D.; Qu, L.; Müller, U. (2005). Hot and cool aspects of executive function: Relations with early development. *In:* W. Schneider et al. (Eds). *Young children's cognitive development: Interrelationships among executive functioning, working memory, verbal ability, and theory of mind*. Mahwah, NJ: Lawrence Erlbaum and Associates.

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