



Education for All in Low-Income Countries: A Crucial Role for Cognitive Scientists

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Author's contribution

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ABSTRACT

Donor funding has helped enroll in school most children of low-income countries. However, students get little schooling and few opportunities to encode and consolidate information. Many fail to learn and automatize the small units needed for more complex skills, such as reading. As a result, many children remain illiterate and drop out in the early primary grades. However, donors and governments often focus on the socioeconomic difficulties of the very poor and have limited insights on how to teach students who get no academic preparation before grade 1. Furthermore, staff experiences with middle class schools may promote complex instructional methods and raise unrealistic expectations regarding the performance of the very poor. In principle cognitive scientists could provide technical assistance and conduct research on issues relevant to learning for the very poor. In practice, however, essential memory functions needed to explicate the knowledge gaps have little value added in high income countries and receive less attention in academia. Few cognitive scientists are sufficiently exposed to them, while education faculties similarly do not teach them. The question arises how to engage cognitive scientists in international development. There is a need for intellectual leadership in this field. New avenues of collaboration are needed between those who research learning and those who plan the education of the very poor.

Keywords: *Education for all; low-income countries; cognitive science; neuroscience, reading; working memory; observational learning; elaboration; encoding*

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specificity; automaticity; chunking; international education; perceptual learning; policy advice; teacher training.

ACRONYMS

DFID- Department for International Development; FTI- Education for All Fast Track Initiative Secretariat; GPE- Global Partnership for Education; RTI- Research Triangle Institute; UNESCO- United Nations Educational, Cultural, and Scientific Organization; UNICEF- United Nations International Children's Education Fund; USAID- United States Agency for International Development.

1. TRIUMPHS AND TRIBULATIONS OF EDUCATION IN LOW-INCOME COUNTRIES

About 60-72 million children are of school worldwide. Ensuring their education, particularly in low-income countries,¹ is an important goal of the international donor community. The United Nations agencies and affiliated organizations have devoted much thinking and resources in the last 20 years to improve access to good-quality education for low-income populations.

In 1990, a worldwide initiative was instituted to ensure that by 2015 all children in the world should complete primary school. The Education for All initiative [1,2] has become a high-profile operation aimed at raising the funds needed to close the gap between national budgets and the investments needed for universal primary enrollment. The funds pay for budget items such as school construction, curriculum development, textbook production, teacher training and hiring, management information systems, student assessment, and evaluation capacity development. Efforts have borne fruit. Some of the poorest countries, such as Niger, Burkina Faso, Ethiopia, or Cambodia increased enrollments by multiples between 2000 and 2010 (See statistics at www.globalpartnership.org; Education for All Fast Track Initiative, 2010).

Annually about US\$13.5 billion are needed to educate the children of low-income countries [3,4]. This herculean task is being financed by scores of donor agencies and partners. There are United Nations organizations, such as UNESCO and UNICEF; multilateral institutions such as the World Bank, African Development Bank, the Organization of American States, and others; bilateral donor agencies, such as United States Agency for International Development (USAID); many national and international non-governmental organizations, such as Save the Children, Oxfam, or Actionaid; civil society groups that advocate for education. Many consulting companies are also involved that vie for contracts to implement various initiatives. Partners have worked hard to harmonize their procurement and accounting rules to ease the reporting burdens of low-income countries. Thousands of very dedicated staff work in these agencies, managing the bureaucracy and providing advice to governments and donors.

So, do schools in low-income countries teach students the needed basic skills that will help them rise out of poverty? Unfortunately not. Many of the enrolled students learn very little and fail to reach even minimal competencies [5,6]. Early-grade reading fluency tests in the primary grades show that in some countries 90% of the second or third graders fail to read

¹ The World Bank defines country groups in terms of per capita gross national income, using the Atlas method. In 2011, thresholds were: low income, \$1,025 or less; lower middle income, \$1,026 - \$4,035; upper middle income, \$4,036 - \$12,475; and high income, \$12,476 or more (retrieved from www.worldbank.org).

even a single word, and many do not even know individual letters [7,8]. As a result, students abandon school early and remain illiterate; in sub-Saharan Africa, only about 67% of the beginning cohort graduate from primary school, and many of the graduates are functionally illiterate [9]. The Africa Learning Barometer (supported by the Brookings Institution) reported that overall 53% of poor children and specifically 43% of children from rural areas fail to learn basic literacy and numeracy skills [10]. Similar data are reported from other low-income countries, such as Yemen, Papua New Guinea and East Timor.

Failures are not just limited to basic reading or the poorest countries of Sub-Saharan Africa; they extend to higher grades of lower-income countries. International comparison tests such as TIMSS and PIRLS² show large performance differences among the 49-63 countries that participate. (Most low-income countries do not participate.) For example in grade 4, the 2011 PIRLS score for Hong Kong was 571 compared to 310 for Morocco and a scaled score of about 330 for Botswana and South Africa [11, p. 45]. Similarly in the 2011 TIMSS, the 4th grade average score for Singapore was 606 compared to 238 for Yemen.

TIMSS and PIRLS socioeconomic data have showed large score differences by parental levels of income and education. For example overall students of many resources scored in TIMSS an average of 535, and those of few resources scored 415 [12, p. 13]. The students who could do early numeracy tasks very well when they began primary school scored 524 compared to a score of 451 for those who could not do them well. On the basis of these and other data, it was found [13] that children in low-income countries are able to answer correctly only about 30 percent as many questions as children in upper-income countries. It has been estimated [6,11,13] that the learning of the average child assessed in low-income countries is at about the 5th percentile of children in upper-income countries.

It appears, therefore, that many lower-income countries are raising a generation of nominally schooled but illiterate students. Organizations such as UNESCO have raised alarms (e.g., [14]). Some publications and blog articles describe the situation as a "learning crisis." [15]

In some respects, the learning crisis should not come as a surprise. Many students lack the skills necessary for performance. They often go to school without preschool experience or home preparation for academic tasks. They may have limited vocabulary even in their own languages; they may have developmental delays and poor executive control. Many suffer from malnutrition and diseases that are known to compromise skills acquisition [16,17]. These students can certainly learn, but they need specific inputs and extra teaching time to master preliminary tasks. In high-income countries, such students would get individualized attention by well-educated teachers, a surfeit of materials, and follow up at home. In many low-income countries, the only available option would be private tuition [18].

Another important reason for failure is limited instruction and little or no feedback. To implement Education for All, public schools of countries such as Malawi or Congo Democratic Republic must admit massive numbers of children with very limited class space or staff. In cities like Lilongwe, classes may have over 100 students in the early grades [19]. The teachers may have the equivalent of 4th grade education, may not know how to teach, and may be absent on average 20% of the time. Schools often start late in the school year and end early [20]. Countries that lack sufficient buildings and teachers may reduce class hours to fit all students in multiple shifts. As a result of all these constraints, the students may only get 39% or less of the instructional time given to first graders in higher-income

² *Trends in Mathematics and Science Study, Progress in International Reading Literacy Study (TIMSS).*

countries [21]. And when teachers teach, they may interact with the few who can do the work and ignore the rest [22,23]. Nonperformers may attend sparsely until they drop out.

Multilingualism further complicates the picture. In many low-income countries citizens speak numerous languages; so many governments have adopted English, French, Portuguese or Arabic as their language of instruction. Nearly all countries of Sub-Saharan Africa and the South Pacific face this complexity. Students must learn the official languages during class at the same time as reading. The above languages happen to have complex spelling systems, which may take two or three years to master. In addition, textbooks are usually imported, expensive, scarce, or inappropriate for the students' knowledge level. Without them, class time is largely spent copying incomprehensible texts from the blackboard. Scant instruction suffices only for those few who are inordinately intelligent or the better off who get help at home. Thus, Education for *All* becomes in fact education for the gifted.

Clearly the above circumstances reduce the opportunities to obtain new information, elaborate it, practice basic tasks to the point of effortless execution, get feedback. Despite systemic limitations, certain classroom activities could be modified to increase precision, timing, or frequency of some inputs. However, classroom issues receive limited attention. Instead, sociocultural factors are emphasized such as child marriage, child labor, or the effects of income inequalities, emotional and physical well-being in schools, safety issues in conflict-affected countries, or gender (e.g., [24,25,26,27]). Attention to sociocultural complexity may detract attention from instructional variables,³ or result in conflicting advice about educational quality and use of funds.

These exigencies are directed at government and donor staff who are burdened with the complex financial and logistical problems involved in expanding their school systems. Procurement events, disbursement schedules, budget meetings, contracts have clear deadlines and take up much of officials' time. Multiple and complex demands for accountability may push learning issues low on the agenda.

Given the exigencies of political economy and the extreme limitations of low-resource schools, how can students learn more and perform better? Whose advice to governments and donors is most likely to achieve results? The article presents some aspects of this very complex topic and suggests how research on memory and cognition can be used to improve learning outcomes for the poor.

One note is important on documentation. Many cited reports by donor agencies and consultants are work documents that may not necessarily meet rigorous academic standards. Also, certain topics that are well-known in international development have not necessarily been documented, such as the academic background of staff. However, the issues are critical and merit publication.

To illustrate the knowledge needed, some real-world questions are presented below.

³ For example one draft consultant report about Ethiopia stated in 2013: "Learning outcomes depend on a variety of factors, both on the side of educational provision, and with regard to sociocultural, environmental, and individual factors. Any assessment of the impact of higher teaching quality on learning outcomes must take account of this complexity."

2. THE LEARNING CRISIS AND POLICY ADVICE DILEMMAS

A foreign service officer from a European country manages the bilateral aid program of her country in certain African countries. Citizens in these countries speak 15-37 languages, so instruction takes place in English, French, or Portuguese. Textbooks are scarce, so most classroom time is spent on transcription; and about 85% of students remain illiterate. In the course of a week, the following topics require input. What policy advice could be offered and on what basis?

- Many donors advocate that children should learn in a language they know best, so one government developed a policy of teaching children in local languages for the first three years. One colleague wonders why it is necessary to delay English-medium instruction. His children went into French immersion class and did very well. Which research studies can be used to facilitate decisions?

- A team of economists spent about a million dollars for a randomized experiment that tested whether better school management improves learning outcomes. The answer was negative. (See for example [28]. The economists searched for answers, but they did not think of examining the grade 1 reading book used in that country. The book started with entire sentences in English and no obvious attempt to teach letter sounds. How important was the textbook vis-a-vis school management?

-The primary education director in the Ministry of Education is preparing new books for grade 1 reading but gets contradictory advice. Some specialists believe in phonics and others in the whole word approach. Some suggest that instruction should start with entire sentences, then words, then letters, and others believe in the opposite order. Which research could be used to predict likely outcomes of each viewpoint?

- Many students completing primary school can barely decode, so the government was advised to start youth centers that would teach “flexible” 21st century skills. A consultant will develop competency-based curricula that will minimize teaching of facts and focus instead on critical thinking and catalytic communicative skills. Does existing research suggest that this will work?

- To develop creativity among students, one government plans to buy one million inexpensive laptops. Most students are illiterate, and the computers do not include software for teaching basic skills. (See for example [29]). Proponents say that computers will improve ‘lateral thinking’. Should this low-income government spend scarce revenues to buy laptops for all children?

The above questions are hard to answer and are rarely encountered in higher income countries. Governments and donors must decide on certain solutions that are reasonably effective and politically acceptable, and then dedicate taxpayers’ money to them. Many decisions have far-reaching consequences for citizens and typically involve millions of dollars. They must often be made in a matter of days or weeks, so research studies are out of the question. It is important therefore to follow the most reasonable advice available at a given moment.

Which body of knowledge can effectively advise governments and donors on how to improve learning in low-income classrooms? No clear contender exists. Staff who work in international development typically have advanced degrees in a wide variety of fields, which

typically offer no learning-related coursework: Economics, finance, statistics, political science, international relations, comparative education, education policy, sociology, political science, or literature. Not surprisingly, donor agencies tend to recommend policies that reflect the academic preparation of employees. Few documents offer actionable instructional advice (e.g., [30,31]. Instead, agencies produce countless documents attributing learning problems to low incomes, gender biases, psychosocial development, community conflicts, social theory, or malnutrition [32,33].

Economic and management advice may also detract attention away from classroom learning. Certain economists consider the classroom a “black box” and they posit that if teachers are made accountable, they will somehow find means to make more students learn. To improve quality, governments are urged to invest in school-based management and give grants to schools under the supervision of citizen committees [34]. Countries are also advised to invest in merit pay and training, in hopes that incentives will increase attendance and teaching quality. To assess and evaluate the results of various interventions, the donors have heavily invested in statistical data collection and international comparative tests [35].

Added to the varied academic backgrounds of donor agency staff is the human tendency to interpret unfamiliar situations through easily available memories (e.g., availability bias, [36, pp 65, 129-136]. Few studies have explored the educational beliefs of staff (e.g., [37, p. 71; 38]. But whenever instructional advice is given, it seems to reflect a middle-class perspective of well-trained children who have been learning academic content since birth. As shown above there are large test score differences across socioeconomic strata; the better-off students may be better prepared to study more complex topics, and they are more likely to have better educated teachers. These may be reasons why education advisors often condemn memorization and recommend “modern” discovery methods over “traditional” routines. They may recommend a child-friendly classroom climate, “active learning”, child-centered learning, constructivism, transformative education, teaching that is individualized and relevant to children’s lives (e.g., [39,40]. They may expect teachers who are barely literate to carry out reflective practices and complex classroom activities [41], [24, pp. 54, 110]. Some expect all teachers to use computer technology, discounting the training and procurement problems likely with large-scale applications.

Since there is no clear corpus of research that guide on difficult issues, large-scale consultations are sometimes held to arrive at “best practices”. Certain organizations may invite hundreds of staffroom international agencies and organizations involved in education and ask them to comment on various questions until a consensus emerges. For example, the Interagency Network for Education in Emergencies (INEE) has conducted hundreds of workshops seeking advice from persons involved in education on how to teach conflict-affected children. The consensus resulted in about 70 variables to be used as Minimum Standards for education in emergencies (www.ineesites.org). The theoretical framework created by these standards emphasizes community involvement, security, human rights, emotional healing, and teaching according to cultural context. The Brookings Institution also led a large consultation in 2012-13 to determine what the students of the world should know and how to measure their achievement [42]. In the first two phases of the study, nearly 1,000 people in 84 countries informed task force recommendations. However, few of the participants had experience in teaching school or studying memory research. The document with the initial findings uses in 101 pages the words ‘learn’ or ‘learning’ about 209 times and

'teach,' 'teaching,' or 'teacher' about 26 times. However learning research is rarely cited in conjunction with these.⁴

Overall, the chorus of advocates about the education of the poor rarely includes people with expertise on how people learn. Few if any staff working in international development have studied cognitive psychology, cognitive neuroscience or related disciplines. If expertise in learning were more widely available, information processing principles could be used to advise governments. An international strategy to make learning more efficient could focus on the information processing commonalities of humans rather than cultural and individual differences: encoding, consolidation, retrieval, forgetting [43]. The environment certainly modifies some aspects of learning and cognition [44]. However, similarities of cognitive development across cultures at about the same age suggest applicability of basic information processing functions to children [45]. It could be possible to optimize classroom activities of low-income countries and increase efficiency in encoding, consolidating, and retrieval of needed information.

Research suggests that people must first learn to execute essential skills fast and automatically, so that they can devote their working memory to more challenging and complex cognitive tasks. Fluent performance in various skills results from practicing and automatizing progressively larger chunks of information ([46,47,48,49]. Students must also acquire networks of well-connected knowledge that will effortlessly arrive in working memory to help reach conclusions and make decisions [50]. As mentioned earlier, many students in low-income countries fail to master fundamental skills, and subsequently perform poorly in the more advanced skills. This pattern suggests failures to learn what might be called for a lack of a better collective term, "simpler" cognition:⁵ perceptual learning, chunking, mapping letters to sounds, reading and math automaticity, executive control. To put it simply, it is difficult for students to analyze the meaning of text when they can hardly lift it "off the page". It is hard to engage in critical thinking and transformative learning when students must consciously search their memory for essential information items. Survivors able to tackle more complex concepts do so years later than students of the same grades in better off countries.

Government and donor staff have not sufficiently focused on these prerequisite skills. The "simpler" cognitive functions are largely unconscious, so people have limited insights about them [51, p. 47]. Also middle-class children, with whom donor staff are familiar, learn them quickly. This may be one reason why documents often lament the lack of basic skills but rarely drill down into the specific variables that must be reinforced.

These variables could come sharply into focus if an information processing framework guided educational decisions. It would emphasize in all cultures the acquisition of speed and automaticity in basic skills, such as reading, writing, or math [52]. Without this focus, advice to low-income countries can be misleading. The following section offers some examples.

⁴ Another document on the education of marginalized children uses the word "learn" or "learning" 153 times in 35 text pages. It also uses "teach" and "teaching" 18 times, but it does not refer to any research or propose means for students to learn better [27].

⁵ "Lower-level" processes are not simple, but the term 'simpler' cognition is used as a placeholder, given the frequent use of the term "complex cognition".

2.1 Reading Instruction for the Very Poor

Reading is the skill that falters most often in low-income countries. Early action is crucial because often students drop out in grades 1 and 2. Fluency acquisition by the end of grade 2 at the latest may help them stay in school; and if life circumstances force dropout, fluent readers may continue to decode environmental print and thus retain the skill [53]. To teach such high-risk populations governments should aim for efficiency. Teaching methods should target the weaker students and aim to teach nearly everyone to read.

Reading neuroscience helps point to the important variables and activities that may speed up automaticity. Visual perception research suggests that simpler visual patterns are faster to automatize and critical spacing affects reading speed [54]. Practice with corrective feedback reduces reaction time and links letters into increasingly larger chunks [55]. Eventually, the visual word form area is activated, enables recognition of entire words [56], and makes it possible to process multiple letters in parallel. Many psychological and educational studies suggest that teaching individual letters matched with sounds may efficiently automatize reading (e.g., [57, 58]. In consistently spelled languages, which constitute the vast majority of the world's languages, fundamental instruction requires only about 100 days in most scripts [59]. By contrast, literacy instruction in the complex orthographies of English or French takes about three years and requires some learning of whole words [58]. Word shapes constitute more complex patterns that take longer to automatize.

Unfortunately low-income countries often get garbled advice. Reading specialists tend to come from high-income Anglophone countries and may have ambivalent feelings about phonics, given that instruction in English cannot completely rely on them. And since middle-class children progress quickly, curricula are often designed to focus on textual meaning rather than teach the script [60, pp. 2, 116].

However, to understand, students must read fast enough to input sufficient text into working memory and retain it long enough to make sense out of it. If they know the words, they may understand their literal meaning [59]. The relationship between speed and comprehension has been documented repeatedly in education [61,62,63], but without understanding working memory functions, the relationship makes no sense to some education advisors. Some argue that speed should be discouraged because children may just “bark at print”. [64] Several others state that if students do not understand what they read, they are not really reading; they are merely decoding. But with limited practice, it may take years to acquire fluency. And those who manage after years of schooling may read too slowly to make sense of texts or learn much information from them [7].

Teacher training transmits these ambiguities about reading. For example, Kenyan teachers are rarely taught how to teach reading and may even use whole word techniques for consistently spelled languages like Swahili; they are sometimes advised to focus on language development, picture recognition, inferences, and prediction [65]. Another result of ambivalence with respect to speed and practice is the design of grade 1 reading textbooks. They typically have big pictures, few pages, and small amounts of text, so children who parents cannot afford books cannot get more practice [66].

The outcome of confused beliefs about reading acquisition is evident in the textbooks of many low-income countries (e.g., [67]). Students receive whole-word instruction without

textbooks in an unknown language that has a complex orthography. It seems a bizarre way to teach reading, but all over Africa it happens every day.

With political will, this fundamental cause of the learning crisis can be mitigated in about two years. Given the time limitations of low-income students and schools, curricula might prioritize fluency. To help nearly all students attain automaticity, governments are advised to adopt synthetic phonics and teach reading in local languages whenever possible, since the latter are consistently spelled. Letters are to be taught one by one, with pattern analogies, plenty of practice opportunities, phonological awareness, and writing. Grade 1 textbooks should have well-spaced letters, should maximize text than pictures, and contain substantial amounts of text since no other reading materials exist to help achieve automaticity [66]. Reading in official languages such as English or French might best be deferred until students have acquired automaticity in the same script. During the months that students are engaged in this process, the official language could be taught orally.

Some governments agreed to implement this advice, and school-level pilots showed greatly improved student performance compared to control schools: In Cambodia, performance improved from one year to the next in all measures. For example, letters by minute rose by over 100% (from 30 to 63 letters), words per minute by 63% (from 23 to 35 words), and comprehension by 70% (from 48% to 68% answers correct; [68]). In the Gambia, only 50% of the lessons were taught on average. Still, the percentage of first graders knowing at least 80% of the letters was 69% in the Pulaar language and 57% in Wolof (target was 85% of children [69]. Following six months of application in grade 2 in Egypt, word and text reading fluency rates doubled in comparison to rates obtained two years earlier (from 7 to 15 and from 11 to 21 words per minute respectively; syllable reading tripled from 10 to 28 syllables per minute. By contrast, the same measures in control schools improved only by about 27%. The percentage of students reading 0 correct words was cut by half in project schools (from 44% to 21%) while in control schools it improved only by 10% [70]. The Cambodian and Egyptian programs have been scaled up nationwide by the third year of implementation.

Learning research also helps predict and improve outcomes of teacher training. Poorly educated teachers have been hard to train, and methods imported from middle-income countries have given limited results [71]. Knowledge gaps may impede the retention of unfamiliar pieces of information, and efforts to bring consciously much material in mind may result in cognitive overload [72,73]. In addition, inservice training often is offered through intense brief courses given at training centers. Under such circumstances state-dependent learning and spaced learning research would predict limited recall for long-term use [74,75]. Thus when teachers return to their classrooms, the content may become a vague memory and without reviews, it may fade as work urgencies take over. However, observational learning research findings suggest that teachers may remember better to carry out activities they watched, particularly if they also visualized themselves executing them in class [76,77,78]. Thus, videoclips of the desired behaviors may effectively help train teachers of limited education. These and other learning concepts can help use donor funds more effectively when teachers are trained.

The need to execute effortlessly the building-block skills before engaging in more complex problems seems applicable at all educational levels. Methods that skip preliminary steps or assume that students will learn them rapidly on their own may succeed in teaching mainly those who are better off. Also methods that require little-educated teachers to make multiple rapid decisions and keep track of many items simultaneously may be abandoned. For governments this implies revision of curricula to ensure fluency in component skills,

affordable textbooks for all students to facilitate formation of cognitive networks, use of classroom time for practice and elaboration of knowledge, training of teachers to engage students in relevant tasks, and remediation at public expense to those lagging behind.

To disseminate and apply these concepts on a large scale in lower-income countries, experts are needed who understand these principles in detail and can clearly enunciate them. But very few exist. The following section discusses the reasons and proposes some solutions.

2.2 Attracting Cognitive Scientists to International Development

Most studies exploring chunking, automaticity, working memory capacity, or conditions that optimize retention are old. Hundreds of publications from the 1940s to the 1990s explored elementary memory operations. (See for example [79].) The findings have been taught in cognitive psychology courses for decades. Over time, research has specified variables better and measured them more exactly, while neuroimaging has succeeded in linking some cognitive functions to brain functions. Overall, the information processing framework remains valid.

This older body of research has considerable utility for low-income schools. Often nonsense words were used in order to limit knowledge about a subject, and in some ways the paradigms resemble the poor students' limited knowledge. For example, the relationship between instructional time and practice can be clarified by using the cognitive psychology experiments of that period (see for example, [80]).

For the education of high-income countries, however, elementary memory operations offer little added value. Students enter grade 1 with much academic knowledge and move quickly beyond basic skills towards issues of greater cognitive complexity [81]. With parents attentive to children's learning at home, the relationship between classroom time and outcomes becomes muddled. Thus fundamental topics such as chunking have become less interesting, and they get less space in cognitive science syllabi. And as complexity increases, the earlier paradigms may appear simplistic. For example, Daniel Reisberg's 2001 edition of undergraduate cognitive science had informative illustrations of nodes and links of cognitive networks, but by the 2009 edition, they had been omitted [50,82]. Lack of opportunities in explaining and applying these concepts may make it hard for cognitive scientists to identify potential applications and advise low-income countries.

Psychologists may be leaving these concepts behind, but colleges of education have rarely taught them. Traditionally, educators and psychologists have rarely collaborated [83,84,85,86]. Faculties of education have constructed theoretical frameworks on the basis of practices and philosophies of educators such as John Dewey, Lev Vygotsky, Maria Montessori, or Paulo Freire. These luminaries exerted their influence before most cognitive research was carried out. Some contemporary educators discuss learning in terms of ultimate results, as in transformative learning [87, p. 3-4]. Specific or intermediate memory processes seemed to have been locked in a black box. Few know where to find the key, and there is limited interest in looking for it.

Moreover certain education professors express caution against cognitive science or neuroscience. Some believe that information processing is a reductionist framework that leads to narrow and mechanistic prescriptions [88,89,90,91]. Similarly certain textbooks that teach reading to university students caution against using cognitive science [92]. Such beliefs are inevitably transmitted to students who are the next generation of workers in

international development. It is difficult to base justifications on concepts that specialists have learned to ignore.

To mitigate the learning crisis in low-income countries therefore, the challenge is considerable. The existence of building-block cognitive concepts must be demonstrated, often to skeptical audiences. The concepts must become attractive to teach in seminars or training events aimed at government or donor decisionmakers. Potential middle-class biases must be discussed diplomatically, and somehow decisionmakers must be trusted to remember and use explanations that run counter to their beliefs.

Thus solutions with a high payoff for the poor may be mired in perennial philosophical disputes among academics and lie unused. Arguably, the standards of higher-income countries create obstacles for the education of the marginalized.

Can cognitive scientists fill the needed role of learning specialists in international development? Graduates are relatively few and are usually absorbed in the job markets of higher-income countries. When they conduct research, it is funded by institutions as the National Science Foundation that are interested in topics pertinent to high-income countries. So cognitive scientists are unfamiliar with donor agencies, and the latter are similarly unfamiliar with what cognitive scientists can do.

And the cognitive scientists who are interested in international development need preparation. They must become familiar with the learning needs of very constrained environments. It is hard for inexperienced people to conceive of students dropping out in grades 1-3 or of the need to make children literate by the middle of grade 1. There is a need to understand international development issues and the functions of various donor agencies. There would also be a need to function in foreign languages such as French, Portuguese, or Arabic. Coursework and internships in bilateral or multilateral organizations would fulfill these needs. Thus, interested professionals would become able to function as consultants or full-time staff of donor agencies or contractors.

Some cognitive scientists might collaborate productively with departments of comparative and international education. These departments focus mainly on sociocultural and economic issues of education across countries and offer no courses in learning. However, the faculty and students often conduct field research in low-income areas, sometimes observing classes for months in rural Sub-Saharan Africa. Joint research might be most useful in addressing priority topics on improving learning efficiency for the poor. And it may encourage international education departments to introduce coursework on learning.

3. PRIORITY LEARNING RESEARCH FOR LOW-INCOME COUNTRIES

The research on the building blocks of learning is broadly applicable to all humans, but the studies were mainly conducted with college students in the U.S. Findings are being used translationally to formulate hypotheses. However, new rigorous research is needed to unravel the learning issues that hold the very poor back at all stages of education.

Of primary importance are topics pertaining to the acquisition of automatized perceptual and performance skills by children and adults. Crucial are visual pattern recognition features that can help speed up literacy acquisition in children and unschooled illiterate adults [93,94]. To help determine the easiest methods to teach basic reading to nearly all students, parameters for chunking might also be developed, picking up where older research left off (e.g., [95]).

For fluent and effortless performance in basic math, there is a need to understand better how to develop the number sense and the Weber fraction of poor students, particularly given the limited instructional means of poorly resourced schools [96].

One risk of dropout in the early grades could be referred to as *literacy attrition*. If a student drops out soon after acquiring reading automaticity, is that lost? Research suggests that 6 year olds forget more information than 9 year olds [97]. But is automaticity as forgettable as episodic information? A 1986 study [53] found that Egyptians who dropped out fluent readers in grade 4 maintained and improved their skills, while those who could not read well forgot what they knew. As with language attrition, children may forget how to read, but the parameters are not known. Variables influencing the permanence of automaticity could be aggregate hours of practice, maximum reading speed attained, practice intervals, age at abandonment, or something else.

Countries with large numbers of languages are often advised to offer reading in a subset of languages that are used for regional communication. Residents often learn them from casual interactions, such as commercial transactions. Community learning is certainly important [98]. However, the parameters of learning languages from the environment are unknown. On average how much do students learn across time? How does language knowledge limitations affect their reading automaticity?

Some people ask why it is worth using a regional lingua franca rather than use English from the beginning. The consistent spelling seems to confer an advantage over English and French, so one small study showed benefits [99]. But how big are they and what are the costs? Languages are learned through interaction, so children cannot learn a language merely by watching TV [100, pp. 133–144]. However, does a broadcasting teacher in a class constitute an intermediate situation? These issues must be explored.

Students' knowledge is limited by teachers' information processing capacity. To succeed in training teachers who have limited education, many questions ought to be answered. For example, what are the most effective ways to improve teachers' automaticity in basic math calculations so that they can check students' work instantly and effortlessly? Insights are also needed on how many and how complex tasks these teachers can comfortably carry out and how to estimate these empirically. To use observational learning protocols in teacher training, information is needed on the optimal "dosage" that would maximize the probability of executing in class the behaviors presented through videos.

Some officials expect that marginalized students will somehow learn acceptable skills despite scant instruction. To provide some realism, older studies of learning rates could be repeated with low-income populations. For example, what would be the lowest amount of time spent engaging in a task, and what would be the optimal distribution of practice sessions that would enable 85% of learners to attain reading rates of 60 words per minute in two school years? Similarly, what would be the minimum amount of time and optimal distribution that would enable 85% of the students to carry out correct arithmetic operations on 10 or more digits per minute in grades 1-3? [59]. The questions are not limited to primary education. For secondary or higher education students who have spent their school lives without textbooks (as in Mozambique), there is a need to research how to optimize the remaining time and teach efficiently the basic concepts they have missed. The contribution of technology must be studied from this perspective, though large-scale remediation programs have been limited.

An important advantage of engaging cognitive (neuro) scientists in this research is training in neuroimaging and instruments such as event-related potentials. To optimize instruction in difficult circumstances, it is insufficient to collect mere paper and pencil data. There is a need for eye trackers, experience sensing devices, or psychophysics displays. fMRI⁶ can be realistically used mainly in countries such as South Africa or India, but eye tracking and event-related potentials equipment have become portable. These would provide valuable insights in the workings of children who read and count under circumstances that have probably never been researched.

One difficulty with the needed research is that such studies have limited relevance to higher-income countries; therefore funding has been nearly impossible to get. However, donor agencies are becoming more interested in financing learning research. A partnership led by the World Bank has been developing parameters for various topics. It is hoped that suitable amounts of funding can become available. Research targeted on learning basics is urgently needed if the Education for All initiative is to succeed.

4. FUTURE PROSPECTS IN THE EDUCATION OF THE VERY POOR

The learning outcomes of the very poor clearly demonstrate why it is important for the donor community to understand better the principles of learning. Certainly, economic and other socioeconomic factors must be mitigated so that children can enroll, attend, and stay in school. But when children come to class, they must process information according to certain biologically determined requirements. One of them is a need to learn the fundamental components first and perform them with sufficient speed to undertake sequences of operations within the capacity limits of working memory.

In high-income countries, students usually get plenty of elaboration and practice opportunities, so they become adept at basic skills and can quickly progress to more complex tasks. Tackling more complex concepts may help students become more efficient learners, so the amount of information that higher-income students can abstract, organize, and retain increases exponentially [101]. But in low-income countries, the limited prior knowledge and instruction make it hard for learning rate to take off. Delays in acquiring the basics delay the acquisition of complex information. Limited practice with reading, writing, and math may make work slow and tedious and limit what children can achieve. Each operation may require extra milliseconds, and these add up. But operations must nevertheless be conducted inside a working memory window that has limited capacity. Thus, processing speed can affect whether a test item can be answered correctly, incorrectly, or just abandoned. Small but systematic differences in basic skills performance may add up over the grades and result in large performance differences between the higher and lower-income countries in international comparisons.

Differences in learning rate may explain to some extent the findings that the average child of lower-income countries performs at the 5th percentile of wealthier countries [13]. The score difference in PIRLS between Hong Kong and Morocco suggests that very roughly fourth graders in Hong Kong may get 150% more information than Moroccans, given an equivalent text and same timeframe. Fourth graders in Singapore may do roughly three times more arithmetic operations than fourth graders of Yemen.

⁶ *Functional magnetic resonance imaging (fMRI)*

Scores of tests like TIMSS are analyzed through sophisticated procedures and extensively discussed in various countries and the donor community. Much is made of the differences in international comparison tests, but insights about their evolution are rather limited. Certainly home background is important, but in some respects it is distracting. Educational systems cannot educate homes; they must concentrate on what can be done in class.

The author has found a few cross-cultural studies on reaction time [102]; τ but no studies have been found that tracked performance on variables leading to those test scores, such as response time to simpler and more complex tasks and amount of information retained over weeks or months of school. Possibly response times to simple reading passages and math operations could follow a logistic S curve, with low-income countries at the bottom. But without a good handle on information processing variables, government and donor decisionmakers find it hard to focus on the critical variables to improve during school. And without a valid causal chain, it is not easy to remedy deficits.

Intellectual leadership is therefore needed to explain issues convincingly and open new areas for research. Such leadership might best be provided by scientists who understand the how memory works. If governments focus curricula on the automaticity of small information chunks, the performance gap between the poorer and richer countries may be reduced. Without expertise on information processing, such an outcome is unlikely. Colleges of education produce legions of PhDs every year who lack the training to deal with information processing. And there is no evidence of imminent change in this respect.

Due to a lack of expertise, the education of the children who live on a dollar pay day may be compromised by the very people who aim to help them. Education specialists in low-income countries routinely design curricula that seem aimed at average rather than lower scores of international tests. The curricula cover large amounts of material, expect students to read several pages on their own per day, develop reading textbooks on the basis of whole-language methods, assume that students somehow have learned thousands of English and French words by grade 4, and leave much to the discretion of poorly educated teachers [103]. Therefore students get little if any exposure to the preliminary knowledge needed for learning the more complex materials. This is how middle-class standards may rob the poor of the scant learning opportunities that international donors put at their disposal with so much effort.

As things stand in 2013, the academic community that once generated the basic memory principles has moved on. But the mission to educate the millions of students who live on a dollar per day is barely underway. To serve them, we must reintroduce the 20th century research pertinent to simpler cognition. Teaching and researching essential memory principles might produce better informed policies and learning outcomes. Without them, pouring billions of dollars into the budgets of low-income countries is tantamount to dropping food packages on isolated villages and hoping that some will fall into cooking pots. Disappointment may reduce donor investments or divert them from education to other sectors (See for example [104]).

The challenges to disseminate and apply these concepts are significant but if suitably prepared cognitive scientists become engaged, there is hope. To teach the poor efficiently and fulfill children's UN right to education, human cognitive commonalities offer unique opportunities. In all countries, governments must offer students dense and well-connected networks of knowledge, with automatized basic skills. Thus human capital can be optimized

worldwide. And some currently obscure psychological research can be shown to have worldwide implications.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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