Socio-Cognitive-Affective Barriers to Mathematics Education in Developing Nations

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Socio-Cognitive-Affective Barriers to Mathematics Education in Developing Nations

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Synonyms

Access to quality mathematics education; Inclusivity in mathematics education; Poverty and mathematics learning

Definitions

Mathematics (maths) education can be defined in terms of formal mathematics learning and teaching, typically within a primary/secondary school, college, or university context. This usually involves one or more qualified professionals taking responsibility for learners of maths. However, it also encompasses informal maths learning, e.g., pre-school and home environments. This involves parent–child interactions ranging from number-play to more structured support with children's school homework. The concept of maths itself can be considered in relation to basic number facts and procedures, including simple multiplication facts and counting. It also includes elements of maths progressively covered within formal education, e.g., numerical reasoning and problem-solving, measurement, shapes, geometry, fractions, and algebra. Functional maths includes the application of maths to real-world contexts. In the context of maths learning and education, social barriers include home-level socioeconomic factors, but also the wider economic position and availability of resources of a country. These factors range from poverty related to food, sanitation, relevant materials (e.g., textbooks or information technology), and money. Influencing factors can also be intangible factors such as societal attitudes that hinder or disadvantage certain groups. Cognitive barriers are limitations in the development of cognitive resources required for successful mathematical competency, e.g., attentional processes, language, and memory. Affective barriers are feelings and emotions that can hinder one's ability to successfully learn and apply maths, the most common being maths anxiety. Such barriers can be discussed in the context of developing nations, which can be defined according to whether they appear in the Development Assistance Committee (DAC) list of countries eligible to receive official development assistance (ODA). This is based on countries with a comparatively low income per capita (according to the World Bank) and the least

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developed countries as defined by the United Nations. The list is updated every 3 years. As such, discussion of empirical evidence within a specific country needs to be in the context of whether the country appeared as a DAC-list ODA recipient at the time at which the work was conducted.

Introduction

The impact of poverty is far reaching; across the globe 200 million children under the age of 5 do not achieve their developmental potential, with most of these disadvantaged children living in South Asia and sub-Saharan Africa (Grantham-McGregor et al. 2007). Difficulties in reaching developmental milestones contribute, both directly and indirectly, to educational under-achievement later in childhood and adolescence (Dickerson and Popli 2015). Intergenerational transfer of poverty is also apparent, with data from Indonesia indicating that children who have experienced persistent poverty are 31% more likely to live in poverty in adulthood than children who did not experience poverty (Pakpahan et al. 2009).

The fourth goal outlined by the United Nations 2030 Agenda for sustainable development is to "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all." The current chapter focuses on a discussion of how this relates specifically to mathematics (maths) education, which we consider to include the academic (e.g., school) and nonacademic (e.g., home) environment. Specifically, the discussion mainly focuses on barriers to maths education that are not directly pedagogical, but rather social, cognitive, or affective in nature. In this respect, the value of interdisciplinary research is highlighted, often involving the collaboration of maths educators and psychologists.

Maths skills are increasingly recognized as being essential for everyday functioning (Xing 2013). Strong numeracy and literacy skills are associated with a lowered risk of poverty (World Bank 2012). Many wide-reaching negative outcomes are associated with low maths skills, such as significantly higher risk of unemployment, lower wages, mental health problems, physical illness, arrest, and incarceration (Gross et al. 2009). In a country-level context, the cost of low maths skills has been reported to be substantial (i.e., approximately billions of pounds) due to lost revenue in taxes through unemployment and increased costs of welfare (Gross et al. 2009).

Low maths skills impact a substantial number of people globally. For example, the UNESCO Institute for Statistics has stated that 617 million young people do not have sufficient skills in either reading or mathematics (UNESCO 2017), with over half of these children living in countries outside of the Group of 20 (G20) grouping. Global comparison studies such as Trends in International Mathematics and Science Study (TIMMS) and the Programme for International Student Assessment (PISA) indicate a wide variety of maths achievement, with East-Asian nations typically performing at higher levels than all other countries (OECD 2015). Recent OECD data from 2018 shows maths attainment to be the lowest in countries in the global south (OECD 2020). In fact, several countries with the lowest maths attainment are ODA recipients (e.g., Indonesia, Columbia, Cuba, Costa Rica, and Brazil), highlighting the association between low national economic status and maths attainment. However, there is an imbalance in the research that has been conducted to address low attainment levels and barriers to maths learning, with the majority of research being carried out in Europe and North America (see Simms et al. 2019, p. 20). Part of the issue is a limited set of resources to investigate barriers to inclusive, quality maths education within developing nations. With that being said, there are many researchers in this area who are based within developing nations and, while some empirical evidence exists, it does not always receive widespread acknowledgment among academics or the general population on a global level.

In addition, within-country comparisons have indicated an impact of low income on children's early maths development (Jordan et al. 2006). However, more broadly, it is important to note that a substantial minority of children from high-income families may also have problems with learning in general (i.e., Woolfson et al. 2013). These data suggest that global differences in maths achievement may not only be explained by poverty, but other additional factors, such as cultural differences in attitudes towards mathematics (Prendergast and Hongning 2016) and access to *appropriate* resources (Anders et al. 2012).

Socio-Barriers to Maths Education in Developing Nations

Clear contributing factors to modern job performance are sound basic numeracy and literacy skills. These skills are vital to economic success and play a central role in allowing workers to adapt and advance professionally (Windisch 2016). Yet, poverty is related to lower mathematics achievement (World Bank 2012). While economic growth reduces poverty, associated change is slow and hence poverty reduction is gradual for people from poor backgrounds (Boxill and Quarless 2005). Indeed, direct programs such as economic investment are ideal for poverty alleviation but medium-term programs such as expanding access to land and credit for citizens ultimately do more to reduce the incidence of poverty (Boxill and Quarless 2005). Effort towards the implementation of reducing poverty directed towards people from poorer backgrounds has been slow in developing countries (Boxill and Quarless 2005). Despite the efforts that have been made, such as extensive vocational training programs and credit assistance for unemployed and poor youth (e.g., HEART Academy and Micro Investment Development Agency (MIDA) in Jamaica) it seems that governments may have used these strategies to mask youth unemployment, instead of dealing directly with youth poverty (Boxill and Quarless 2005).

Children living in poverty in developing countries face many barriers to accessing education, such as having an untrained or no teacher, no classroom, lack of learning materials, and hunger and poor nutrition. Further, there is a global teacher shortage that threatens efforts to ensure universal access to primary education. The greatest challenge, according to UNESCO's projections, is in sub-Saharan Africa where more than one million teaching posts were needed by 2015 to meet the needs of a growing number of primary students (UNESCO 2014). Additionally, it is generally difficult to recruit teachers with high levels of maths-teaching qualifications (Ingersoll 2003). Teachers teaching mathematics to lower-secondary students are trained as generalists in some countries (e.g., Chile) and therefore, may not have a deep level of understanding of mathematics in order to teach (Tatto et al. 2012). This could have a knock-on effect. For example, children who score lower in mathematics at age 12 are more likely than others to drop out by age 15 in countries such as Ethiopia, India, Peru, and Vietnam (UNESCO 2014).

An additional barrier to maths learning is not only the lack of trained teachers in developing countries, but also the shortage of teaching resources for children living in disadvantaged areas, particularly rural areas. In some Latin American countries, (i.e., El Salvador, Guatemala, Panama, and Peru), achievement gaps in mathematics between rural and urban students exceed 15% (UNESCO 2014). There are fewer available resources such as textbooks in rural areas, but also other basic resources may be lacking, such as water and toilets. In Chad, only 1 in 4 classrooms have toilets with only one-third of toilets being for girls only. This is a substantial barrier for girls attending school, leading to further inequalities between boys and girls in education (Rueckert 2019).

Teachers need good-quality, up-to-date learning materials to be effective and to guide their lessons, yet many teachers do not have access to textbooks themselves, never mind their students having these resources. In many parts of the world, outdated textbooks are often shared by six or more children (UNESCO 2016). In Cameroon, there are 13 second-grade students for every grade-appropriate maths textbook (Rueckert 2019). These inequalities in resources further divide developed and developing countries. Currently, 87% of primary school–aged children in developing countries will not achieve minimum proficiency levels in maths compared to 8% in developed countries (UNESCO 2017). Further, the growing digital divide will only continue to have severe implications for education in developing countries.

There are many different factors that contribute to socioeconomic status (i.e., occupational measures, parental income, mother's educational levels, etc.) with some strongly relating to academic achievement. In fact, there is evidence that parental education is the best predictor of socioeconomic status, with maternal education being most predictive in the early years (Sammons et al. 2004). However, with there being more barriers for girls to attend school (e.g., lack of safe toilets) there is less likelihood of women, and therefore mothers, obtaining an education. Findings, from 56 countries, show that when mothers gain an additional year of education, the average child attains an extra 0.32 years in school, and for girls the benefit is slightly larger (UNESCO 2014). In order to overcome these inequalities, women should be encouraged to attend school. Further, investment towards facilities (e.g., proper sanitation and running water) should be increased as there are many benefits, not only for the economy, but also in narrowing gender gaps in work opportunities and pay (UNESCO 2014) when children are able to attend school.

Cognition and Poverty

A large body of evidence has identified numerous cognitive skills that are important for acquiring maths knowledge and processing maths content (e.g., Geary and Moore 2016; Gilmore et al. 2018). Cognitive skills describe a wide variety of higher-level thinking skills that develop rapidly throughout childhood (Geary and Moore 2016).

Specifically, the development of executive function skills has been observed to be associated with maths achievement in numerous studies (Mulder et al. 2017). The constellation of higher-order thinking skills enable children to process novel information in an adaptive manner and include inhibitory control (being able to control cognitive and behavioral responses), cognitive flexibility (being able to switch between tasks, follow different rules, and use different strategies), and working memory (holding and manipulating information in the mind). The application of these skills to mathematics learning are particularly pertinent when developing conceptual knowledge of mathematics and learning to adaptively and flexibly apply strategies (Gilmore et al. 2018).

Data from the UK Millennium Cohort Study indicates that children who have experienced sustained poverty in early childhood display cognitive development scores (as measured by assessment on the British Ability Scales and National Foundation for Educational Research Standard Progress in Mathematics test) that are on average 20 percentile points lower than children who have never experienced poverty at 7 years old, even after controlling for multiple confounders (such as family size, birth weight, and maternal education; Dickerson and Popli 2015). Research in developing countries has indicated that early cognitive development is predictive of later academic progress (South Africa; Liddell and Rae 2010) and persistence in school registration in later adolescence (Guatemala; Gorman and Pollitt 1996). In addition, findings reported by Grantham-McGregor et al. (2007) indicate that, even after controlling for multiple confounders, early cognitive skills predict later school achievement outcomes in Brazil, Jamaica, and the Philippines. However, it is clear that there is a lack of robust, longitudinal data generated in developing countries to explore the relationship between specific cognitive skills and later maths achievement in these contexts.

Children who experience poverty, independent of the country in which they live, have heightened risk of lower levels of cognitive development (Grantham-McGregor et al., 2007). There are numerous factors that may contribute to this risk. Malnutrition is a severe problem in developing countries and is the underlying cause in 45% of deaths of children under 5 years old globally (Inter-agency Group for Child Mortality Estimation 2019). Education is essential to eliminate malnutrition, especially education that empowers women (Ricardo 2013). There are established clear links between lack of access to nutritious food or malnutrition and lower levels of cognitive development (Biesalski 2016). A large body of research indicates that malnutrition impacts on brain development, particularly areas of the brain associated with language and memory development. Brain development is particularly sensitive to lack of micronutrients such as protein, zinc, and vitamin A (Georgieff 2007). Iron deficiency associated with malnutrition increases the risk of poor cognitive development due to the importance of this nutrient in the myelination of the brain and the development of neurotransmitters (Pollitt 1994).

There is also evidence that caregiving experiences are important in relation to cognitive development. The Multiple Indicator Cluster Survey (MICS) was a nationally representative international comparison study of over 127,000 families in 28 countries. This study identified two important environmental constructs for supporting child development: social and cognitive caregiving (Bornstein and Putnick 2012). Cognitive caregiving describes the support that parents provide for their children to interact and learn in their environment, through formal or informal activities. These types of activities, such as reading with children, storytelling, drawing, counting, and child-directed speech vary vastly between cultures. Socio-emotional caregiving enables interpersonal connections and supports children to develop a sense of worth, emotional resilience, and communication skills. Activities such as pretend play, singing, and dancing enable children and parents to explore roles, scaffold understanding of relationships, and develop secure attachments. Caregivers from countries high on the Human Development Index (HDI) engaged in more socio-emotional and cognitive caregiving activities than those from low HDI countries, although there is large variation in behaviors across comparable HDI countries and within countries themselves. Both types of caregiving are associated with better child achievement and social outcomes. However, caregivers from all countries engaged in more socio-emotional than cognitive caregiving; this may hold particular importance when researching and intervening to improve academic outcomes.

In addition, exposure to stress is known to impact on amygdala and hippocampal development, areas of the brain that are essential for language development, emotional regulation, and learning (Johnson et al. 2016). Prenatal and postnatal exposure to stress has been reported to impact on cognitive development (Wacharasin et al. 2003) and should therefore be considered in the context of maths learning.

Mathematics Affect: A Focus on Maths Anxiety

Within the broader study of affect in the domain of maths education, maths anxiety has been the focus of much research. Maths anxiety can be described as a negative emotional response to maths. It can involve an in-the-moment anxious reaction, often associated with panic, increased physiological reactivity, and worrisome thoughts. However, maths anxiety may also be associated with prolonged anxiety, often in the buildup to maths situations perceived as threatening, such as exams or even simply being in a maths class.

There is an increasing body of literature regarding cross-cultural comparisons of maths anxiety, owing in part to the existence of some large, international datasets (e.g. PISA studies). For example, Wood et al. (2012) found maths anxiety to be higher in Brazilian children than children in Germany. This is consistent with PISA (2003) data that showed older Brazilian children to be among the most maths anxious out of 41 countries included in the study. In a further cross-cultural comparison, Brown et al. (2020) found Colombian University students scored higher than US students on the learning maths anxiety subscale of the Abbreviated Math Anxiety Scale (AMAS, Hopko et al. 2003) compared to no difference on the maths evaluation anxiety subscale, although it should be noted that the US sample size was quite small ($n = 20$). In a study of elementary school children in Serbia, significant negative correlations were observed between both subscales of the modified AMAS (Carey et al. 2017) and maths achievement, although a weaker correlation was found for the maths learning anxiety scale (Milovanović and Branovački 2020). These findings demonstrate the need to consider the multidimensionality of maths anxiety when researching cross-cultural differences.

According to 2018 PISA data (OECD 2020), Indonesia had the lowest maths attainment out of all the countries involved. Ayuningtyas et al. (2019) provided descriptive findings to indicate high levels of maths anxiety in Indonesian high school students, including somatic markers, such as a fast heart rate, and cognitive components (e.g., being unable to think clearly in maths classes). Consequently, the authors emphasize the need for compassionate maths teachers. Meta-analyses have consistently demonstrated a negative relationship between heightened self-reported maths anxiety and lower levels of maths performance (Hembree 1990; Namkung et al. 2019). The link between high maths anxiety and low maths attainment is particularly strong in ODA-recipient countries, specifically Tunisia, Jordan, and several Central and South American countries (PISA 2012 data, OECD 2015). These are mostly the same countries that have the poorest maths attainment according to PISA 2018 data. A meta-analysis investigating the association between maths anxiety and maths achievement in Turkish students was carried out by Sad et al. (2016). The analysis involved 11 studies, including a total of 8,327 students from different stages of education. The results of the analysis for all 11 studies involved showed significant negative correlations between maths anxiety and maths achievement. Moderation analysis based on school level showed that the combined effect size for the studies conducted at both middle and high school level was significant, negative, and at a moderate level. Generally, there have been reports of high levels of maths anxiety among learners in Africa (e.g., Mkhize 2019) and this has been associated with low academic achievement (Mohamed and Tarmizi 2010). In a sample of Malaysian matriculation students, Zakaria and Nordin (2008) found maths anxiety to be significantly negatively related to maths achievement and motivation. Similarly, Kargar et al. (2010) observed a significant negative correlation between maths anxiety and maths attitudes in Malaysian university students. Loong (2012) surveyed 76 international students on a pre-university program in Malaysia. Students came from 26 different countries, 87% of which were ODA recipients. Loong found maths anxiety significantly negatively predicted maths performance. Interestingly, the strongest bivariate correlation with maths anxiety ($r = -0.54$) was with a measure of concentration, suggesting maths anxiety is related to an inability to pay attention to, concentrate on, and think about learning materials. These findings suggest that maths anxiety should be a focus of researchers aiming to look at ways in which maths attainment can be supported in a sustainable way.

As with the direction of maths anxiety research in developed nations, research in developing nations has started to focus on factors beyond the individual, including the role of parents and teachers. For example, Soni and Kumari (2017) studied almost 600 10- to 15-year-olds and their parents in India. Path analyses suggested parents' maths anxiety and maths attitudes acted as a precursor to the development of maths anxiety and maths attitudes in their children, which in turn may influence children's achievement. Srivastava et al. (2016) also demonstrated a significant negative association between Indian students' maths anxiety and their parents' level of education. A survey of children and their parents in Bangladesh showed a significant relationship between parents' maths attitudes and children's maths anxiety (Haque and Farhana 2017) and, in a further study of Bangladeshi students, Syed and Anwar (2016) noted that almost 50% of children identified as consistently poor performers in maths could be classified as highly maths anxious. Furthermore, students reported a range of factors that may contribute to this, including family pressure and the desire for more interesting or creative maths teaching. Perceptions of teaching quality appear to be important. For example, in a study of over 300 students in Pakistan, Sultan et al. (2015) found a moderate negative correlation between maths anxiety and students' perception of social support from their teachers. According to Kesici (2018), parental maths anxiety is a key contributor in the formation of maths anxiety in children in

Turkey. Kesici measured maths anxiety in 132 secondary school students and their parents and found that parental maths anxiety predicted children's maths anxiety. The researcher argues that maths anxiety is a cultural problem and can be transmitted from parents to children. In a related study, Sari and Hunt (2020) surveyed 186 child–parent dyads in Turkey. They found that in grade-three children's maths affect (comprising maths anxiety and maths attitudes) significantly predicted their maths achievement. Interestingly, in grade four, as maths education in Turkey becomes more pressurised and assessment focused, parents' maths affect predicted children's maths achievement. Sari and Hunt emphasize the need to consider both the home numeracy environment and particularly tension in the family associated with maths learning and assessment. They also highlight the issue of poor educational status of parents. In their study, almost a third of parents were educated to below high-school level. This is important in the context of their children's maths learning given that parents' maths affect was associated with their educational status (more negative effect in those with a lower education status) and their child's maths achievement (children whose parents had a lower education status performed significantly lower in maths).

Radišić et al. (2015) note the relative importance of intra- rather than inter-school differences in predicting maths anxiety, emphasizing maths achievement, interest, self-concept, and school and classroom atmosphere as the strongest predictors of maths anxiety. Reviewing empirical studies of maths anxiety in developing nations reveals the variation in approaches taken and the range of variables considered. For example, in a study of Iranian seventh graders, Hoorfar and Taleb (2015) reported a significant negative relationship between maths anxiety and metacognitive knowledge, with the authors arguing that metacognition may mediate the relationship between maths anxiety and performance. In a similar age group in Iran, Arji et al. (2018) observed a significant positive correlation between maths anxiety and test anxiety, and in a large sample of Ugandan students, Muwonge et al. (2018) found maths anxiety to be significantly related to low intrinsic motivation, low enjoyment, and low value for maths. It is likely that the relationship between maths anxiety and maths achievement is complex and a range of variables are at play. In a study of over 600 secondary school students, Çiftçi (2015) found students' maths anxiety varied as a function of how they perceived the quality of their maths education. The author argued that, given all the students were exposed to the same education, it is the students' perception of their education that is important in determining the level of maths anxiety they experience, rather than there being any real variations in maths education experiences between students. Such a proposition aligns with more recent argumentation that maths anxiety should be considered in the context of an individual's appraisal of past maths experiences (Ramirez et al. 2018), whereby negative appraisals may shape the development of maths anxiety.

Researchers have devised several innovative strategies to help people overcome maths anxiety (Dowker et al. 2016). However, studies that gain notoriety tend to be based within the developed world and it is important that assumptions should not be made about the generalisability of the efficacy of such interventions to ODA-recipient countries. Firstly, there is less evidence of the testing of maths anxiety interventions in ODA-recipient countries. Secondly, careful consideration should be given to the generalisability of existing interventions, accounting for the specific barriers to inclusive and equitable maths education in countries with lower gross domestic product (GDP). Some existing studies based in lower GDP countries have revealed innovative and useful insights. For example, Lavasani and Khandan (2011) used a cooperative learning intervention (involving interactions among peers and the teacher) among Iranian eighth graders and found it resulted in a significant reduction in maths anxiety and an increase in help-seeking behavior. Similarly, in a study of secondary school students in the Philippines, Segumpan and Tan (2018) found a flipped classroom approach reduced maths anxiety, arguably due to the greater interactivity and dynamic nature of learning afforded by this alternative approach.

Conclusions

As outlined in this chapter, maths skills are consistently related to levels of employment and income (i.e., at a personal and national economic level) in addition to a range of other factors such as mental and physical health. There is also a robust evidence base that highlights the relevance of maths skills to sustainable economic development. It is clear there is a maths achievement gap between developed and developing nations, and much evidence points towards the importance of socio-cognitive-affective barriers in understanding why this is the case. Improvements in physical resources is required for sustainable maths education, including adequate nutrition, suitable teaching (and sanitation) facilities, and trained teachers. Poverty has far-reaching impacts not only on access to nutritious food essential for optimal cognitive development and enriching home resources, but also on family functioning and stress. A systemic approach will probably be necessary to improve maths outcomes in ODA-recipient countries.

It is essential that governments in developing nations target areas that would alleviate poverty directly. For example, by (1) targeting youth poverty directly, and (2) attracting specialized teachers and/or develop teacher training programs where teachers have the opportunity to gain a deep level of understanding of mathematics in order to teach children maths skills and concepts (instead of being generalists). Furthermore, governments should aim to (3) improve teaching resources for teachers and children and (4) provide a safer environment for girls to attend school by providing proper sanitation and girls-only bathrooms. This last recommendation of promoting girl's education is perhaps the most important given the subsequent benefits to society as a whole. More equitable maths education is likely to help women develop the skills, knowledge, and the self-confidence necessary to be a better parent and educator for their children, as well as a better employee for the workplace. Gender inequality in maths education in ODA-recipient countries is striking and interventions must ensure that females are adequately supported to achieve in maths in order to secure the economic and social benefits of being mathematically literate.

Consideration must also be given to psychological factors such as motivation, attitudes, and maths anxiety, particularly in the context of gender equality and maths. It is also clear that a range of factors need to be considered to fully understand the development and impact of maths anxiety at a global level. However, the impact of maths anxiety as a barrier to maths education in some developing nations (e.g., African nations) remains understudied. Although attempts have been made to develop and adapt research instruments for assessment of maths anxiety elsewhere (e.g., US, Spain, and the UK), there has been minimal effort to develop suitable measures of maths anxiety in developing countries where, for example, teaching and assessment practices may differ from those in developed nations.

At a global and local level, socio-cognitive-affective barriers need to be considered together. At an individual, societal, and economic level, addressing the barriers outlined here is essential for the sustainable development of maths education and the proceeding benefits in ODA-recipient countries. Such considerations are required in order to meet the fourth United Nations sustainable development goal "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all." A number of recommendations are outlined:

- Longitudinal studies are essential in order to improve understanding of facilitators and barriers in maths development and education in the developing world. These studies must be sensitive to cultural differences.
- Researchers should take a more inclusive approach when reviewing the academic literature on barriers to maths education. Systematic literature searches should be encouraged to generate globally representative syntheses of the literature.

- An interdisciplinary and globally collaborative approach is likely to be the most effective strategy in fully understanding barriers to maths education.
- Developing broader networks of those studying barriers to maths education is required, including partnerships between academics across ODA-recipient and non-ODA-recipient countries.
- The move towards open-access publishing is encouraging. However, the costs to authors, especially those from ODA-recipient countries, are prohibitive. In order to garner a truly global perspective on any topic area academics must campaign for broad access to open-access publishing.

Cross-References

► Adult Education: Contribution to the Sustainable Development Goals
► Education
► Education for Sustainable Development: Strategies and Key Issues
► Global Access to Education for Sustainable Development

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