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Learning for adaptation and 21st-century skills: Evidence of pupils' flexibility in Rwandan primary schools

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ABSTRACT

Recent global challenges like the COVID-19 pandemic have highlighted the growing importance of children learning 21st-century skills for adaptation and flexibility. Competence-based curricula encourage creativity and problem solving but little is known about their development in low-income countries or relationship with conventional academic outcomes like literacy. This study examines pupils' cognitive flexibility, the underlying basis for many 21st-century skills, in Rwandan primary schools and finds little association with their reading abilities. The findings advance international knowledge regarding child development in resource-poor contexts, suggest a need for more holistic measurement and offer a new approach for understanding learners' adaptability.

1. Introduction

The growing prominence of complex global challenges in recent years has highlighted the increased importance of learning for adaptation at both personal and collective levels. Protracted conflicts have destroyed lives and livelihoods, undermined the delivery of education and other public services, and precipitated widespread migration as populations flee violence and search for safety (Greaves et al., 2019; Milton, 2019). Scenes of student protests have drawn attention to the dual threats of changing climate patterns and unsustainable human consumption (Bangay and Blum, 2010). Meanwhile, the COVID-19 pandemic has impacted populations around the world, closing schools, prompting new approaches to teaching and learning, and widening existing social inequalities (Crossley et al., 2020; Kaffenberger, 2021).

Even before the pandemic, many education systems and policies had identified the need to build so-called '21st-century' skills to meet the diverse demands of modern life (Amadio, 2013; Ananiadou and Claro, 2009; Partnership for 21st Century Learning (P21), 2016; Trilling and Fadel, 2009). These include competences like creativity and problem solving, which can help learners both respond to 21st-century challenges and tackle their underlying causes. To foster these skills, numerous countries across sub-Saharan Africa and worldwide have introduced outcome-driven frameworks that support children's aptitudes for flexibility at all levels of their education and training (Boahin and Hofman, 2014; Cunningham, 2018). Rwanda is one such example and in 2016 launched a competence-based curriculum to promote learning beyond literacy and numeracy, to "engender adaptability in young people so that they are prepared for an uncertain future" (Republic of Rwanda Ministry of Education (MINEDUC) and Rwanda Education Board (REB), 2015a, p. 19). However, implementing such curricula appears to present a major obstacle for systems that are already over-stretched and under-resourced, and questions remain about how and when these broader skills can best be measured, monitored and nurtured among learners in low-income populations.

This study therefore aimed to address this gap through an empirical examination of Rwandan pupils' cognitive flexibility, the mental process that underpins skills for adapting like creativity and problem solving (Cartwright, 2012; Cragg and Chevalier, 2012; Diamond, 2014; Jurado and Rosselli, 2007). In particular, the research explored its measurement among learners in four public primary schools, its relationship with other, more conventional, learning outcomes, and factors associated with its development. The paper starts by mapping out the conceptual and contextual backgrounds, as well as the quantitative methods used to collect data with the Rwandan children. The results are then presented and discussed, before the paper concludes with reflections on the implications of the findings for education research in Rwanda and similar low-income countries. It thereby provides an important contribution to literature and evidence regarding children's acquisition of skills for adaptability in resource-poor environments.

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2. Background

Primary schooling for many learners worldwide provides a key opportunity for building crucial competences that they will carry with them into all aspects of their adult lives. Literacy and numeracy provide essential foundations for later educational experiences and practical lifelong learning, but alone they appear insufficient to drive financial prosperity, enable inclusive social change and address the different challenges outlined in the Sustainable Development Goals (Raikes et al., 2017). Research on more applied skills like creativity, problem solving and critical thinking meanwhile tends to focus on higher levels of education, secondary and tertiary, as students prepare to enter the labour market (Chege, 2015; Kivunja, 2014; Schendel, 2015, 2016). However, such studies, in both high- and low-income contexts, often overlook the relevance of fundamental traits and competences that enable these complex skills to emerge, and which typically develop during learners' younger years (Abadzi, 2016).

The present research therefore drew on principles of child development to investigate these more basic underlying mental processes and during a period when most learners, at least in Rwanda, appear to be in school (Abbott et al., 2015; MINEDUC, 2016; United Nations Educational, Scientific and Cultural Organization (UNESCO), 2020). In particular, cognitive flexibility seems to offer valuable benefits for primary pupils' 21st-century skills, as this section now explores.

2.1. Understanding 21st-century skills

Since the turn of the millennium, education discourse, policies and curricula have highlighted the importance of '21st-century' competences with rising frequency and urgency. Factors including globalisation and the explosive proliferation of technology have prompted education planners to consider the fitness of their school systems for purpose so that learners enter the workforce with the skills needed to exploit any future opportunities (Brown et al., 2001; Rubagiza et al., 2011; Tikly et al., 2003). Similarly, broader competences may play key roles in empowering individuals and communities to participate in political processes, realise their potential and enforce essential rights both to and through formal education.

Numerous frameworks have been developed for understanding and promoting 21st-century skills. In this context, 'skills' and 'competences' concern the ability to display certain behaviours or perform particular tasks, possibly measured against standardised benchmarks (Kuboja and Mbarushimana, 2016). There are subtle differences between them but for convenience of reference and in light of the considerable overlap, the two terms are used interchangeably throughout this paper. Precise formulations of *21st-century* competences also vary by model, but generally they tend to combine diverse intra- and interpersonal abilities like self-efficacy, critical thinking and collaboration skills, with more technical aptitudes, knowledge and awareness, for example in relation to information and communications technology (Learning Metrics Task Force, 2013; P21, 2016).

Indeed, the diversity of competences has given rise to a variety of terms being used. Depending on the relevant framework, such abilities may be described as core, soft, life, catalytic or transferable skills (UNESCO, 2012; World Bank, 2005). In many cases, they are not new concepts or educational outcomes, but rather reflect growing acknowledgment of the complex mix of different competences needed to navigate modern life successfully (Care et al., 2017). Within this set of 21st-century skills, the current study focused on learners' capacity for adaptation, creativity and problem solving, specifically examined through the lens of cognitive flexibility.

2.2. Framing cognitive flexibility

Cognitive flexibility, also known as 'switching' and 'shifting', comprises an important aspect of children's early development. It first starts to appear around 3–5 years old and evolves into adolescence and even later (Cartwright, 2012; Cragg and Chevalier, 2012; Jurado and Rosselli, 2007; Zelazo et al., 2013). Diamond (2014) describes it as "creatively 'thinking outside the box', seeing anything from different perspectives, and quickly and flexibly adapting to changed circumstances" (p. 206). As such, cognitive flexibility may not only foster creativity and problem solving but also resilience, the ability to identify risks and adapt to adverse conditions, whether political, economic or environmental (Greene, 1995; Masten, 2014; Ungar, 2015). Similarly, by enabling children to understand and engage with multiple perspectives, it may support tolerance, more effective communication and critical thinking skills, and greater appreciation of other people, different species or the wider natural world (Commonwealth Commission on Respect and Understanding, 2007; National Advisory Committee on Creative and Cultural, 1999).

Within formal education, cognitive flexibility appears to confer particular advantages for school readiness and more traditional academic achievement (Traverso et al., 2015; Vitiello et al., 2011). Children who can adapt quickly between home and school, between reading and mathematics, may be better equipped to engage with the learning content and immediate tasks at hand (Chevalier et al., 2010; Yeniad et al., 2014). Sitting tests demands that children switch back and forth between topics and subjects to apply their learning to new problems or different contexts (Meltzer and Bagnato, 2010). Cartwright (2008, 2009, 2012) further emphasises the importance of flexibility for literacy, specifically for new readers to progress from simply decoding words to integrating multiple simultaneous representations to comprehend their meaning and significance. For example, once children can recognise the letters to pronounce the word 'water', their shifting helps to create a link between the written and spoken word, and the clear liquid often used in cooking and washing.

By contrast, much less is known about how schooling supports learners' cognitive flexibility. The vast majority of related research to date has focused on children in high-income countries in Europe and North America where access to education and early learning opportunities are assumed (Bellaj et al., 2016; Dias and Seabra, 2015). Even recent initiatives to understand young children's development in lower-income settings through Measuring Early Learning Quality and Outcomes (MELQO) and Save the Children's International Development and Early Learning Assessment (IDELA) omit any explicit measure for cognitive flexibility (Pisani et al., 2015, 2018; United Nations Educational, 2017). However, the situation is slowly changing, with growing data on learners' ability to shift and switch being collected in diverse settings across Asia, Africa and Latin America (Berkes et al., 2019; Cook et al., 2019; Hermida et al., 2015; Holding et al., 2018; Howard et al., 2020; Legare et al., 2018; Obradović et al., 2016; Talwar et al., 2011; Tarullo et al., 2017; Willoughby et al., 2019, 2021).

2.3. The Rwandan context

Research on cognitive flexibility holds particular importance and prominence in a context like Rwanda. Since the devastation of the 1994 genocide, the country has seen a period of rapid economic growth and been celebrated as a beacon of African development and reconstruction (Knutsson, 2012; Knutsson and Lindberg, 2019; Straus and Waldorf, 2011). Specifically, Rwanda aims to become a technology hub for sub-Saharan Africa, create 214,000 new jobs each year for its expanding private sector, and achieve upper-middle-income status by 2035 (Republic of Rwanda, 2020; Rubagiza et al., 2011; van de Kuilen et al., 2019). However, human development indicators remain low (157 out of 189 countries) (United Nations Development Programme, 2019), and with a young and growing population (54 per cent are under 20 (Abbott et al., 2015)), the country's workforce will need not just education for basic literacy, numeracy and employment, but also skills for enterprise and job creation (Abbott et al., 2020; Bamwesiga, 2013; Pells et al., 2014; REB, 2012).

Beyond the changing *economic* situation, shifts in climate patterns also highlight the importance of adaptability among Rwandan learners. Increasing temperatures and fluctuating rainfalls have given rise to both floods and droughts, each of which can threaten food security and efforts to reduce poverty. With 70 per cent of the population employed in agriculture, such environmental factors risk exacerbating the existing challenges of accessing and sustaining viable livelihoods (United States Agency for International Development, 2019). Going forward, Rwanda, like many other lower-income countries, may yet find itself shouldering a disproportionately heavy share of the global climate change burden (Bangay and Blum, 2010).

Given these concerns, MINEDUC and the REB launched a competence-based curriculum in 2016 to diversify national learning outcomes and foster pupils' 21st-century skills (Ngendahayo and Askell-Williams, 2016). Specifically, the new curriculum represents an opportunity for progress on several key fronts: first, to build human capital by inculcating practical competences for real-life problems and settings; second, to advocate for core social values of peace, citizenship and tolerance; and third, as a comprehensive framework for improving the quality and coherence of Rwandan education at all levels (MINEDUC and REB, 2015b).

Regarding flexibility, the curriculum explicitly aims to nurture students as "[s]uccessful life-long learners, ready to adapt to new situations, and be agents of change…[c]reative and innovative individuals who are curious, adaptive and productive" (MINEDUC and REB, 2015b, p. 3). It further identifies creativity and problem solving as 'generic competences' that can be fostered in all subjects and applied in everyday life. Example activities include making toys from local materials, creating and telling a story, and establishing small projects or enterprises to generate income (MINEDUC and REB, 2015a).

To date, however, the implementation of the curriculum remains at an early stage, teachers are still being trained, and the relevance, availability and use of textbooks are variable and inconsistent (Milligan et al., 2017). Even before the new curriculum, schools were already contending with the effects of language reforms that replaced French and Kinyarwanda with English as the primary medium of instruction (Pearson, 2014). Since 2008, Rwandan educators have been expected to teach their students in a language that many themselves have yet to master, with far-reaching implications across all aspects of the system (Williams, 2020; 2018).

Over a decade later, questions continue about the success of these changes and their impact on children's academic learning. Little, if anything, is also known about their broader skills and cognitive development, let alone their flexibility to think creatively, adapt quickly and adopt different perspectives. This study therefore aimed to address this gap through an empirical inquiry involving quantitative research methods, as the next section explains.

3. Methodology

The main purpose of the study was to investigate learners' cognitive flexibility in Rwandan primary schools.[2] In particular, it sought to answer the following three research questions:

- How can cognitive flexibility be measured among primary school pupils in Rwanda?
- What factors appear to be associated with Rwandan primary school pupils' cognitive flexibility?
- How does Rwandan primary school pupils' cognitive flexibility relate to their other learning outcomes, specifically their literacy and non-verbal reasoning?

[2] The study forms part of a larger programme of research that also examined Rwandan teachers' attitudes, practices and behaviours regarding learners' skills for adaptability.

The research questions were addressed through assessments and surveys to collect quantitative data from learners attending public primary schools in the central province of the Rwandan capital, Kigali. The four schools were selected in pairs from two districts to reduce any socio-economic differences between them. In each case, they drew their students from nearby informal urban settlements, villages where at least 90 per cent of housing stock is considered 'rudimentary', which provided a proxy for poverty within the local population.

The study adopted a cross-sectional design and gathered data at a single time point, during several weeks in early 2018. A longitudinal approach was not feasible within the overall time frame, and so the research investigated pupils' performance in two class cohorts, Primary 1 and 4 (Schendel, 2015). Working with both of these groups offered valuable insight regarding learners' competences at two key points in Rwandan education, at the start of basic schooling and shortly after their transition to upper primary. In the absence of longitudinal data, such design helped to highlight the gains in children's learning and development during the first 3 years of Rwandan primary education. This approach also held particular relevance in the context of research on pupils' cognitive flexibility. While children's academic skills and outcomes are generally believed to improve with age and education, some evidence suggests a possible *decline* in learners' flexibility over time as increased knowledge and preconceptions limit their capacity to adapt, innovate and think 'outside the box' (Bilalić et al., 2008; Defeyter and German, 2003; Ionescu, 2012). For this reason, data collection with two Rwandan cohorts enabled the study to shed potentially useful light on cognitive flexibility's complex developmental trajectory.

Within the Primary 1 and 4 classes, pupils were chosen randomly from at-age learners who were 7–8 and 10–11 years old respectively (MINEDUC, 2016). The research used a minimum sample size of 296 based on calculations conducted in GPower 3.1.9.2, which also provided sufficient power to examine differences and correlations between the measures. This further allowed a minimum sample of 30 pupils from each school cohort, being the smallest number required to achieve a normal distribution under the central limit theorem and for parametric analyses to remain valid (Cohen et al., 2015; Field, 2009; Lumley et al., 2002; Maas and Hox, 2005).

Learners completed the same assessments and questionnaire in a fixed order, in their mother tongue, and individually with one of four trained Rwandan research assistants (Espy et al., 2006; Podjarny et al., 2017; Traverso et al., 2015). Such enumerators were selected based on their prior experiences of conducting studies with young children and their proven ability to create rapport to put the pupils at ease. The sessions were frequently observed to ensure data quality and consistency, and took place in various quiet spaces around the schools, which included book stores, computer laboratories and occasionally an empty classroom.

Working across English and Kinyarwanda presented an additional challenge in collecting the data. The task instructions for the Rwandan learners needed to be clear, intelligible and consistent to ensure the reliability of the data. Ensuring this involved a several-stage process: an initial translation of the relevant rubric; a back-translation by a different interpreter to assess the translation quality, as advocated by Brislin (1970); a discussion with the translator in person to explain the tasks in detail, identify errors and correct ambiguities; and lastly, ongoing and iterative feedback with the bilingual field assistants throughout the training, the piloting in two schools and the main data collection. During the latter stages, the assistants' prior experience conducting research with Rwandan pupils helped to assure the simplicity, suitability and child-friendliness of the final instructions.

Ethical issues arising during the study were addressed in accordance with the British Educational Research Association (BERA) guidelines (BERA, 2011, 2018), and clearances obtained from the Universities of Cambridge and Rwanda (Approval Notice: No 421/CMHS IRB/2017). Head teachers at the schools provided consent in *loco parentis* for the learners to take part, but the pupils were also briefed orally at the start of

each session to clarify their rights to decline or withdraw, and to invite their voluntary assent (Cocks, 2006; Cohen et al., 2015; Homan, 2001). For each participant, the research assistant then entered the responses into android tablets loaded with SurveyCTO software, for subsequent cleaning and analysis by the author in Stata.

The tasks themselves included two adapted versions of established measures for cognitive flexibility, an assessment for learners' non-verbal reasoning and a series of short exercises to gauge pupils' reading skills in Kinyarwanda. Each activity used tactile objects or stimuli to reduce the effect of any participants being unfamiliar with screens or laptops (Zuilkowski et al., 2016). Similarly, the measures for both cognitive flexibility and non-verbal reasoning did not require the children to be literate or numerate to be able to take part,[3] and the cognitive flexibility assessments started with practice rounds and criterial trials to ensure that the pupils had understood the purpose and nature of the tasks.

3.1. Cognitive flexibility measures

The first measure for assessing children's cognitive flexibility was the Dimension Change Card Sort (DCCS), created by Frye, Zelazo and Palfai (1995) and refined by Zelazo (2006). The DCCS was initially developed in North America, but has recently been used successfully in various low- and middle-income countries (Berkes et al., 2019; Howard et al., 2020; Legare et al., 2018; Tarullo et al., 2017). During the first practice round of the task in Rwanda, pupils were invited to sort cards by colour against two target cards depicting a green goat and a yellow motorcycle.[4] In the second round, participants were instructed to sort the cards by shape, while in the third and fourth rounds they switched between dimensions depending on whether the card featured a black border. Each child's score was calculated as the proportion of correct sorts following the first switch from colour to shape (Cook et al., 2019; Podjarny et al., 2017).

The Rwandan pupils' cognitive flexibility was also tested using the Flexible Item Selection Task (FIST) established by Jacques and Zelazo (2001) and expanded for use with older learners by Dick (2014). During the FIST, children are presented with sets of three or four picture boxes, in each case showing up to three familiar items. In Rwanda, these comprised shoes, cups and chickens,[5] and pupils were asked to match boxes by identifying '"two things that go together in one way' and then to point to 'two things that go together in another way'" (Podjarny et al., 2017, p. 207). The participants therefore needed to first discern a common dimension across the boxes (being shape, size, colour or number), and then to shift and consider the same stimulus pictures from up to three different perspectives. Again, pupils' scores were the proportion of correct matches but, unlike the DCCS, the FIST has been used in far fewer international contexts.

3.2. Non-verbal reasoning

Non-verbal reasoning concerns the ability to hold several pieces of information in mind to see how they relate, identify patterns or predict sequences from a group of visual stimuli (Diamond, 2014). To ascertain Rwandan learners' non-verbal reasoning, the study used the Object-based Pattern Reasoning Assessment (OPRA) developed in Zambia (Zuilkowski et al., 2016). The task involves a pattern of local items like beads, beans and stones arranged on a paper grid. One space is left empty and the pupil decides which object completes the sequence. Participants completed a mix of basic and advanced patterns, such as AAAAAA, ABCABC and ABCCBA, and scores were calculated as a proportion of correct items over ten trials.

3.3. Literacy tasks

Unlike the measures for cognitive flexibility and non-verbal reasoning, there were established, validated and accessible tools for assessing Rwandan children's reading skills throughout their primary education. Pupils in the study therefore undertook up to four grade-appropriate literacy activities selected from the Early Grade Reading Assessment and the Oral Reading Fluency Assessment of Rwandan Schools (FARS) (Education Development Center, Inc, 2017; RTI International, 2012). In each case, the instruments were created for use with nationally representative samples, tailored to the Rwandan context and language, and created in collaboration with specialists from MINEDUC or the REB. Tasks started with reading up to 100 letters and 50 familiar words in Kinyarwanda, while more advanced students also read two short stories and answered questions to demonstrate their comprehension. Performance across the activities was combined to calculate learners' oral reading fluency, comprising the number of words read properly per minute, and for the advanced readers, their proportion of comprehension questions answered correctly.

3.4. Pupil questionnaire

Finally, the Rwandan pupils were surveyed on various personal characteristics and household factors. Literature in several high-income contexts has identified certain background variables which show statistically significant associations with children's cognitive flexibility development and are summarised in Fig. 1. Sarsour and colleagues (2011), for example, found that socio-economic status (SES) explained 24 per cent of its variance among American 8–12 year-olds, but that living with two parents mediated the effects of their disadvantage. For these reasons, the participants answered diverse questions on topics including their family structure, behaviours and whether they had attended any pre-primary education.

In some cases, the questions drew on established measures for Rwandan poverty from the FARS, like eating or drinking at home before school (Education Development Center, Inc, 2017). In others, they were drafted by the author based on existing literature regarding factors like multilingualism, home stress and reading practices, which have shown relationships with children's cognitive flexibility in previous international studies (Bialystok and Viswanathan, 2009; Blair, 2016; Diamond, 2016). In both cases, the responses provided valuable insight on background factors that could concern Rwandan pupils' cognitive flexibility, and important covariates to be controlled for when exploring the interactions with wider learning outcomes.

With the study methods and measures now set out, the next section describes the results of the research, in particular details of the Rwandan participants, their performance on the different tasks, variables displaying statistically significant associations, and the findings of the linear regressions.

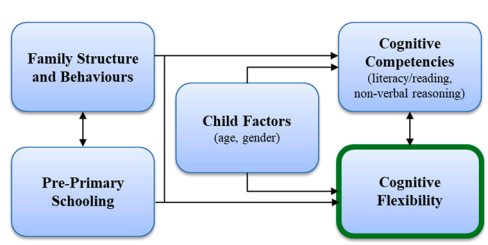

Fig. 1. Conceptual Framework for Cognitive Flexibility Development.

[3] Only one measure of cognitive flexibility, the Flexible Item Selection Task, needed pupils to be able to count to three, or at least distinguish between one, two and three items.

[4] The target images were adapted from a blue rabbit and red boat to increase their familiarity for Rwandan children.

[5] As for the DCCS, the images were changed from a boat, a flower and a rabbit to be more instantly recognisable to the Rwandan participants.

4. Results

4.1. Research participants

The study collected data from a total of 306 primary pupils, which exceeded the minimum sample size and provided sufficient power to conduct the intended analyses. Table 1 shows a breakdown of the participants according to their gender, class grade (Primary 1 or 4), the school they attended and the district in which their school was located. A small majority of learners tested and surveyed were male (55 per cent), and much of this difference resulted from an under-sampling of female Primary 4 pupils in one particular school (School 2). Follow-up analysis of the Primary 4 population at the school revealed no significant imbalance between genders, and so the disparity can be attributed to variation arising from the randomisation process. In any case, international evidence concerning children's cognitive flexibility development, at least in high-income contexts, suggests no difference between girls and boys, which accounts for the non-stratification of the sampling by gender (Bellaj et al., 2016; Willoughby et al., 2019).

Regarding pupils' backgrounds and family situations, there were fairly consistent patterns of responses across the survey data. Bivariate analyses using chi-square, Mann-Whitney and Kruskall-Wallis tests, not reported in this paper, showed that the only significant differences concerned learners in School 2 who often described characteristics and behaviours typically associated with higher SES.[6] For example, they were significantly more likely to have drunk something at home before school that day, described greater levels of family reading and indicated a higher consumption of fish and eggs in their diets. Of further interest, School 2 was the only setting where some learners declined to participate in the research, which could suggest not only greater average family wealth, but also a higher degree of child agency, empowerment and confidence. By contrast, pupils in the other three schools provided much more similar responses to the questionnaires.

4.2. Assessment results and reliability

Table 2 sets out the descriptive statistics for the Rwandan pupils' assessment scores, also disaggregated by class grade. The combined cognitive flexibility score comprises an average of the DCCS and FIST scores, while the Primary 1 comprehension results are omitted as only six pupils undertook the advanced reading tasks (Ellefson et al., 2017; Willoughby et al., 2019). For each measure, the Primary 4 learners displayed overall stronger skills than the Primary 1 children, as typically expected, and independent *t*-tests confirmed the statistical significance of these differences (Mehmetoglu and Jakobsen, 2017) (see the Annex for the results).

Table 1
Participant by gender, class grade, school and district ($n = 306$).

District/School	Primary 1 (7–8 years)		Primary 4 (10–11 years)		Total
	Girls	Boys	Girls	Boys	
District 1					
- School 1	19	20	22	17	78
- School 2	21	19	10	29	79
District 2					
- School 3	17	22	16	22	77
- School 4	18	17	16	21	72
Total	**75**	**78**	**64**	**89**	**306**
	153		**153**		

Source: Primary data, 2018.

Within the cognitive flexibility measures, and especially for the Primary 1 learners, the standard deviation is relatively large and even exceeds the mean. This is not unusual among studies using the DCCS or the FIST, or otherwise assessing children's cognitive flexibility (Clark et al., 2010; Cook et al., 2019; Sarsour et al., 2011; Tarullo et al., 2017). The histograms in Fig. 2 shed further light on this issue and show the spread of scores for the DCCS and the FIST (also see the Annex for histograms disaggregated by class grade). In both cases, they reveal a sizeable number of pupils performing at or slightly above floor, and then a wider range of results for learners who could demonstrate some degree of switching and shifting. Indeed, most international research on cognitive flexibility has focused exclusively on the former, the binary distinction between 'switchers' and 'non-switchers', and the point at which young children transition between the two (Blackwell et al., 2014; Carlson, 2005; Podjarny et al., 2017; Zelazo, 2006). By contrast, this study examined cognitive flexibility among *older* learners aged 7–11 to understand how it might improve even after the basic switches have been mastered.

Although not shown in this paper, the distributions for the Rwandan pupils' non-verbal reasoning and the Primary 4 learners' literacy were much more typical, even normal, although sometimes with a slight skew. The OPRA scores compare closely with the results of the study by Zuilkowski and colleagues (2016) in Zambia, while the Primary 4 pupils displayed at least basic, if not good, oral reading fluency, a mean of 41.61 words correct per minute, well within the range of 33–47 words required to achieve a minimum fluency in Kinyarwanda (Moulton, 2016). However, the Primary 1 learners largely performed at floor and were unable to read many, if any, words correctly. This was expected because the younger pupils were generally at the very start of their formal education, indicated mixed attendance at pre-school and were often still learning the letters of the alphabet. As a result, the Primary 1 reading comprehension scores were too few to offer meaningful data and the distribution affected the analyses conducted.

Reliability for the cognitive flexibility and non-verbal reasoning measures was tested by calculating Cronbach's alpha which indicates the degree of inter-item internal consistency (Cohen et al., 2015). Overall coefficients for each of the three tasks exceeded .70 (DCCS: .81; FIST: .85; OPRA: .72), which suggested that they offered a good level of reliability in the Rwandan context. Likewise, the alphas compared favourably with reported coefficients for the same or similar measures of switching and non-verbal reasoning used in other settings, which ranged from .73 to .91 (Blair and Razza, 2007; Dick, 2014; Engel de Abreu et al., 2014; von Suchodoletz et al., 2015).

4.3. Significant factors

With reliability of the tasks established, bivariate analyses were undertaken to explore the personal, family or educational factors that showed significant associations with the Rwandan learners' cognitive flexibility. These involved *t*-tests, analyses of variance and Pearson's correlation coefficient, depending on the nature of the specific explanatory variable (Field, 2009). In each case, the analyses were carried out for Primary 1 and 4 pupils separately, recognising that different factors could hold relevance at different stages of children's development. Also, they were not conducted to impute causal relations, which would have required an alternative research design, but rather to identify statistically significant associations that could, with further research, offer insights for fostering learners' cognitive flexibility.

Regarding pupil characteristics, there were no significant differences in performance according to children's gender, which corroborated the findings of other international studies (Bellaj et al., 2016; Willoughby et al., 2019). Among the Primary 1 learners, 8-year-olds achieved higher scores than 7-year-olds, but this difference disappeared when controlling for other variables in linear regressions. More surprisingly, Primary 1 pupils who reported drinking something at home before school and

[6] Further analyses revealed that there were no discernible differences by gender or class grade among pupils' responses in School 2, such as to give rise to systematic bias resulting from the under-sampling of Primary 4 girls.

Table 2
Descriptive Statistics for Assessment Scores ($n = 306$).

Assessment Measure	Primary 1			Primary 4			Combined		
	Mean	SD	Range (actual)	Mean	SD	Range (actual)	Mean	SD	Range (actual)
Cognitive flexibility									
- DCCS	0.26	0.29	0-0.80	0.51	0.26	0–1	0.39	0.31	0–1
- FIST	0.14	0.18	0-0.61	0.48	0.22	0-0.94	0.31	0.26	0-0.94
Combined score	0.20	0.18	0-0.62	0.50	0.18	0-0.88	0.35	0.23	0-0.88
Non-verbal reasoning (OPRA)	0.33	0.16	0-0.80	0.61	0.23	0–1	0.47	0.24	0–1
Oral reading fluency	0.51	2.42	0–22	41.61	14.49	0–84.40	21.06	23.05	84.40
Reading comprehension	–	–	–	0.78	0.18	0.23–1	–	–	–

Source: Primary data, 2018. Notes: SD = Standard Deviation; DCCS = Dimension Change Card Sort; FIST = Flexible Item Selection Task; OPRA = Object-based Pattern Reasoning Assessment.

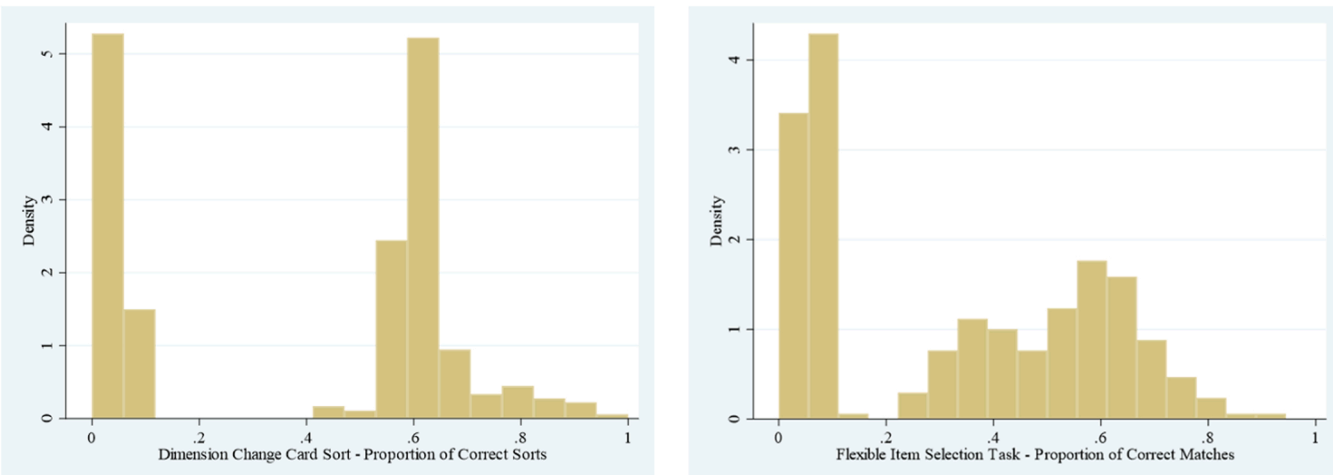

Fig. 2. Distribution of DCCS and FIST Scores.
Source: Primary data, 2018.

eating more meals in an average day performed significantly *worse* on the DCCS. This conflicts with wide research from numerous high-income settings regarding the *positive* relationship between children's SES and their cognitive development, but again all significant differences disappeared in multivariate regressions and none of the background or school-related factors predicted Primary 1 pupils' cognitive flexibility at the 95 per cent confidence level.[7]

Conversely, data for the Primary 4 learners' cognitive flexibility revealed two factors that significantly predicted their scores, even after holding other variables constant. First, children from single-parent households ($n = 41$) performed higher ($b = 0.29$, $p = .02$) than those from two-parent families ($n = 101$), in contrast to the results of the study by Sarsour and colleagues (2011) with learners in North America. Second, pupils attending the schools in one district scored significantly better than children in the other district ($b = 0.51$, $p < .01$). Although such school-based differences do not necessarily indicate causality, they make sense for Primary 4 but not Primary 1 learners because the former had experienced 3 more years of formal education at the schools than the latter.

4.4. Relationships between competences

In addition to the factors associated with Rwandan pupils' cognitive flexibility, the research questions also queried its relationship with other learning outcomes, not least their non-verbal reasoning and literacy. First, however, it was necessary to examine the relationship between the two cognitive flexibility measures themselves. Bivariate analyses of the DCCS and FIST scores revealed a Pearson's correlation coefficient of .35, which was statistically significant at the 0.10 per cent level ($p < .001$) and represented a medium effect size (Field, 2009). This aligns with similar comparisons of different cognitive flexibility tasks in other studies, which range from .23 to .40 (Dick, 2014; Engel de Abreu et al., 2014). Overall, the correlation indicates that despite some variance in performance across the DCCS and the FIST, both assessments appeared to tap the same underlying construct and therefore provide a valid measure of children's cognitive flexibility in the Rwandan context.

Exploring the relationships with non-verbal reasoning and literacy entailed a series of multivariate regressions. In each case, the regressions were conducted for the Primary 1 and 4 pupils' results separately, and then for the combined dataset. They used standardised *z*-scores for each of the performance measures, except for the Primary 1 children's oral reading fluency which was converted into a binary variable for whether or not the learner could read a single word, and examined using logistic regressions. Rwandan pupils' DCCS and FIST scores[8] comprised the main explanatory variables, as well as an average combining the two,[9] but the regressions also controlled for factors that had shown

[7] Bivariate analyses for both Primary 1 and 4 learners revealed other factors that showed statistically significant associations, for example pupils who reported seeing their grandmothers or aunts reading at home, but for which the number of respondents was too small to offer meaningful data or insights.

[8] Standardised DCCS and FIST scores were only included in regressions where they had shown statistically significant correlations with the relevant non-verbal reasoning or literacy dependent variable.

[9] To avoid multicollinearity, the average cognitive flexibility score was included as an alternative to the DCCS or FIST variables, but never in addition to them.

statistically significant associations with Rwandan learners' switching and shifting at the 10 per cent level (Clark et al., 2010).

Tables 3 and 4 show the results of the regressions and the extent to which pupils' cognitive flexibility predicted their non-verbal reasoning and literacy respectively.[10] Specifically, they set out the beta coefficients, significance and standard errors of the key predictors and covariates, save for the Primary 1 children's reading skills where the relevant odds ratios are presented. Table 3 shows that measures of cognitive flexibility significantly related to non-verbal reasoning scores at both Primary 1 and 4 levels, and for the combined dataset. In contrast, only the combined cognitive flexibility score for Primary 1 learners predicted their ability to read a single word, with none of the measures emerging as significant for either Primary 4 fluency or comprehension.

Beyond cognitive flexibility, several covariates showed significant associations even after other factors were taken into account. As expected, pupils' class grade explained the main difference in both types of learning outcome, and children who indicated living in more stressful homes scored significantly worse on the non-verbal reasoning and reading comprehension tasks. Learners' grade repetition similarly predicted their performance, but in line with other Rwandan studies, the precise interaction varied according to the particular class level (Education Development Center, Inc, 2017; Moulton, 2016).[11]

A final set of regressions then sought to examine the relationships in the opposite direction, namely whether pupils' non-verbal reasoning and literacy significantly predicted their cognitive flexibility. These analyses were important both given the dearth of data from lower-income countries and the limited evidence, including from higher-income contexts, regarding the bidirectionality of the association and how children's learning may also foster their switching and shifting. The combined cognitive flexibility score comprised the dependent variable and the results of such regressions are shown in Table 5. Overall, they reveal a significant relationship between pupils' cognitive flexibility and non-verbal reasoning only, in particular at the Primary 4 level.

In summary, this section has outlined the analyses and results relating to the study of cognitive flexibility among Rwandan primary school pupils. The next section therefore discusses the findings and explores their wider significance.

Table 3
Regression Coefficients (and Standard Errors) for Non-Verbal Reasoning.

	(1) Separate Measures for Cognitive Flexibility	(2) Combined Measure for Cognitive Flexibility
Primary 1		
FIST	0.28** (0.08)	–
Combined score	–	0.14 (0.09)
Repeated primary	0.35** (0.12)	0.33** (0.12)
School 3 (District 1)	-0.39 (0.21)	-0.49* (0.22)
Constant	0.05 (0.93)	0.01 (0.98)
Primary 4		
DCCS	0.23* (0.09)	–
Combined score	–	0.38** (0.13)
Family stress	-0.91** (0.26)	-0.91** (0.26)
Constant	-0.53 (1.74)	-0.43 (1.72)
Combined Data		
DCCS	0.07 (0.06)	–
FIST	0.20** (0.07)	–
Combined score	–	0.25** (0.08)
Family stress	-0.38** (0.13)	-0.39** (0.13)
Class grade	0.73*** (0.14)	0.79*** (0.14)
Constant	-0.05 (0.31)	-0.02 (0.31)

Source: Primary data 2018. Notes: * $p < .05$, ** $p < .01$, *** $p < .001$. FIST = Flexible Item Selection Task; DCCS = Dimension Change Card Sort.

Table 4
Regression Results for Oral Reading Fluency and Reading Comprehension.

	(1) Separate Measures for Cognitive Flexibility	(2) Combined Measure for Cognitive Flexibility
Primary 1 Reading Fluency	**OR (SE)**	**OR (SE)**
FIST	2.27 (0.97)	–
Combined score	–	2.94* (1.59)
Repeated primary	4.40* (2.95)	4.09* (2.71)
Constant	0.00 (0.01)	0.01 (0.06)
Primary 4 Reading Fluency	***b* (SE)**	***b* (SE)**
FIST	0.13 (0.07)	–
Combined score	–	0.11 (0.09)
School 2 (District 1)	-0.34 (0.18)	-0.36* (0.18)
Enumerator 4	-0.45* (0.20)	-0.51* (0.20)
Constant	2.69* (1.19)	2.62* (1.20)
Combined Reading Fluency	***b* (SE)**	***b* (SE)**
DCCS	0.01 (0.03)	–
FIST	0.07 (0.04)	–
Combined score	–	0.07 (0.04)
Repeated primary	-0.22*** (0.05)	-0.22*** (0.05)
Class grade	1.74*** (0.08)	1.76*** (0.07)
Constant	-0.72*** (0.17)	-0.71*** (0.17)
Primary 4 Reading Comprehension	***b* (SE)**	***b* (SE)**
DCCS	0.05 (0.10)	–
FIST	-0.03 (0.11)	–
Combined score	–	0.02 (0.14)
Reading fluency	0.46** (0.14)	0.45** (0.14)
Family stress	-0.78** (0.27)	-0.79** (0.27)
Constant	0.42 (1.85)	0.48 (1.84)

Source: Primary data 2018. Notes: * $p < .05$, ** $p < .01$, *** $p < .001$. OR = Odds Ratio; SE = Standard Error; b = Beta Coefficient; FIST = Flexible Item Selection Task; DCCS = Dimension Change Card Sort.

Table 5
Regression Coefficients (and Standard Errors) for Cognitive Flexibility.

	b (SE)
Primary 1	
Non-verbal reasoning	0.10 (0.08)
Reading fluency (binary)	0.30 (0.17)
Constant	-1.59 (0.86)
Primary 4	
Non-verbal reasoning	0.18** (0.06)
Reading fluency (continuous)	0.05 (0.09)
Reading comprehension	0.01 (0.06)
Single-parent family	0.28* (0.12)
School 3 (District 2)	-0.46** (0.16)
School 4 (District 2)	-0.51** (0.16)
Constant	0.21 (1.16)
Combined	
Non-verbal reasoning	0.14** (0.04)
Reading fluency (continuous)	0.13 (0.08)
School 3 (District 2)	-0.30* (0.13)
Class grade	0.65*** (0.18)
Constant	0.06 (0.24)

Source: Primary data 2018. Notes: * $p < .05$, ** $p < .01$, *** $p < .001$. b = Beta Coefficient; SE = Standard Error.

[10] For reasons of space and brevity, only the results for cognitive flexibility variables and statistically significant factors are shown. For more full results, see the corresponding tables in the Annex.

[11] Specifically, Primary 1 pupils who indicated repeating at least 1 year of schooling performed significantly better on the non-verbal reasoning task and were more than four times as likely to read one or more words correctly in Kinyarwanda. However, when Primary 4 learners' scores are taken into consideration, children who reported repeating *any* years of formal education showed significantly *worse* literacy and read 5.07 fewer words correct than their peers.

5. Discussion

The research questions set out above highlighted the focus of the current study as the measurement of children's cognitive flexibility in Rwanda, the factors associated with its development, and its relationship with their non-verbal reasoning and literacy.

In terms of assessment, the research and its results have shown that the DCCS and the FIST, as adapted cognitive flexibility tasks established in other international contexts, can indeed be used to measure learners' switching and shifting successfully and reliably in Rwanda. Between them, the FIST showed a slightly higher level of association with wider learning outcomes, in particular pupils' non-verbal reasoning. This was largely as expected because the FIST is an *inductive* measure of cognitive flexibility, compared with the *deductive* DCCS task (Jacques and Zelazo, 2001, 2005). Specifically, respondents in the former must themselves identify the common dimension on which to match the stimuli, whereas in the latter they are provided with explicit rules and instructions. The FIST therefore represents a more complex exercise which draws on participants' other skills and may consequently give rise to a greater degree of task impurity (Jurado and Rosselli, 2007; Miyake et al., 2000).

The DCCS also offers a further advantage for researching cognitive flexibility in diverse contexts and multiple languages. Learners' responses to sort the different cards against the targets, in this case the green goat or yellow motorcycle, were clear and unequivocal. By contrast, the FIST requires that respondents both match boxes *and* explain their choices, which increases the scope for interpretation and may compromise the reliability of the resultant data.

The study nevertheless highlighted several factors that showed robust associations with pupils' cognitive flexibility. The strongest concerned children's class grade, with Primary 4 learners scoring significantly higher than Primary 1 pupils for both measures of cognitive flexibility, as well as the assessments for literacy and non-verbal reasoning. On initial interpretation, this was unsurprising as we know that children grow and mature in diverse ways throughout their school careers. However, the trajectory for cognitive flexibility is less straightforward than for many traditional academic outcomes (Defeyter and German, 2003). Although some individual Primary 1 pupils scored better on the DCCS and FIST than certain Primary 4 learners, the overall results for the cohorts aligned with more conventional thinking regarding children's development *and progress* over time. Nevertheless, more research on cognitive flexibility in low-income settings, perhaps involving longitudinal data or out-of-school youths, could help to understand the relative importance of formal education versus wider life experiences in fostering its long-term development.

In addition, there were significant differences in Rwandan learners' cognitive flexibility according to the school they attended, even after controlling for background variables. Table 5 shows that children attending Schools 3 and 4 located in District 2 scored worse on the tasks than those in District 1, at least at the Primary 4 level. Across the learning outcomes, there was no consistent pattern of overall underperformance, for example, pupils in District 2 read on average more words correctly per minute than their counterparts in District 1, but the significant difference in cognitive flexibility between schools suggests that there *are* things that they or education planners can do differently to aid its growth.

Outside schools and classrooms, the study found that Primary 4 learners' family structure significantly predicted their cognitive flexibility scores. In contrast to the research by Sarsour and colleagues (2011), children from single-parent families performed *better* on the combined measure than pupils from two-parent households, even though they reported living in more basic houses and eating fewer protein-rich foods. This could align with the findings from studies in Bolivia and South Africa where disadvantaged children scored higher on divergent thinking and creative problem-solving tasks than their less-deprived peers (Dahlman et al., 2013; Howard et al., 2020). However, to understand this result fully and any related mechanisms in the acquisition of such competences would require more in-depth and possibly qualitative research on Rwandan learners' lived home experiences.

The results also shed light on the relationship between Rwandan children's cognitive flexibility and other learning outcomes, namely their non-verbal reasoning and literacy. Regarding the former, the data show a significant association with pupils' cognitive flexibility, particularly their performance on the FIST and at the Primary 4 level, predicting their non-verbal reasoning and vice versa. However, in contrast to research by Cartwright (2008, 2009, 2012), there appears to be very limited evidence of any robust relationship between Rwandan learners' cognitive flexibility and their reading skills, both their oral fluency and their comprehension. Only for Primary 1 pupils did their combined switching and shifting score increase the odds of them reading one or more words in Kinyarwanda, a low threshold for even basic literacy. Such a result may reflect the reality of Rwandan children's early lives, specifically their limited exposure to printed and written material before entering the classroom, at least compared with young learners in many higher-income contexts (Zuilkowski et al., 2016).

Similarly, the study found no significant association between the participants' cognitive flexibility and their language skills. This was of particular interest following Rwanda's switch to English as the medium of instruction for primary classes and above (Pearson, 2014; Williams, 2020). Two factors could explain this result: first, only a small number of children ($n = 18$) reported using a language other than Kinyarwanda at home, being too low to offer statistical power; and second, with all primary learners in Rwanda now expected to speak and understand at least basic English in addition to their mother tongue, some degree of bilingualism is no longer the exception but increasingly the norm. Indeed, improved proficiency among Primary 4 learners to switch quickly between English and Kinyarwanda in the same lesson could account for some of the variation in cognitive flexibility between the class grades, and warrant closer investigation in future research on the long-term impact of the language reforms.

The findings must nevertheless be understood in light of several important limitations. First, the study was conducted in the narrow urban setting of Kigali and pupils' outcomes could be very different in small towns or cities, or indeed in rural locations across Rwanda (Rose and Alcott, 2015; Williams, 2017). Second, the cross-sectional design enabled the identification of differences between children and cohorts, but precluded any claims around causality or inferences on learners' *actual* development over time (Gruijters and Behrman, 2020). Third, the research omitted any measure of numeracy, which other studies have shown to be associated with children's early development, and which comprises a key aspect of basic learning, both in Rwanda and worldwide (Blair and Razza, 2007; Clark et al., 2010). Cognitive flexibility in particular could hold relevance for pupils' numeracy by supporting them to make the mental links between the word 'five', the character '5' and the idea of five items, compared with four or six. Finally, capturing reliable data from such young children through assessments and surveys presented certain practical difficulties. For example, some learners did not know their birth dates or even their age, and so it was necessary to rely on the information recorded in school registers (Mwaura et al., 2008; Wan et al., 2017). Future research would ideally corroborate pupils' responses on household factors with data collected from their parents, guardians or other caregivers.

6. Future work and conclusions

Many aspects of living and learning have changed since the study was conducted in 2018, both in Rwanda and globally. In such a shifting reality, the importance of skills for adaptability is ever more apparent. As education systems continue to explore different models and means of delivery, whether through online learning, radio programmes or take-home packages, pupils, teachers and policymakers will need to adjust their behaviours, practices and priorities now and for the foreseeable

future (Dreesen et al., 2020).

This research offers several original contributions to that end. In particular, the study builds on a small but expanding body of evidence regarding children's cognitive development in low- and middle-income countries. Such a corpus will, in time, allow for a more complete understanding of how diverse children grow, mature and learn worldwide, as well as the true effects of chronic poverty, malnutrition and other disadvantage (Grantham-McGregor et al., 2007; Schulson., 2020). The research has also emphasised the potential value of cognitive flexibility beyond basic switching, and its relevance for more complex 21st-century skills like creativity and problem solving. Further, the study has provided a practical example and guidance for how learners' cognitive flexibility can be assessed in resource-poor settings using adapted measures created in wealthier contexts (Obradović and Willoughby, 2019).

The findings also have implications for education strategies and research, both in Rwanda and beyond. First, the study and its focus on cognitive flexibility have provided a framework for understanding and quantifying children's emerging skills for adaptability. This is relevant for countries like Rwanda where the government attaches huge importance to evidence including measurable indicators, targets and outcomes (Abbott et al., 2020; Knutsson and Lindberg, 2019). By drawing on established assessments for cognitive flexibility and demonstrating that they can generate valid and reliable data from a range of primary pupils using basic and inexpensive materials, the study presents an option for researchers, educators and policymakers in Rwanda and elsewhere to track learners' development during a period when most children are in school and remedial actions could still be taken.

Related to this is the need for increased data and understanding of learners' flexibility, adaptability and the educational processes that support them. Already, instruments like MELQO and IDELA assess young children's school readiness on an international scale, and future versions could be usefully expanded to include a measure for their cognitive flexibility. Beyond *early* learning, policymakers and researchers might also benefit from greater data on students' broader skills and adaptability at *all* stages of the education trajectory. The lack of relationship between Rwandan pupils' literacy and their cognitive flexibility implied that one may not necessarily foster the other, and highlighted the importance of both nurturing and measuring children's wider competences as they acquire more complex 21st-century skills. This could be achieved under the growing umbrella of 'socio-emotional learning' or by drawing on tools from child development or psychology, as appropriate. Regarding educational *processes*, rigorous protocols are needed to observe and analyse existing practices in low-resource classrooms. The World Bank's *Teach* tool contains indicators relating to autonomy, critical thinking and social and collaborative skills, but as yet no items to gauge behaviours to promote children's creativity, flexibility or problem-solving aptitudes (Molina et al., 2020).

Lastly, the findings point to future research in Rwanda that could build on the current study and offer additional valuable insights concerning learners' adaptability. Follow-up assessments with the same pupils several years later, for example, would reveal how their cognitive flexibility and other competences had actually changed over time. These could be supplemented with data from any children who have dropped out or are unable attend school to explore how adaptability and other 21st-century skills evolve through alternative non-academic channels. In-depth case studies using observations and qualitative methods in the same schools might also uncover differences between them and provide reasons for the variation in their pupils' cognitive flexibility.

To conclude, the global community faces ongoing uncertainties as we continue to contend with the pandemic and tackle our broader collective challenges. In Rwanda and other low-income countries, national development and poverty reduction remain important priorities, and this paper has highlighted the value of schools fostering pupils' adaptability in parallel with more traditional educational outcomes. With skills to think 'outside the box', adopt different perspectives and adjust to changing circumstances, learners might not just solve the problems of today, but also avoid creating the problems of tomorrow.

CRediT authorship contribution statement

Stephen H. Bayley: Conceptualization, Methodology, Software, Formal analysis, Writing – original draft, Writing – review & editing, Project administration, Funding acquisition.

Declaration of Interests

I declare that I have no competing or conflicting interests with respect to the authorship or publication of this article.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ijedudev.2022.102642.

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