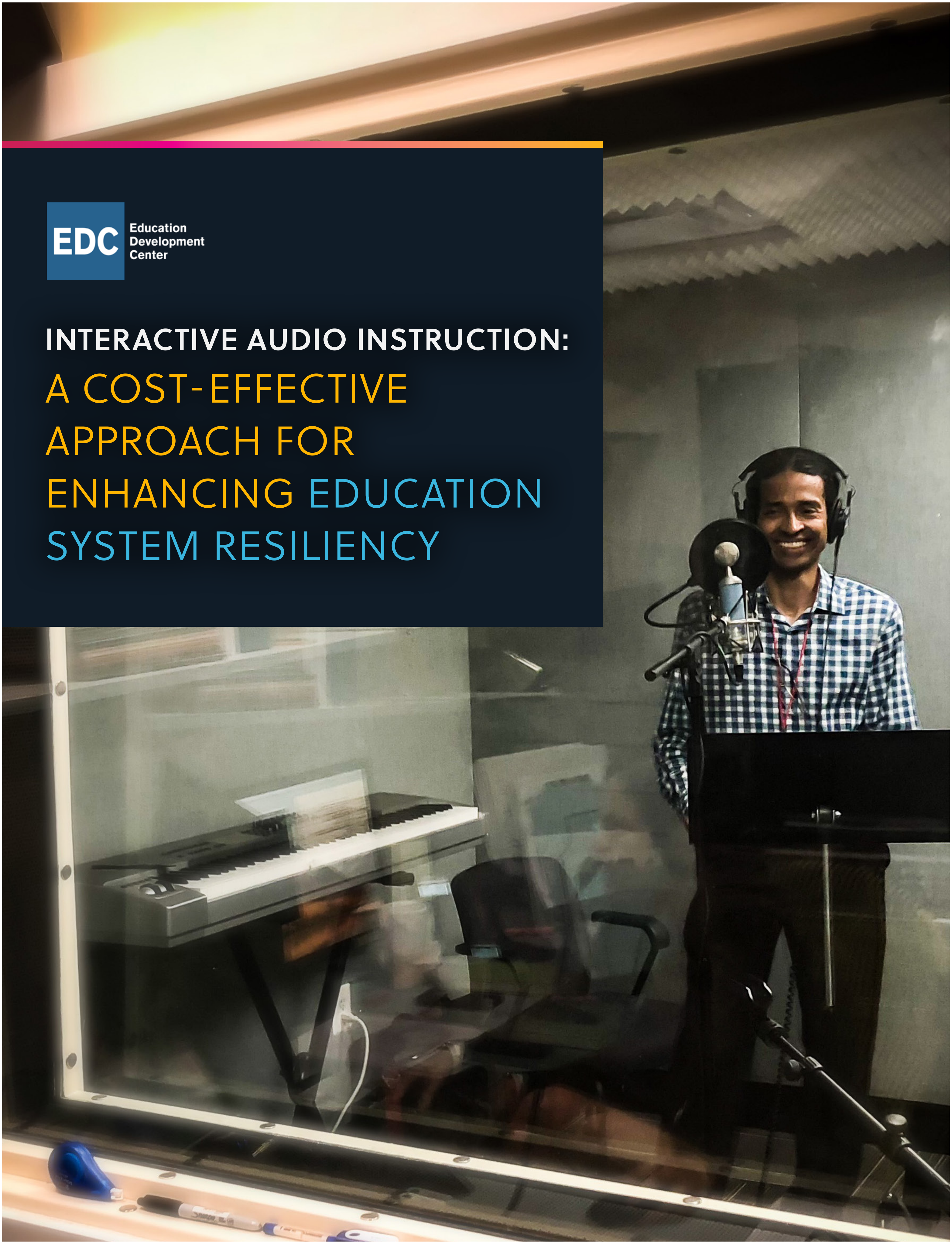
EDC Education Development Center

INTERACTIVE AUDIO INSTRUCTION: A COST-EFFECTIVE APPROACH FOR ENHANCING EDUCATION SYSTEM RESILIENCY



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ACKNOWLEDGEMENTS

Education Development Center hired Dr. Dewees as an independent consultant to conduct *Interactive Audio Instruction: A Cost-Effective Approach for Enhancing Education System Resiliency*.

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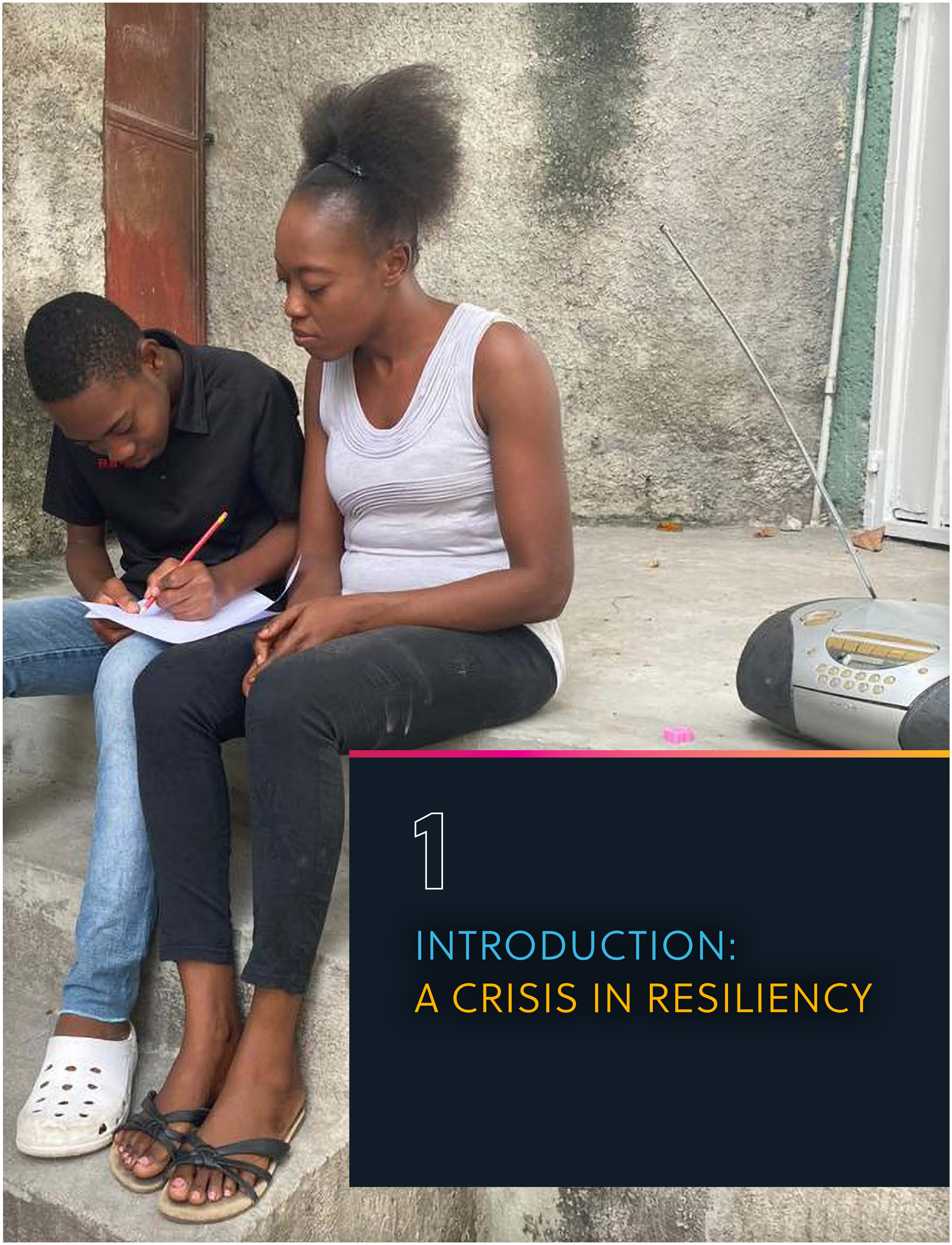
Citation:

Dewees, A., Yasin, K., & Cetina, A. M. (2022). *Interactive audio instruction: A cost-effective approach for enhancing education system resiliency.* Education Development Center.



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INTRODUCTION:
A CRISIS IN RESILIENCY

In February and March of 2020, country after country sent students home from school to protect them and the wider population from the spread of the novel coronavirus. It is estimated that 90 percent of students worldwide were affected by these actions. In the last months of 2020, significant limitations to in-person schooling were still in place in many systems.

The sudden emergence of the crisis exposed the fragility of the schooling model and left decision-makers in even the best financed and highest-performing systems scrambling for solutions to maintain the continuity of learning. Depending on the country, new distance learning systems were rapidly created or existing systems were scaled up to meet the needs of the entire student population. Technology has played a central role in the responses, with teaching and learning migrating to virtual versions of classrooms and/or reliance on self-paced study using online platforms, radio, television, and tablets or phones on mobile networks. In some cases—especially for younger learners where existing remote learning initiatives were rare—children were left without support.

Even when education systems were able to rapidly develop and deploy responses, some undesirable consequences were anticipated and impacted almost all systems to some degree. Limitations in connectivity and access to technology exacerbated already significant levels of inequity. Educators—most with little or no formal training in using education technology—were overwhelmed with new responsibilities and demands. Existing learning platforms and content were rapidly leveraged to address additional subjects and many more students, which raised serious concerns about the quality and relevance of the content and approaches being implemented.

The rapidly developed responses also tended to reinforce approaches to teaching and learning that were already failing many learners. Passive engagement with materials provided through radio, television, and online distribution mirrored the all-too-common experience of many learners in their schools. While the COVID-19 threat will recede, the "normal" that many learners will return to will see them attending schools with meagre resources and a passive and unproductive approach to teaching and learning. For many learners, time for supporting their households' economic recovery from the crisis will be prioritized over daily in-person school attendance, and few of those households will have the capacity or resources to ensure a continuity of learning.

Episodic challenges to the continuity of learning will not end with the current crisis. Children in many systems will continue to experience extended periods with normal school attendance disrupted by catastrophic weather events, seismic events, or conflict. There is no reason to assume these challenges will become less frequent in the near future. While previous large-scale disruptions to schooling were mostly limited to areas and systems with histories of disruptive events, COVID - 19 has affected nearly all systems and exposed an underappreciated fragility of the schooling model and the consequences for learning. This new awareness has accelerated a search for strategies that move beyond crisis responses to approaches that enhance system resiliency and ensure the continuity of learning for all children.

As with the responses to the COVID-19 crisis, technology has a critical role to play in enhancing the resiliency of education systems. The urgency of developing responses also highlighted the limitations and consequences of a technological solution that is not complemented with supportive policy and investments in capacity for all the actors: decision-makers, teachers, students, and parents/caregivers.

In this paper, we explore the potential of interactive audio instruction (IAI) as a cost-effective strategy for improving the resiliency of education systems. We begin with a brief historical review of the evolution of IAI followed by a description of the fundamental characteristics of the approach. Prior assessments of the cost-effectiveness of IAI are then reviewed and updated, incorporating new options for development and implementation enabled by the evolution of information and communication technology (ICT). Finally, we explore the potential cost effectiveness of IAI as part of a comprehensive strategy to enhance the resiliency of education systems and to promote the continuity of learning for all students.

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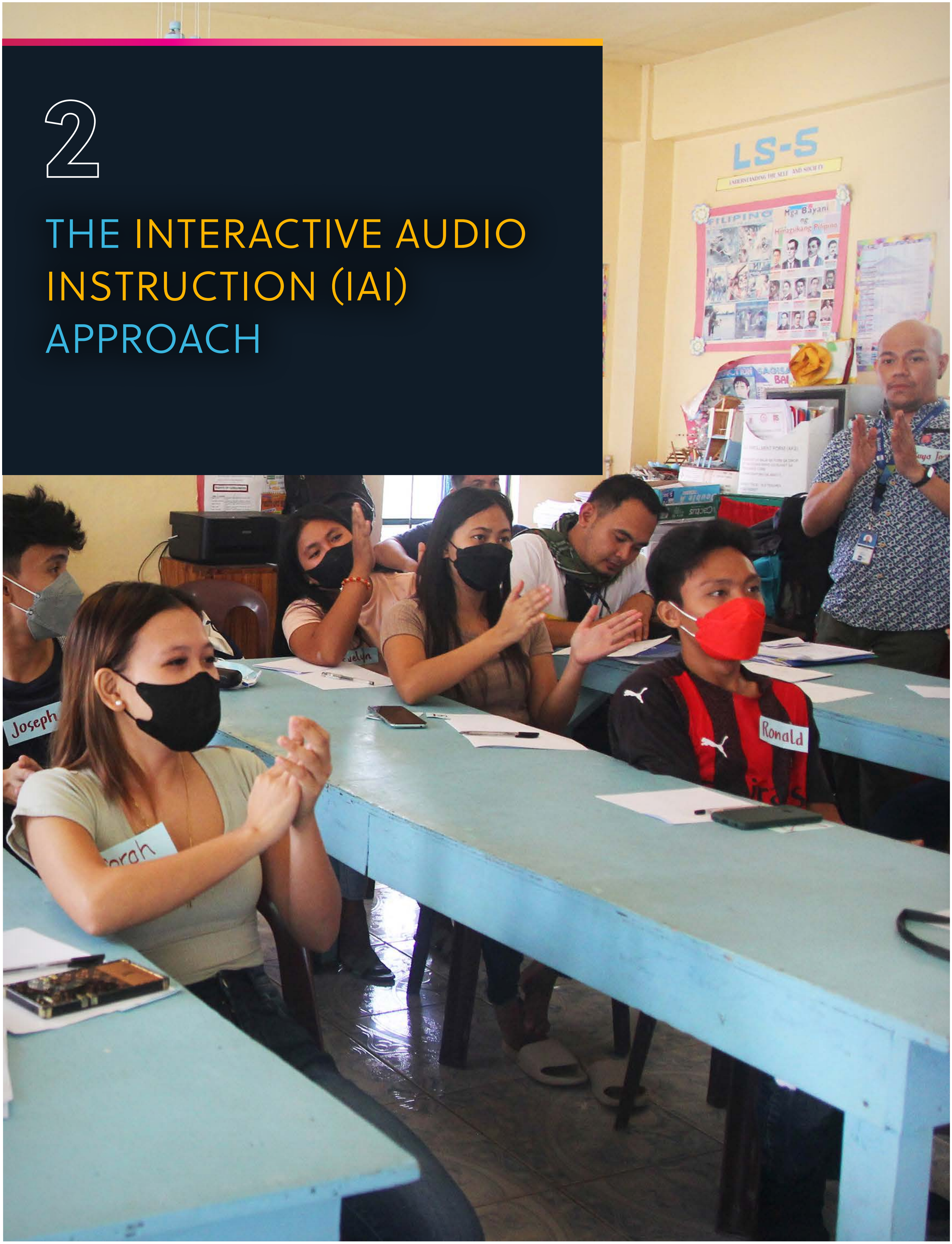
THE INTERACTIVE AUDIO INSTRUCTION (IAI) APPROACH



Interactive Audio as a Strategy for Enhancing Education System Resiliency

IAI has long been a tool to address the types of educational needs that arise during emergencies. It has the ability to reach students and improve quality despite physical and even psychological barriers.

Students in Somalia experiencing the shutdown of schools due to conflict were able to continue to follow their IAI programs via radio. Students in Liberia who were kept home due to the Ebola virus were able to continue to learn vital life skills, including important information regarding the spread and prevention of the disease. Teachers in a remote region of Colombia who were not able to safely attend teacher trainings in the regional capital were able to gather in small groups to improve their teaching skills with the assistance of IAI programs. Teachers and students unable to attend formal schools in Zambia due to the number of teachers lost to the AIDS epidemic were able to gather in nonformal settings with a designated adult who was guided by the IAI programs. Such programs enabled the untrained teacher or facilitator to learn, along with his or her students, how best to provide instruction. In the case of the Dominican Republic and Colombia, many instructors required to teach English to middle and secondary students, learned or improved their own English-speaking skills while simultaneously guiding an IAI English lesson for their students.

In non-crisis situations, IAI has served to complement classroom instruction or, in some cases, to help provide instruction when it did not exist. Given that many countries suffer from a lack of access to teacher training as well as a lack of instructional materials, IAI has provided carefully guided lessons that not only co-teach with the classroom teacher but also, at times, explicitly explain to the teacher what is happening during instruction. For example, an IAI lesson might prompt a teacher to have students work in small groups. That same prompt might be followed by an explanation aimed at the teacher: “Remember, when we work in small groups, everyone has a chance to participate.” That brief interchange gives the teacher a context in terms of content, prompts the teacher to actually divide up the class, and explains to the teacher why it is effective to use this strategy. This in-service methodology enables training to take place while students are learning, hence providing instruction immediately rather than waiting for teachers to first undergo training. It also avoids much of the deterioration of training content that can happen when teachers are expected to remember strategies presented during a training but forgotten by the time they face their students.

In crisis situations, IAI can provide a lifeline to continued instruction and crucial content.[1] Schooling may be sporadic or even non-existent; students in many countries may have little or no access to the Internet to participate in online learning; and parents and teachers may have little preparation in how to step in and help guide instruction during such circumstances. IAI can reach students anywhere there is a radio or anywhere someone can download audio files. Even electricity is not necessary when wind-up and solar radios and speakers are used. Programs can include content related to whatever the crisis necessitates: the importance of face masks and handwashing during COVID-19; water-filtration during cholera epidemics; techniques to prevent soil erosion, such as tree planting in countries suffering from devastating floods; and ways to ensure personal protection in countries suffering from violence and civil unrest. Such important content is often embedded in formal schooling

[1] See Yasin, 2020.

content. Violence prevention or some health tips may come across as propaganda to some parents, but math and reading are generally supported. Thus, sensitive topics can be integrated into formal school subjects in word problems or dramas. Where previously recorded programs are used to reach students at home during school shutdowns, special spots are often recorded explaining when and how students and parents can follow the programs at home. Communities are informed about the importance of continued instruction and their role in helping provide consistency in the lives of their children. In many cases, local broadcasting via community radio stations has helped to supplement national or shortwave broadcasts.

Characteristics of the IAI Approach

There are different types of audio approaches, such as broadcast lectures, podcasts, and self-paced programs. One form of audio instruction promoted by EDC since the 1980s is interactive audio instruction (IAI), which is also known as interactive radio instruction (IRI) when delivered via radio.

IAI initiatives incorporate active engagement with learners. Most IAI programs developed by EDC have been implemented with trained facilitators who are typically classroom teachers. Initially, the most common form of delivery was radio broadcast, although cassettes and CDs have been used. Currently, many projects use MP3 players, mobile phones with digital file storage, or SD cards inserted into speakers.

IAI is an approach defined by its focus on engagement. The early applications of IAI were primarily in language and mathematics instruction. More recently, the approach has been utilized for science, life skills, workforce development, teacher training, and other subjects. The key identifying characteristic of the IAI approach is the focus on the interaction between the characters in the audio programs, the classroom teacher or facilitator, and the students through a variety of segments that include songs, games, activities, and dramas related to the learning objectives. This focus on engagement is what distinguishes the IAI approach from other more passive engagements of students with audio content, such as radio lectures.

Developing an IAI program requires a significant investment in program development. To ensure that the program is attractive and relevant to the participants, the development process typically begins with an audience profile. The profile assesses the audience with respect to their age; their setting; their current knowledge, interests, and attitudes; and their learning styles. In addition to the students, the profile also assesses some of the same characteristics of teachers, parents, and community members. The goal of the audience profile is to ensure that lessons are developed in the context of the real-world experiences of the students and their communities.

The design of an IAI program is based on a formal development of the scope and sequence of the content objectives and standards to be addressed. A design document translates the scope and sequence into the description of each proposed lesson (and segments of lessons) for scriptwriters to use in elaborating dramas, games, songs, etc., for the lessons. When scripts are developed and produced—including the recorded actors, sound effects, songs, and other aspects of production—they are subjected to a formative evaluation and then revised as needed.

Data based on pre- and post-tests of children's skills and knowledge have been collected throughout the world over the past four decades. What is clear is that the interactive nature of IAI programs, which differentiates it from traditional lectures via radio educational radio programs, produces highly significant results when IAI students are compared to their counterparts in schools not receiving the IAI programs. In countries such as Zambia, Honduras, the Dominican Republic, Bolivia, Haiti, Somalia, Ethiopia, South Africa, Guinea, and Thailand, students participating in IAI programs showed greater gains than those in schools without access to the IAI programs. Even in countries where out-of-school students received the programs for only one hour per day, the students generally outperformed students who attended school but who did not receive the programs.[2]

Technology-Enabled Modifications to Development and Implementation of IAI

The technology required to produce and disseminate IAI lessons has advanced significantly since the earlier days of interactive radio production and dissemination. The wide adoption of digital recording technology has resulted in the replacement of some dedicated hardware by software that operates on PCs and laptops. Physical media (tapes, CDs) have been replaced by digital files, significantly reducing the costs of storage and facilitating the management and dissemination of IAI content. Improvements in the recording equipment have reduced the need for complex studios, and updated music and sound effects libraries are more readily accessible. Digital products are also not subject to physical deterioration and/or damage when using cloud-based storage. More sophisticated mobile devices, such as mobile phones and tablets, are now capable of recording remote audio of sufficient quality for IAI, and many less sophisticated mobile devices can play audio files.

Most of the population in developing countries now reside in areas covered by mobile networks with at least 3G capability, and the costs of mobile devices and connectivity have fallen significantly. These changes have enhanced the ability of IAI implementers to engage with teachers and receive real-time feedback on implementation and outcomes. These same telecommunications advances have provided new capabilities for technical support to program development via Web-based conferencing.

[2] For summaries of effectiveness evaluation results, see Anzalone & Bosch, 2005; Ho & Thukral, 2009; Tilson et al., 1991.

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THE COST-EFFECTIVENESS OF INTERACTIVE AUDIO INSTRUCTION (IAI)

Cost-effectiveness analysis (CEA) is a methodology widely applied in many sectors to support decision-makers in choosing among alternative strategies for achieving public policy objectives. In CEA, the alternatives under consideration are compared in terms of the relationship between total costs and the changes in outcomes or outputs that can be attributed to that alternative. Comparisons are usually expressed in terms of the relative level of impact or effect achieved for a given investment or as the cost for producing a given effect or outcome.[3]

For the comparisons to be valid, the costs for implementing the alternative strategies or approaches must be captured in their entirety.[4] While the cost of many of the necessary ingredients can be captured with market prices,[5] some may require the use of *shadow prices*. Shadow prices are required when the market price of an ingredient necessary to implement an alternative is not directly observable. Examples of the use of shadow prices in an education CEA include the cost of volunteers or the use of already existing materials, equipment, or infrastructure. While some ingredients may not require a monetary expenditure, omitting them from the CEA can produce a biased comparison of the cost-effectiveness of alternatives.[6]

The costs of program development (development costs) and capital goods, such as infrastructure and equipment, are typically *discounted*. Discounting is a standard technique from finance that is used to convert once-off investments on ingredients that produce benefits over a longer period of time[7] to an annualized equivalent. Discounting allows the costs of all the alternatives being considered to be presented as annualized costs and avoids a bias against approaches that may require greater up-front investments or are more capital intensive.

Typically, a CEA is developed from the cost and outcome data from specific initiatives. In this exploration of the cost-effectiveness of IAI as a strategy for enhancing resilience of the education system, the costs and impact of both IAI and the alternatives compared will be synthesized from experiences documented in program reports, evaluations, and academic publications. To make our exploration manageable, we focus on basic education, although the concepts would apply in some form to all levels of education.

We think the CEA assessments presented represent a good faith and reasonable effort to fairly capture both costs and impact in the application of IAI and other alternatives in the context of stand-alone initiatives[8] and as a component of a holistic effort to promote resiliency and the continuity of learning for all children. Since both costs and impact will reflect assumptions drawn from experience rather than robust detailed costing and evaluation of

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[3] For example, the improvements in reading scores for each dollar invested or, alternatively, the cost ($) of producing a 10% increase in scores.

[4] Otherwise, the determination of the more cost-effective option would depend on which costs were included and which were ignored.

[5] Examples would include staff or personnel necessary for implementation, equipment, materials, facilities, etc.

[6] It is important to note that the methodological details in an assessment of cost-effectiveness are always a response to the specific decision-making demand. For example, if decision-makers were weighing the cost-effectiveness of utilizing existing textbooks for a new curriculum versus the development and production of new texts, the development costs of the existing texts would be considered "sunk costs," and the cost comparison would be between the recurrent annual cost of printing and distributing the current texts (including replacements for loss and damage) versus the annualized cost of developing, producing, and distributing the new texts. The most cost-effective choice would be the option that produced the most impact per dollar spent.

[7] An item that has a useful life of more than one year.

[8] By *stand-alone initiative* we are referring to what might be viewed as a "typical'' IRI initiative implemented in the 1970s and 1980s. While these earlier IRI initiatives could vary in approach depending on the context, most utilized radio broadcasts (or physical media like CDs) and were implemented by a teacher in a classroom using additional printed materials. Most commonly they were developed to improve the quality of instruction in specific subjects.

specific implemented activities, all assumptions and calculations will be described in the text or in the annex, and all assessments will include an examination of the sensitivity of the results to the underlying assumptions we have made.

The Cost-Effectiveness of a Stand-Alone IAI Implementation

Before examining the potential cost-effectiveness of IAI as part of a systemwide resiliency-enhancing strategy, we examine IAI cost-effectiveness as a stand-alone initiative. The establishment of a baseline for assessing the cost-effectiveness of IAI draws on CEAs and evaluations of interactive radio instruction (IRI) initiatives first widely implemented in the 1970s and 1980s. Typically these IRI initiatives were developed to improve access to education in areas where an education system was unable to provide classroom-based programs, or they were a means to enhance quality by supporting better teaching practices and providing up-to-date content through audio lessons delivered via radio broadcast or physical media—usually cassette tapes or CDs. Programs were most often utilized in classrooms with teachers playing an important facilitating role.

The shift in terminology to *IAI* reflects the extension of the application of interactive audio to a wider range of participants,[9] greater diversity in the nature and role of the facilitator, and new options in the technology utilized for disseminating the audio content and support materials. While the change in terminology to *IAI* reflects more diversity in the approach, we utilized a radio broadcast model to develop a baseline costing model as a tool for estimating the impact of technological change and the applications of IAI as an investment in education system resiliency.

The costing model was developed utilizing Adkins'[10] assessment of the cost-effectiveness of six IRI initiatives[11] implemented in Africa and Latin America (1976–1990). His cost analysis drew on actual costs provided from the implementing or managing entity for the initiatives. Our costing model synthesizes the features and structure of those assessments, which we apply to estimating the impact of technology choices and alternatives in the application of interactive audio.

The costing model assumed the following:

- One subject
- Radio broadcasts to classrooms
- Classroom teachers playing the role of facilitator
- Provision of supporting materials (guides, student materials, posters, etc.)

Program development costs included the following:

- Elaboration of the lessons/scripts
- The technical production of the broadcasts (i.e., recording technology investments and production of the broadcast lessons)
- Upfront costs, including training for the teacher-facilitators

Recurrent costs included the following:

- Broadcast time
- Radios (or other devices) for classrooms
- Batteries and other maintenance costs for devices

[9] Participants beyond those in formal school classrooms with teachers as facilitators.
[10] See Adkins, D., 1999.
[11] Bolivia, Dominican Republic, Honduras, Lesotho, South Africa, and Venezuela

- Production and distribution of printed materials
- Ongoing revisions of the lessons
- Management expenses
- Other fixed and variable expenses

The cost of program development was estimated at $2.75 million[12] for a one-subject program for 100 thousand students and $5 million for a program for 1 million students. The costs for most of the ingredients for program development for the 100 thousand student program and the 1 million student program were identical.[13] The majority of the cost difference in program development between the small- and large-scale programs was the need to provide the initial training to many more teachers[14] in the larger (1 million students) program.

Table 1 summarizes the development and implementation costs for the program and illustrates the impact of scale and development costs on total cost per student. The small-scale program has a total annual cost per student nearly 2.5 times that of the large-scale program, with most of that difference due to the much higher costs per student for program development.

Table 1: IAI Development costs, implementation costs and scale (students)[15]

	Program Development			Program Implementation			Total
	Annual	Annual per Student	% of Total per Student	Annual	Annual per Student	% of Total per Student	Annual per Student
Small scale (100 thousand)	$515,471	$5.15	65%	$296,878	$2.97	36%	8.12
Large scale (1 million)	$937,220	$0.94	29%	$2,318,781	$2.32	71%	3.26

Cost-effectiveness comparisons are typically presented in the form of the ratio of the effect size (impact) to the annual cost per student. While effects can be measured in many different forms, a common means of measuring the effect of an intervention in education is the difference in standard deviation (SD) points between the students participating in the intervention and similar students who were not participants.[16] So, for example, an intervention that had an annual cost of $5 per student and an effect of 0.5 SD points would have an effect per dollar spent of 0.1 SD (.05/5 = 0.1). Alternatives that produced less benefit from each dollar of spending would be considered less cost-effective.

Evaluations of IRI or IAI initiatives that combine detailed information on costs with rigorous evaluation of effects are relatively rare. In *Education and Technology Technical Notes* summarizing the costing model described above, Adkins calculates the cost-effectiveness of five IRI initiatives, as well as four textbook initiatives and two teacher training initiatives (see Table 2). The calculations of cost-effectiveness draw on separate sources for impact (effects) and costs. He cautions readers to interpret results with care as the cost data for the initiatives may be incomplete or inconsistently captured or reported across the different initiatives.[17] The initiatives reviewed suggest that each dollar invested in IRI produced more improvement in reading and mathematics scores than an

[12] Note: All dollar amounts in this report, including in the tables, are in U.S. dollars.
[13] For example, the cost of script development and the recording of the lessons were assumed to have the same cost as the as they reflected identical program content and the number of lessons to be produced.
[14] Based on the assumption of a typical class size of 30.
[15] Summarized from Adkins, 1999.
[16] Using standard deviation points allows comparisons when the actual measures/assessments may have different scales.
[17] See Adkins, 1999.

equivalent dollar amount spent on textbooks or teacher training—nearly twice the effect per dollar as the alternative approaches.[18]

Table 2: Summary of cost-effectiveness analysis for IRI, textbooks, and teacher training[19]

Country/Year	Subject	Effect Size (SD)	Annual Cost per Student	Effect per $
IRI				
Nicaragua 1976–80	Math	0.55	$1.80	0.31
Thailand 1980	Math	0.58	$0.44	1.31
Kenya 1982–84	Language Arts	0.53	$0.40	1.33
Honduras 1990	Math	0.49	$1.01	0.49
Bolivia	Math	0.90	$0.81	1.10
Average				**0.91**
Textbooks				
Philippines 1977	Math	0.40	$.027	1.48
Nicaragua 1978	Math	0.36	$1.75	0.21
Thailand 1981	Math	0.06	$0.25	0.24
Brazil 1981–83	Reading/Math	0.34	$1.65	0.21
Average				**0.54**
Teacher Training				
Thailand (math courses)	Math	<0.01	$0.09	0.06
Brazil (in-service primary)	Reading/Math	0.21	$2.21	0.09
Average				**0.08**

[18] An effect of 0.91 SD points per dollar spent on IRI compared to 0.54 SD points for a dollar invested in textbooks or 0.08 for teacher training.

[19] Summarized from Adkins, 1999.

Exploring the Impact of Technology-Enabled Changes in Production and Implementation on Cost-Effectiveness

The IAI Baseline Cost Framework

The estimates of the costs and cost-effectiveness of stand-alone IAI initiatives reviewed until now represent typical practice and existing technology in the 1980s and 1990s. Technological change in the intervening period has enabled new approaches to developing programs as well as new technological choices for disseminating content. To examine how these changes may impact the cost-effectiveness of IAI as a stand-alone initiative or as a strategy for enhancing system resilience, it is necessary to first establish an IAI baseline cost framework.

For clarity of presentation, the costing model developed by Adkins in the previous section summarized aspects of the costing process—omitting some underlying details (or ingredients) of the calculation of costs. Script development, audio program production, and start-up costs for both the small-scale and large-scale initiatives were summarized into single line items. Most of the IRI initiatives in that era relied on significant external support—in particular for program development and other start-up costs. When development costs are primarily funded by external entities, budgets and reported expenditures for program development reflect to some degree procurement practices, rules, allowances, and overheads. These practices differ across funders and implementers and can produce differences in costs that are not fully explained by differences in activities or inputs,[20] thereby complicating the comparisons of costs and cost-effectiveness.

In order to best understand how technology-enabled alternatives to program development and program implementation may change costs and cost-effectiveness, it is necessary to examine costs from the perspective of economic or opportunity costs rather than reported expenditures or budgets.[21] For this study, we estimated an IAI baseline cost framework applying an "ingredients method."[22] We began with a defined model of program development and implementation and listed all required inputs or ingredients. Each ingredient was costed using a current market price or an estimate of a shadow price where necessary. The list of necessary ingredients as well as prices drew on our review of more recent IAI budgets and expenditure reporting as well as professional opinions from experienced practitioners. Capital and/or development costs were converted into annualized equivalents using assumptions regarding the useful life of the item and a prevailing social discount rate. The resulting IAI baseline cost framework is presented as an annualized development cost per student, annual implementation cost per student, and annual total cost per student. This method produced a framework in which changes in technology or approach can be translated into new cost estimates.

The IAI baseline cost framework incorporates the same assumptions as used in the previous section: one subject, radio broadcasts to classrooms, classroom teachers as facilitators, and the distribution of support materials (guides, student materials, posters, etc.). The estimated costs reflect the opportunity cost for delivering the initiative described. We do not include costs particular to the different funding institutions or implementers, so the estimates should not be seen as the cost estimates for an IAI "project."

[20] Costs typically required for proposals to funders such as institutional overheads, fringe benefits, and home office rental, are excluded.

[21] Budgets often present an incomplete picture of the resources required. An intervention may depend on already existing assets or contributions of time and money by other parties not included in the budget. Budgets also frequently present a distorted picture of costs as spending on capital items that are utilized for multiple years are only captured in the year they were incurred.

[22] See Levin, & McEwan, 2001.

Table 3 presents a summary of the IAI baseline cost framework.[23] The IAI baseline estimates costs for a relatively small initiative of about 100 thousand students and a larger scale effort of 1 million students. Total program development costs were converted into annualized spending over seven years of program implementation.[24] When the annualized cost of program development was divided by the number of students, the cost of development was $2.10 per student for the small program and $0.93 for the large program. The costs of developing the program and recording the lessons were the same for both the large and small programs as those costs were determined by the number of lessons rather than the number of students. The cost of the initial orientation for facilitators and managers was about 10 times greater for the large program, reflecting the difference in the number of participating classrooms and teachers. The annual implementation cost per student for program dissemination and support materials was similar for both the small and large programs with some economies of scale in the cost of managing the large program.[25]

[23] The complete detailed baseline framework is provided in the annex.
[24] The seven-year period was assumed as representative or typical. A social discount rate of 7% was used for the conversion.
[25] While the number of students in the larger program is 10 times that of the small program, total management costs for the larger program were estimated to be just 1.5 times the cost of the small program.

Table 3: IAI baseline cost framework

IAI Baseline Cost Framework (Stand-Alone)		
	Scale (Students)	
Program Development	**100,000**	**1 Million**
Program development management and coordination	$142,700	$142,700
of program design	$46,700	$46,700
Script development (training of writers, elaboration of scripts)	$174,400	$174,400
Development and design of support materials	$73,200	$73,200
Establishment of audio production capacity (training and equipment)	$41,200	$41,200
Recording of content (training actors, recording, mixing, and finalizing)	$183,800	$183,800
Planning and delivery of training and orientation	$447,000	$4,314,000
MEAL development (design, planning, systems)	$21,000	$25,500
Total cost program development	$1,130,000	$5,001,500
Annualized cost program development	$209,675	$928,044
Annualized cost program development per student	$2.10	$0.93
Program Implementation		
Management and coordination	$133,200	$240,600
Program dissemination (broadcast and devices)	$171,714	$1,717,145
Support materials (production and distribution)	$33,198	$331,982
Annual cost program implementation	$338,113	$2,289,726
Annual cost program implementation per student	$3.38	$2.29
Total annual cost per student	**$5.48**	**$3.22**
Percent annual program development	**38%**	**29%**
Percent annual program implementation	**62%**	**71%**

- 200 lessons delivered via radio broadcast to classrooms facilitated by teachers (2 classes per school, 30 students per class)
- 12 months of program development:
  - Design program
  - Train writers
  - Write scripts
  - Design support materials
  - Train voice actors
  - Establish production capacity – technology and human resources
  - Record lessons
  - Plan and deliver initial training to teachers and officials
  - Develop MEAL framework and tools and deliver MEAL orientation
  - Develop social communication and support messages

- Implementation for 7 years:
  - Manage and coordinate/MEAL
  - Disseminate content (broadcast and devices)
  - Produce and distribute support materials
- Assumes 2020 competitive local labor market remuneration for managers and technical staff ($2,000—$3,500 per month) and internationally competitive remuneration for specialized technical experts ($500 per day)
- International travel and local accommodation for short-term experts

For both program development and implementation, a benchmark figure between $2,000 and $3,500 per month was used to estimate the costs for managers, administrative staff, and technical staff. A figure of $500 per day was used to estimate the cost of technical assistance provided by short-term experts with specific training and experience in the design and implementation of IAI. The costs for these experts also included a benchmark figure of $2,000 for international travel and a $120 per diem for local accommodations and expenses. For the IAI baseline, 465 days of technical assistance were estimated for the development and implementation of the small program and 485 days for the large program. Most of the technical assistance was used for program development: IAI program design, training script writers and writing scripts, establishing technical capacity for recording the lessons, providing quality assurance for recordings, designing support materials, and developing monitoring and evaluation, accountability and learning (MEAL) systems and instruments. A limited amount of technical assistance was included for ongoing support in MEAL and quality assurance (20 days for the small program and 40 days for the large program). The technical assistance is provided via both in-person support and remote engagement. Six international trips were included in the estimate for the small program and seven international trips for the large program.[26]

The cost estimates in the IAI baseline framework are, of course, dependent on our assumptions—and other assumptions would yield different estimates of a baseline cost. The purpose of the baseline cost framework is to provide a clear description of all inputs and assumptions thereby enabling them to be changed in response to alternative technology choices or alternatives to the application of IAI, for example, as a stand-alone classroom-based initiative versus a more comprehensive strategy to improve system resiliency.

Technology-Enabled Alternatives and Their Impact on Cost-Effectiveness

While the model of program development and implementation that produced the IAI baseline cost framework remains a viable and potentially cost-effective approach,[27] the evolution in ICT now provides new alternatives for IAI program development and program implementation.[28] In both the public and private sectors, one of the most visible responses to the COVID-19 crisis was the shifting of work from in-person settings to remote. Video conferencing is not a new technology as the capability has existed for some time. However, the demands placed on public and private sector entities to protect their workforce during the COVID-19 pandemic resulted in a significant expansion of the capacity[29] and the proliferation of the skills for using these technologies more effectively.

The model used to estimate the IAI baseline cost framework assumed that technical assistance for program development and implementation would be provided primarily via in-person consultation between experts with specific IAI training and experience and program managers and technical staff. With increased access to bandwidth and technology for Web conferencing, some of the required technical assistance may be provided remotely without changes to the quality of the program.[30]

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[26] Estimate of $2,000 for each international trip
[27] As reviewed previously, Adkins estimated a favorable cost-effectiveness ratio for IAI compared to textbook and teacher training initiatives (Adkins, 1999).
[28] See Education Development Center, 2020.
[29] The new investments in hardware, software and increased bandwidth necessary for the rapid response to COVID - 19 school closings.
[30] We have incorporated the assumption that some technical assistance can be provided remotely without lowering the quality of the program.

The baseline estimate includes seven international trips and 320 days of support for local accommodations and meals for technical experts.[31] To estimate potential savings by utilizing Web conferencing as a substitute for in-person support, the baseline estimate has been modified by eliminating some travel and/or accommodations for the following:

- Technical assistance in program design: Reduced by one trip and 50 days of local accommodations
- Training of script writers and providing quality assurance for scripts: Reduced by one trip and 160 days of local accommodations
- Technology planning, procurement, and initial training of recording technicians: Reduced by 25 days of local accommodations

The following travel and accommodations have been maintained:

- In-person technical support is maintained for an initial mobilization of stakeholders and to provide input on staffing the program: 1 trip and 50 days of local accommodations.
- Short-term in-person support for the recording process is maintained: 1 trip and 15 days of local accommodations
- The annual MEAL Q&A support during program implementation is maintained: 1 trip and 20 days of local accommodations for the small program and 2 trips and 40 days of local accommodations for the large program.

The baseline estimate also incorporates analog recording technology typically utilized in the 1980s and early 1990s. The shift from analog to digital production has resulted in lower costs for high-fidelity equipment and the substitution of software for some elements of the production process that previously required dedicated hardware. We have re-estimated the investment cost for production, substituting an updated digital package for the one used to elaborate the IAI baseline cost framework.[32] It is important to note once again, that there is a strong assumption that these substitutions of remote engagement for some in-person support and digital recording and production for analog maintain or improve the quality of the program.

Table 4 provides a summary of the impact of substituting Web conferencing for some in-person technical assistance and updated recording and production technology. While the travel in these cases has been reduced, the level of the effort (the number of days) for the technical support remains the same as in the baseline. Overall, these substitutions have reduced the cost of program development by about $70,000. While these technology-enabled substitutions reduce cost without adversely impacting program quality, their impact on the annualized cost of program development and the annualized cost per student for program development are extremely modest—lowering costs just $0.13 per student for the small program and $0.01 for the large program.

[31] Eight trips for the larger program

[32] Lists are included in the annex.

Table 4: Technology-enabled modifications to program development

Impact of Technology-Enabled Modifications to Program Development				
	Scale (Students)			
	Baseline		Remote Engagement & Updated Production Technology	
Program Development	**100,000**	**1 million**	**100,000**	**1 million**
Program development management & coordination of	$142,700	$142,700	$142,700	$142,700
program design	$46,700	$46,700	$20,700	$20,700
Script development (training of writers, elaboration of scripts)	$174,400	$174,400	$153,200	$153,200
Development and design of support materials	$73,200	$73,200	$73,200	$73,200
Establishment of production capacity (training and equipment)	$41,200	$41,200	$18,200	$18,200
Recording of content (training actors, recording, mixing, and finalizing)	$183,800	$183,800	$183,800	$183,800
Planning and delivery of training and orientation	$447,000	$4,314,000	$447,000	$4,314,000
MEAL development (design, planning, systems)	$21,000	$25,500	$21,000	$25,500
Total cost program development	$1,130,600	$5,001,500	$1,059,800	$4,931,300
Annualized cost program development	$209,675	$928,044	$196,649	$915,019
Annualized cost program development per student	$2.10	$0.93	$1.97	$0.92
Program Implementation				
Management and coordination	$133,200	$240,600	$133,200	$240,600
Program dissemination (broadcast and devices)	$171,714	$1,717,145	$171,714	$1,717,145
Support materials (production and distribution)	$33,198	$331,982	$39,838	$398,378
Annual cost program implementation	$338,113	$2,289,726	$338,113	$2,289,726
Annual cost program implementation per student	$3.38	$2.29	$3.38	$2.29
Total annual cost per student	**$5.48**	**$3.22**	**$5.35**	**$3.21**
Percent annual program development	**38%**	**29%**	**37%**	**27%**
Percent annual program implementation	**62%**	**71%**	**63%**	**73%**
• The substitution of Web conferencing for in-person support for program design, script development, and establishment of production capacity, as well as updated digital production technology reduces program development investment costs by $52,200 for both the small and large programs	• When converted to an annualized equivalent, the substitutions reduce the annual cost for program development by about $13,000 with small changes in the per student cost for program development and for the total annual cost per student.			

Sensitivity to Costs for Dissemination Via Radio Broadcast

In developing the baseline scenario, we used an estimate of $5,000 per year for airtime per radio market to deliver the 200 (30-minute) lessons. We assumed that about 40,000 students were reached by each radio market. The estimate was also based on a $40 replacement cost for radios and $36 per year cost for batteries and other maintenance. However, practitioner experience and a review of the literature indicates that there could be a very large variation in the cost of airtime required to broadcast the 200 lessons.

The available and optimal choices for reaching schools and/or students in their households via radio broadcasts depends on the local context. State and public broadcasters as well as large commercial broadcasters typically have more powerful transmitters and reach much larger audiences than local commercial or community radios. State and public broadcasters receive support from public resources and are much less dependent on revenues generated from selling airtime or advertising to meet their operating expenses. Community radio is also typically subsidized from nongovernmental (NGO) sources for development costs (equipment and training) and in many cases also to cover some portion of their operating expenses while large and small commercial broadcasters rely exclusively on revenues generated from airtime and advertising. Another factor that varies by country context and is likely to have an impact on the cost of radio dissemination is the legal or administrative regime for managing the available frequency spectrum. Differences in these management regimes affect not only the cost of transmission, but also the availability of listening options either in the entire country or in regions of the country.

Even if completely subsidized from public resources, the transmission of the audio lessons uses a limited resource - broadcasting time that could be used by the broadcasters to generate revenues. Ignoring these opportunity costs would invalidate any comparisons of cost-effectiveness with alternative strategies for disseminating the lessons or comparisons with other remote or mixed learning strategies. The opportunity costs can be estimated by applying an ingredients-costing methodology that converts the cost of all investments in capital goods, such as equipment and infrastructure, as well as recurrent expenses, such as human resources and materials, into an annual cost per hour for broadcasting.[33]

Another means of estimating broadcasting costs is to assume that broadcasters have good information on their costs and that prices charged for airtime (longer programs) or advertising (short spots) approximate the broadcasters marginal costs.[34] While large-scale global studies of the economics of radio broadcasting are scarce, a small study of broadcasters in Africa[35] indicates that even state and public radios are becoming more dependent on revenues generated from selling airtime and advertising.[36] For broadcasters of any type, the dissemination of 200 30-minute lessons in a year competes with the revenues that can be generated from other types of popular programming (e.g., music, news, talk shows, drama). While the study of Africa broadcasters is limited in size, it does provide some reference points for revisiting the IAI baseline cost framework estimates for disseminating the lessons by radio broadcast.

In the Farm Radio International survey of rural radio broadcasters,[37] prices charged for 30 minutes of airtime varied considerably, with stations that reached larger markets tending to charge higher rates. A median rate for 30 minutes of airtime was approximately $150 (including large and small commercial stations as well as state, public, and community broadcasters). While this sample is quite small it provides a point of departure for examining the sensitivity of costs and cost-effectiveness of IAI to broadcast airtime costs.

Table 5 examines the sensitivity of the baseline cost framework estimates to alternative prices for disseminating the 200 30-minute lessons. The baseline estimate summarizes the estimated cost for the modified scenario, including remote consultation and the digital recording package (Table 4). If a price of $50 per 30 minutes of broadcast time is assumed rather than the equivalent $25 in the baseline, the total annual cost per student

[33] More precisely, the marginal cost per hour of broadcasting for adding the new/additional education program to an existing broadcaster's schedule (see Mayo et al., 1975).
[34] With the assumption that price is equal to marginal cost.
[35] See Farm Radio International, 2008.
[36] This prioritization of self-generated revenues also varies by country with some countries maintaining support for public and state broadcasters, while others are shifting the burden to airtime and advertising revenues.
[37] See Farm Radio International, 2008: Page 10, Table 15: Fees Charged by Radio Stations for 30 Minutes of Airtime

increases by about $0.12 per student for both the small and large programs.[38] If broadcast costs average $100 per 30 minutes, the annual per student cost increases $ 0.37 per student in the small program and roughly the same amount for the large program. When the median price from the Farm Radio Survey[39] is used ($150 per 30 minutes) the annual cost per student increases by $0.62 per student to $6.10 for the small program. The per student increase for the large program is nearly the same, increasing the total cost per student to $3.84.

Table 5: Impact of broadcasting costs

Radio Broadcasting Costs and Total Program Annual Cost per Student			
		Scale (Students)	
		100,000	1 Million
Baseline	Annual dissemination (broadcast and devices)	$171,714	$1,717,145
	Total annual cost per student	$5.48	$3.22
$50 per ½ hour	Annual dissemination (broadcast and devices)	$184,214	$1,842,145
	Total annual cost per student	$5.60	$3.34
$100 per 1/2 hour	Annual dissemination (broadcast and devices)	$209,214	$2,092,145
	Total annual cost per student	$5.85	$3.59
$150 per 1/2 hour	Annual dissemination (broadcast and devices)	$234,214	$2,342,145
	Total annual cost per student	$6.10	$3.84

As an indication of the magnitude of the impact of broadcasting costs, the total annual cost for the large program increases from $3.2 million in the baseline[40] to $4.3 million with the assumption of an average cost of $150 per 30 minutes for broadcasting the lessons—about a 27 percent increase[41] in the total annual cost. We will keep this variability in mind when alternative means of disseminating content are examined.

Alternatives to Radio Broadcasting

Statistics from the International Telecommunications Union (ITU) indicate that the coverage of mobile networks and the proliferation of mobile phones now rivals the accessibility to radio in many developing countries. In 2019, it was estimated that about 80 percent of the populations in the least developed countries (LDCs) and more than 90 percent of the populations in developing countries (DCs) were covered by a mobile network with at least 3G service. While 3G networks are available to the large majority of the populations in LDCs and DCs, prices for mobile phones and subscriptions to services limit subscribers to 75 percent of the DC population and just 33 percent of the LDC population.[42]

As an alternative to radio broadcasting, we have estimated the cost of substituting the transmission of audio files (MP3 files for lessons and a short file of 5 minutes for teacher orientation and support) via mobile networks for radio broadcasts (Table 6). For this scenario, we incorporate the same assumptions of the delivery of the lessons to classrooms and facilitation by teachers. To estimate mobile network costs at the school level, we assume that

[38] The $40 cost for radios and assumed costs of maintenance and supplies (batteries) as well as the costs of loss/damage replacement were maintained from the original baseline estimate. The students reached per market was also maintained—so the changes in price per student will be equivalent in the small and large programs.
[39] See Farm Radio International, 2008, March.
[40] Equivalent to $25 per 30 minutes of broadcast time
[41] A difference of $0.80 per student for the 1 million-student scale initiative
[42] See International Telecommunication Union, 2019.

teachers will use a mobile device to download the lessons from a simple website and play the lessons on a speaker. We also assume that since the lessons are digital audio files, one download, one mobile device including Mp3 players, and one speaker can provide the lessons to two classrooms (a total of 60 students).

Table 6: Disseminating 200 lessons via mobile network

Disseminating 200 Lessons Via Mobile Network					
	Unit Cost	Total Annual Cost		Total Annual Cost	
		100,000 Students		1 Million Students	
		Class	School	Class	School
Connectivity (1G data mobile monthly)	$8	$293,333	$146,667	$2,933,333	$1,466,667
Mobile device (10% annual replacement)	$35	$31,299	$15,651	$312,993	$156,496
Device Bluetooth speaker (10% annual replacement)	$45	$40,242	$20,121	$402,419	$201,210
Maintenance*	$132	$440,000	$220,000	$4,400,000	$2,200,000
Distribution start-up investment**		$1,113	$1,113	$3,340	$3,340
Distribution maintenance recurrent***		$3,400	$3,400	$5,600	$5,600
Total annual dissemination via mobile network		**$809,387**	**$406,952**	**$8,057,685**	**$4,033,313**
Annual cost per student via mobile network dissemination		**$8.09**	**$4.07**	**$8.06**	**$4.03**

*$5 per month for phone charging; $7 per month for speaker batteries

**Host servers and installation

***Host server maintenance and connectivity

Pricing data on mobile packages[43] captured by the International Telecommunication Union indicate that the average price per month for sufficient bandwidth to download the daily 30 minutes as an audio file would average $88 per year per participating classroom.[44] We have used a benchmark price of $35 for a mobile device with Bluetooth capability and a micro SD card capable of accessing the mobile network and playing the file on a Bluetooth speaker.[45] We have also included a cost of $5 per month for charging the phones, $45 for a Bluetooth speaker and $7 per month for speaker batteries.[46] Both the mobile device and Bluetooth speaker costs have been converted to annualized costs using a social discount rate of 7 percent and an expected life of five years as well as 10 percent per year for lost and damaged devices.

Initial start-up costs include $6,000 for establishing the servers to host the lessons and a per year cost of $3,400 for connectivity and to maintain the host servers for the small program. For the large program, we assume $18,000

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[43] See International Telecommunication Union, 2020.
[44] Mean monthly cost of 1G of mobile data is about $8 per month across 100 middle and low-income countries. We assume that the program operates 11 months per year and total file size for downloads is about 700 MBs per month.
[45] While we have used $35 as a reference price, there are developments in the market for mobile devices with prices (exclusive of distribution) as low as $20 to $25 that have the required capabilities. The assumed price of a Bluetooth speaker is $45.
[46] With the proliferation of mobile devices, there has also been notable entrepreneurial response for repairs and mobile device charging even in very small communities. We have assumed that these entities could charge the mobile devices at a price of 5 dollars per month.

start-up costs and $5,600 for connectivity and annual maintenance.[47] None of these assumptions incorporate resources from any type of universal access funding that governments may have secured from the telecommunications providers.[48]

Table 6 summarizes per student costs for delivering the IAI baseline cost framework if the transmission of audio files (MP3) via mobile network is substituted for radio broadcasts. For the small and large programs, two cost estimates are provided: One cost estimate assumes each class (30 students) has a mobile device and a speaker and downloads the audio file. The second estimate assumes that two classes in a school are using the lessons, sharing the mobile device and the speaker and only downloading the lesson once.[49]

Table 7 compares total annual per student costs for two scenarios for the IAI baseline cost framework of 200 lessons of 30 minutes provided in classrooms with teachers as facilitators: (1) using remote consultation and digital recording and (2) using remote consultation, digital recording, and dissemination of the lessons via mobile network.

Table 7: Baseline model utilizing mobile network to disseminate lessons

Baseline Cost Framework with Dissemination Alternatives				
	Scale			
	100,000		**1 Million**	
	Remote/Digital	**Mobile Network**	**Remote/Digital**	**Mobile Network**
Annual cost per student for program development	$1.97	$1.97	$0.92	$0.92
Annual per student cost for program implementation	$3.38	$5.74	$2.29	$4.67
Total annual cost per student	**$5.35**	**$7.71**	**$3.21**	**$5.59**
With $150 per 1-Hour Broadcast Cost				
Total annual cost per student	**$5.97**	**$7.71**	**$3.83**	**$5.59**
Lessons repeated once in classroom (re: broadcast)	**$6.35**	**$7.71**	**$4.20**	**$5.59**

As summarized earlier in Table 4, the impact on costs of substituting remote consultation and digital recording is minimal—just $0.13 per student per year for the small program and just $0.01 per student per year for the large program. Substituting the dissemination of lessons via mobile network[50] for radio broadcast significantly increases the total annual cost per student. Nearly all the additional cost is for connectivity (see Table 6) as the annual cost of devices (mobile devices versus radios) are similar.[51] In the baseline scenario, the substitution of audio file downloads for radio broadcasts increases the total annual cost per student from $5.35 to $7.71 for the small program and from $3.21 to $5.59 for the large program. Only the dissemination costs were substituted in the

[47] The maintenance costs for the servers and technology are annual estimates. The initial cost of the servers and installation costs have been converted to an annualized equivalent using a discount rate of 7 percent and an expected life of seven years.
[48] Depending on the communication policy and legislative norms, the use of universal access funds could significantly reduce costs—as could $0 connection fees for some of the content sites.
[49] This is equivalent to 60 students per device (mobile device and speaker) and mobile download costs for the lessons.
[50] Described in Table 6.
[51] We have also included a 10 percent annual replacement cost for lost or damaged devices.

comparison; the other implementation costs (physical materials, management and oversight, etc.) were included in both estimates.

While radio broadcasts can be recorded, the quality of recordings from radio can vary significantly. Audio file downloads can be played many times without additional cost and without any loss of fidelity. Audio files can also be paused and/or replayed in parts while replaying radio broadcasts is dependent on rebroadcasts of entire lessons. The final two rows in Table 7 incorporate a comparison of the costs of radio versus mobile network dissemination assuming the higher $150 per 30-minute broadcast airtime cost and a repeat of each lesson at 50% of the original broadcast cost. The assumption of a rebroadcast of the lessons further reduces the difference between radio and mobile network dissemination to less than $1.40 for both the small and large programs.[52] An important underlying assumption is that radio rebroadcasts or using downloaded audio files multiple times (depending on the judgement of the teacher) would be expected to increase the effectiveness of the lessons.

The use of mobile networks also presents the opportunity of adding functionality at low or no cost. Messaging apps such as *WhatsApp* and *Telegram* enable ongoing support and engagement with teachers—and as explored later—with parents and with students. Mobile networks and devices also offer managers the potential of real-time feedback on student outcomes.

IAI and Digital Learning Platforms

Digital or online learning platforms have proliferated over the last decade with the expansion of high-speed fixed and mobile connections. However, the role of these platforms in basic education has been limited—in particular for primary level education. As a response to COVID-19, many education systems turned to the use of these online platforms in an attempt to promote the continuity of learning during the period of school closings, albeit with mixed results.

Considering the IAI baseline cost framework case of provision in schools, the most immediate challenge for scaling up online systems has been the limited and unequal access to the necessary bandwidth and appropriate devices. UNESCO estimates that only about 16 percent of primary schools and about 30 percent of junior secondary schools in DCs have Internet access for pedagogical purposes[53] and the ITU estimates that available bandwidth per Internet user in DCs is about 50 percent that of developed countries and only about 11 percent for Internet users in LDCs.[54, 55] In an environment of school closures, supporting full Internet access and laptops or tablets in homes would be prohibitively expensive and come with significant equity concerns.

Another serious limitation is the alignment of existing content with the national curriculum and/or learning assessment program. The costs of designing, developing, and producing new and appropriate content for an online platform represents a significant financial and technical challenge with only the richest systems having both the resources and expertise. Online platforms are also designed for engagement with individual students. Few education systems outside of the developed economies have the resources to provide a device (desktop, laptop, or tablet) and access to full classrooms of students.

The typical approach is to establish a computer lab where groups of students can access the platform. Vital Wave Consulting has estimated an annual "total cost of ownership" for a primary school computer lab in a developing

[52] For the small programme, $6.35 per student for radio dissemination versus $7.71 per student for mobile network audio file download. For the large programme the cost per student using radio dissemination is $4.20 versus 5.59 for mobile network audio file downloads.
[53] UNESCO Institute for Statistics, 2022.
[54] International Telecommunications Union, 2019.
[55] Many systems in the United States also struggled with significant challenges of bandwidth and devices due to the decision to shift to remote learning.

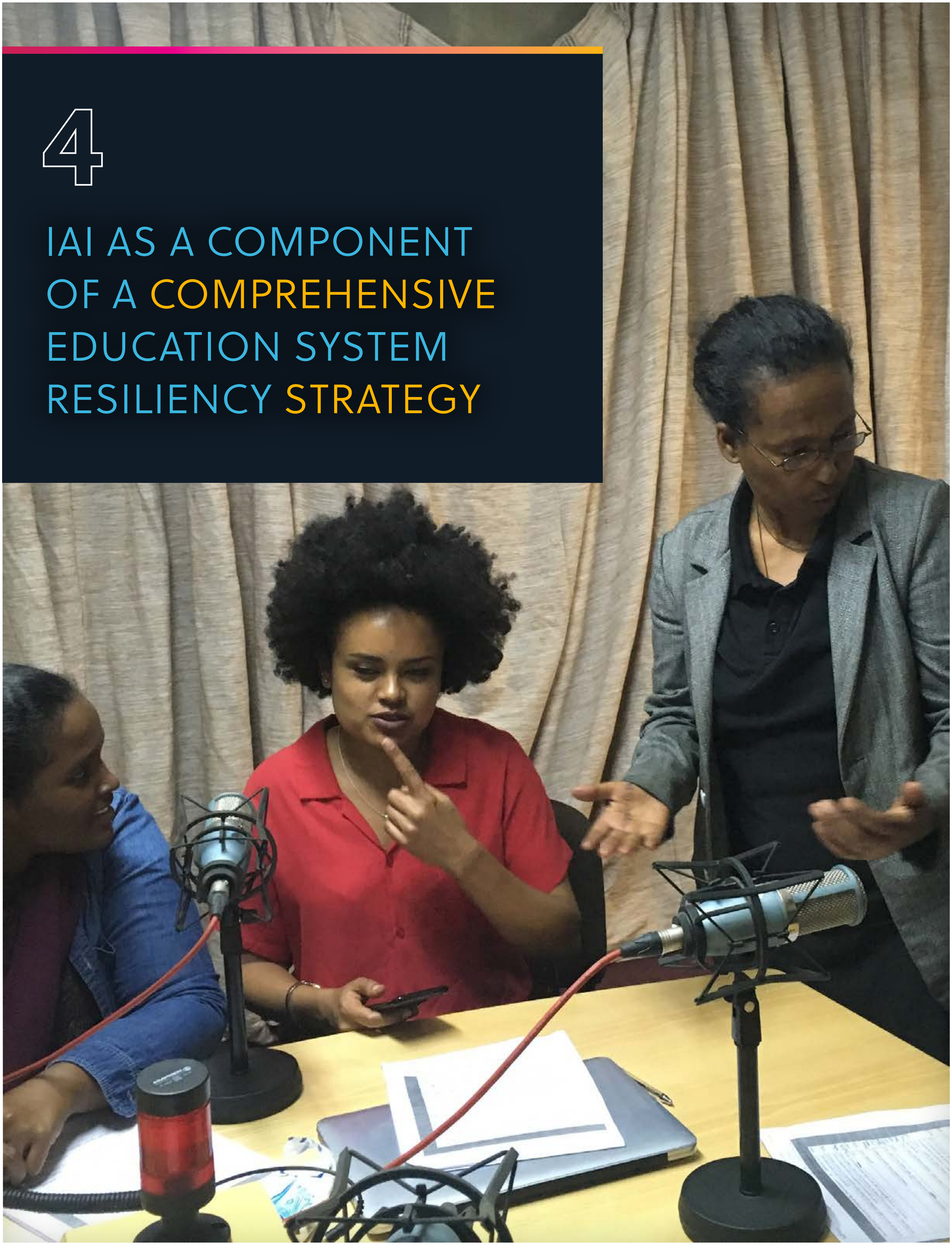
country.[56] Development costs included 16 computers, re-wiring, network installation, and software. Recurrent costs included the training of teachers and technicians, connectivity and power, content subscriptions and platform costs, maintenance, loss of or damages to devices, and network hardware. All costs were estimated with the assumption of a five-year useful life. The total cost of ownership per "seat"[57] was nearly $3,000. If we assume that the 16 "seats" could be shared during the day across 50 students, the cost per student would decline to about $960 per student.[58] These estimates assume that the content provided will be from a subscription to an already existing learning platform—which may or may not be optimal for a given education system. If content (Web-based with interactive capability, graphics, and video) were to be developed, the costs per student would be considerably higher—and considerably higher than the costs of developing the IAI lessons.

While we are not aware of a rigorous comparison of the cost-effectiveness of IAI and an online platform,[59] a cursory examination of marginal costs suggests that it is very unlikely that an online platform would be more cost effective than IAI in most developing country settings. The annual cost for the baseline IAI using mobile network dissemination was $7.71 per student.[60] The estimated cost per student for access to an online learning platform was $960—and this was without the cost of developing content. Even if we assume that the additional capability of the online platform potentially provides better learning outcomes,[61] it is very unlikely that improved outcomes reflect the nearly more than 100 times magnitude of the per student costs.

[56] See Vital Wave Consulting, 2008.
[57] A workstation is a desktop, laptop, or tablet with an Internet connection.
[58]$48,000 per year for the 16 seats for 50 students equals $960 per student.
[59] This would require a randomized study comparing students participating in an IAI program and students receiving similar level content through an online platform.
[60] For the 100,000-student program
[61] The assumption that the additional capability of the online platform potentially provides better learning outcomes is an untested assertion.

4

IAI AS A COMPONENT OF A COMPREHENSIVE EDUCATION SYSTEM RESILIENCY STRATEGY



IAI and the Enhancement of the Resiliency of Learning

Our initial version of an IAI baseline cost framework was based on the development and implementation of a classroom-delivered initiative of 200 lessons of 30 minutes each disseminated via radio broadcasts. Subsequently, the impact of incorporating new technologies for program development and dissemination were estimated. While the classroom-based model with teachers as facilitators has been the most widespread form of IAI implementation, the emergence of the COVID-19 public health emergency created a new environment where education systems have incorporated remote learning (entirely or as part of a blended approach) for large portions of the student population.

With a proven methodology for active engagement of learners, demonstrated impact on learning outcomes, and relatively low costs compared to online learning platforms,[62] IAI is a promising strategy for these episodic substitutions of remote learning for in-person classroom instruction. Even in the absence of a crisis or emergency resulting in the closing of schools, many children have and continue to suffer from what global education stakeholders refer to as *learning poverty*, as defined by the inability to read and understand a simple story by the end of primary school. It is estimated that 53 percent of children in low- and middle-income countries are *learning poor* with the level as high as 80 percent of the children in the poorest countries.[63] The obstacles to learning encountered by these children are many and varied. Many children do not have access to a school in close enough proximity to facilitate regular attendance, and/or they attend a school with overcrowded classrooms and under-trained and poorly equipped teachers. In some cases, children attend a school with a language of instruction that is not spoken in their household. For these children, the incorporation of IAI initiatives as a regular ongoing complement to in-person classroom instruction is a potentially cost-effective investment in improving learning outcomes and enhancing equity.

In assessing the cost-effectiveness of IAI as a strategy to promote resiliency and the continuity of learning—either as a response to episodic disruptions of the school calendar or as a complement to in-person classroom instruction—a key assumption is that all education systems have developed strategies to ensure continuity of learning **before** the emergence of a crisis or emergency.[64] In the case of IAI, this implies that the development of programs (i.e., the design, elaboration of scripts, and production of lessons) would become part of regular annual education system resource or budget allocation.[65] In the case of IAI as a strategy for episodic substitution for in-person classroom instruction, the costs of dissemination would only be incurred when there are significant disruptions of school operations. In systems where significant numbers of children encounter obstacles to participation and learning, IAI as a complementary system can capitalize on these investments in program development. The marginal or additional development costs for the complementary IAI strategy would be minimal—possibly some adaptations of the programs.

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[62] With significantly fewer equity challenges resulting from differences in access to broadband connectivity and an appropriate device.
[63] See The World Bank, 2019.
[64] This is perhaps the most important lesson to be learned from the COVID-19 crisis.
[65] The costs of the initial development and production of the lessons along with resources for ongoing revisions and to ensure alignment with the evolution of the curriculum and the systems' assessment programs.

The cost of IAI as an episodic substitute for in-person classroom learning or as an ongoing complementary support to improve learning outcomes differs from the IAI baseline cost framework in two ways. First, the scale of the program would be expected to be large.[66] Rather than a program in selected schools, the program would be developed to reach all primary or basic education students in their households. Second, the program design would need to consider that the facilitators will be parents, other adults, or older children in the household rather than a trained teacher. The aspects that would be identical in the two cases would be the characteristics of the program—a carefully planned design consistent with a national curriculum and active engagement and promotion of responses by students through interaction with characters in the lessons.[67]

IAI As a Strategy to Address Episodic Disruptions of Schooling

Table 8 summarizes the modifications to the baseline cost framework required to estimate the cost of IAI as a response to episodic school closures. To elaborate the estimate, we have assumed that schools would be closed for half of the school year (5 months) three times in a 10-year period. The cost of the development and production process for the 200 lessons is similar for both the stand-alone model and the episodic closure models, although in this case the models would be developed to support facilitation in households. We have increased the design and production process costs by 30 percent to allow for needed revisions and improvements over a 10-year period.[68] One significant change in development costs is the substitution of the initial in-person training and orientation for teachers with a social communication campaign focused on parents and community members. The assumption is that a communication campaign would be required at the beginning of each school closure period.

[66] While we have used 1 million students in elaborating the estimate, a quick analysis of reported primary enrollments (those reporting to UIS in 2019) yields a 10% trimmed mean of about 2.3 million primary students.
[67] For example, as part of the pandemic response in Haiti, the government is broadcasting on national radio a program previously developed for use for mathematics and reading instruction in grade 2 and 3 classrooms. While the broadcasts cannot count on the support of a qualified teacher, the program was designed to promote engagement with learners and provides a more effective approach than merely broadcasting content.
[68] These resources cover the costs of periodic review and updating of already developed study programs to ensure that they remain consistent with official curriculum and policy.

Table 8: Summary of modifications to the IAI baseline cost framework

IAI as a Response to Episodic School Closures (Modifications of Baseline Cost Framework)	
Development costs –for baseline stand-alone classroom-based program versus episodic response to school closures (3 five-month closures over 10 years)	
Baseline Cost Framework	**As an Episodic Response to School Closures**
Design and production of 200 lessons of 30 minutes each over a 7-year implementation	Assumes 30% increase in total design and production cost for 200 lessons to allow for updating program over a 10-year period
Capacity development: In-person initial training and orientation of teachers over 7-year implementation	Multichannel social communication and awareness program focused on parents and community at the beginning of each closure period (at $0.50 per student)
Development costs –for baseline stand-alone classroom-based program versus episodic response to school closures (3 five-month closures over 10 years)	
Baseline Cost Framework	**As Episodic Response to School Closures**
Small management and technical team maintained full time	Small management and technical team maintained full time
Physical materials for teacher – 1 distribution every 3.5 years per teacher	None – Orientation for parents/caregivers provided in lesson
Radio dissemination as an annual cost for 7 years (alternative estimates of airtime costs)	Radio dissemination (low cost, medium cost, high cost) as airtime costs for 6 months for each school closure period (½ year closure every 3 years) – Broadcast twice daily during closure
Devices: Radio and batteries provided; cost discounted over 7 years with an assumed annual loss/replacement of 10%	Devices: Radio and batteries provided (for all households, for ½ of households, for ¼ of households)
Alternative dissemination via mobile network – Download audio files with mobile device and speaker (one mobile device, one download, and one speaker per school) Mobile device and speaker with an assumed annual loss/damage of 10%	Alternative dissemination via mobile network – No Bluetooth speaker required Mobile device annual loss/damage assumed 10% Mobile device and connectivity provided all households Mobile device provided to ½ households, connectivity subsidized for all Mobile device provided to ¼ households, connectivity subsidized for all

In estimating the implementation costs for IAI as an episodic response, the small core management and technical team included in the estimations for the baseline cost framework was maintained.[69] With the shift from classrooms to households as the implementation site, the teachers' guide and other physical teaching materials have been eliminated. Dissemination costs via radio are estimated based on five months of daily (for five days) of broadcasting lessons for each school closure period. As households' livelihood activities may not facilitate listening to the lessons on a normal schooling schedule, we have assumed that the lessons would need to be broadcast twice daily. The percentage of households with radios varies considerably from country to country and by regions within countries. The baseline cost framework estimates included the provision of radios and batteries for every participating classroom. Clearly, the provision of a radio to as many as 1–2 million households yields a very

[69] The core team manages the review and revisions of lessons as well as the development and maintenance of the relationships with broadcasters, telecommunications providers, etc.

expensive annual cost. We have estimated the costs of IAI as a response to episodic schooling disruptions using the following four different assumptions:

1. The provision of radios to all households
2. The provision of radios to one-half of all participating households
3. The provision of radios to one-quarter of all participating households
4. No provision of devices

In all cases, the estimate includes the assumption that batteries would need to be provided for 30 percent of the households receiving devices. As with the baseline cost framework, estimates are also provided for substituting audio file downloads via mobile networks for radio broadcasts. The audio file and mobile network scenarios also include provision of devices and power for the same proportion of households as assumed in the provision of radios. No Bluetooth speaker is provided to households assuming that in a small setting the phone audio is sufficient.

Table 9 summarizes the annual cost for an IAI response to episodic disruptions of schooling established over a 10-year period. The table data assume that the IAI response will be implemented three times (for one-half of the school year) in a 10-year period and a primary school population of 1 million students. Costs are presented as annual costs over a 10-year period to facilitate advanced planning and possibly the inclusion of IAI resource requirements in a medium-term budget framework.

Table 9: Annual cost for IAI as a response to disruptions of schooling

IAI as a Response to Episodic Disruptions of Schooling (3 ½ Year Disruptions Over a 10-Year Period) Annual per Student for 1 Million Students				
	Provide Devices to All Participants	**Provide Devices to ½ Participants**	**Provide Devices to ¼ Participants**	**No Devices**
Radio Broadcast				
Program development	$0.21	$0.21	$0.21	$0.21
Implementation				
Management	$0.16	$0.16	$0.16	$0.16
Broadcast cost (low)	$0.04	$0.04	$0.04	$0.04
Broadcast cost (high)	$0.23	$ 0.23	$0.23	$0.23
Devices	$14.76	$7.38	$3.69	$0.00
Total annual (low-cost broadcast)	**$15.17**	**$7.79**	**$4.10**	**$0.41**
Total annual (high-cost broadcast)	**$15.36**	**$7.98**	**$4.28**	**$0.59**
Mobile Network, Mobile devices, and Digital Files				
Program development	$0.21	$0.21	$0.21	$0.21
Implementation				
Management	$0.16	$0.16	$0.16	$0.16
Connectivity	$12.00	$12.00	$12.00	$12.00
Devices	$13.14	$6.57	$3.29	$0.00
Total annual	**$25.51**	**$18.94**	**$15.65**	**$12.37**

Even after allowing an additional 30 percent for ongoing revisions and updating of lessons, the annual per student cost of designing and producing the 200 lessons is just over $0.20 per year. Our assumption is that the development process would have anticipated the possibility of the lessons being facilitated by parents, other adults, or older siblings. With such a low cost, the development, production, and "banking" of lessons that could be scaled up quickly in response to school disruptions would seem to be a very cost-effective risk mitigation strategy.

Broadcasting costs were estimated by applying the low ($25 per 30 minutes) and high ($150 per 30 minutes) costs used in the baseline cost framework. It was assumed that each disrupted schooling period would be for one-half of the school year and that lessons would be broadcast twice daily. Under these assumptions, broadcast costs as annual per student costs over 10 years are quite small. Costs for the devices (radios) were estimated in the same manner as the device costs in the baseline: a replacement cost of $40 per radio with an expected life of seven years and an additional loss/damage adjustment of 10 percent. For each estimate, there was an assumption that 30 percent of the radios provided to households would require batteries ($20 per year).

The annual per student costs over the 10-year period were also estimated using the assumption that lessons would be disseminated via mobile networks with households downloading the lessons in the form of an audio file. Other assumptions are identical to those estimating the radio broadcast strategy: school disruptions of one-half of a school year three times over a 10-year period. As the lessons are identical, the same development and production costs are applied. A similar set of assumptions is also applied regarding the provision of mobile devices, that is, devices are provided to all participating households, to one-half of the participating households, to one-quarter of the participating households, and lastly the cost resulting from providing no devices to participating households. Support for charging the mobile device ($20 per period of disruption) is included for 30 percent of the participants being provided a mobile device. Connectivity for the mobile downloads is based on the $8 per month used for the baseline cost framework. Connectivity costs are only included for 5 months for each of the school disruption periods. As with broadcasting costs, the total costs for connectivity for the three periods are expressed as annual costs over 10 years to facilitate comparisons.

Annual cost per student over a 10-year period for dissemination through radio broadcasts range from about $15 when including the provision of radios for all participants to less than $0.60 if no devices are included in the estimate. For delivering the identical program over mobile networks, the annual cost per student ranges from more than $25.50 to about $12.40. The difference in the two approaches is explained entirely by the difference in the costs of dissemination: radio versus mobile network.[70] The potential of additional functionality in using mobile networks in an environment where lessons are being facilitated in households should be considered. Integrating text messages, *WhatsApp* groups, or *Telegram Channels* to support those facilitating the lessons in households and providing real-time feedback from students could add considerably to the value proposition of utilizing mobile networks.

Assessing the cost-effectiveness of IAI as a strategy for ensuring the continuity of learning during episodic disruptions in schooling is limited by the lack of comparisons of effectiveness with other possible strategies. For example, one potential means to address disruptions is extending the number of school days (lengthening the school year and/or number of days per week). The costs of extending the school day or school year are likely to include additional compensation for teachers[71] and the typical school calendar limits the additional days to not

[70] Mobile network costs were calculated at $8 per month for 15 months of connectivity for the three periods of school disruption spread over the 10-year period ((8*15)/10).
[71] While teachers may have received their salary during the disruption of in-person schooling, teaching additional days has an opportunity cost for teachers (those days would no longer be available for other activities). We have made the assumption that teachers would be compensated at ½ their regular pay for the 1.5 months of additional classes per year. The assumed disruptions would total 15 months of schooling lost over the 10-year period—or 1.5 months per year.

more than two months in a given school year.[72] Using a median monthly salary for teachers in 15 African countries of $680[73] as a reference point, as well as the assumptions that the additional compensation would reflect about one-half of a teacher's normal salary and that class sizes would be 40 students, the annual cost per student spread over the 10-year period for additional teacher compensation would be about $12.75. With an assumption that schools would also have additional costs for the additional class time, a more realistic estimate would likely be more than $15 per student over the 10-year period.

This crude estimate suggests that as an annual cost per student, additional days of schooling to compensate for the periods of disruption would be comparable to the IAI costs using radio and providing the radios and not much less expensive than the use of mobile networks and providing some of the mobile devices (see Table 9). The cost-effectiveness question is whether the improvements in learning outcomes per dollar invested are higher for IAI or for extending the school year, and direct evidence of this comparison is unavailable.[74]

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[72] The total planned school vacation periods that could be dedicated to making up losses are typically about two months total.
[73] See Evans et al., 2020.
[74] Adding to the complexity of hypothesizing about the relative cost-effectiveness of IAI versus extending the school year is the question of engagement. In many developing countries and particularly in LDCs, long distances, inadequate school infrastructure, and competing livelihood demands on students' time result in low levels of daily school attendance. Extending the school year would likely exacerbate the challenges to school attendance. For IAI, we do not have information about the consistency of participation when the program relies on households to provide support and facilitation—or how best to promote participation and the costs of activities to effectively promote participation.

IAI As an Ongoing Complementary Program to Support Continuity of Learning for Individual Students

For examining the costs and cost-effectiveness of IAI as a strategy to address episodic disruptions to schooling, we used the assumption of a one-half school year disruption three times over a 10-year period. This assumption represents about 15 percent of school days over the 10-year period.75 There are many children in low-resourced education systems that routinely miss 15 percent of school days even when schools are operating normally. Add to these absences the unproductive days in overcrowded classrooms with few materials and an inadequately trained teacher, and the equivalent "lost" days of schooling becomes massive. IAI presents an opportunity to "recover" lost days of schooling as a regular complement to in-person schooling.

If a system has adopted a policy of having an IAI program in place ("banked") as a risk-management strategy for in-person schooling disruptions, there would likely be minimal to no additional costs for program development for the ongoing complementary IAI.[76] Reaching the children in circumstances where their school participation is disrupted by conflicting demands on their time would require multiple radio broadcasts—including broadcasts outside of regular school hours. Digital downloads address the challenge of reaching this group of geographically disperse learners, but costs can be significant when viewed as a per participant cost.

The costs of IAI as a complement to in-person schooling rather than a substitute can be reduced by carefully targeting the children most likely to benefit. While programs that depend on effective targeting can be challenging to implement, most education systems already provide some conditional programs: school lunches, support for school fees, transport allowances, etc. If the program is to prioritize geographic areas, either radio broadcasts or mobile downloads could be the most cost-effective means of dissemination depending on the context. However, if the process of identifying students for the support results in a geographically disperse group of priority students, the mobile network option is likely to be more cost-effective choice.

Table 10 summarizes the estimation of the annual incremental cost for a complementary IAI program. We are estimating an incremental cost because this complementary program is being conceived of as a complement to the regular provision of in-person schooling in the system and not a substitution.

The cost is estimated at two scales: (1) a program reaching 15 percent of the primary students and (2) a program reaching 25 percent of the students. The estimate of marginal costs excludes the cost of program development and production, which we assume is already embedded in the annual education budget as a policy of risk mitigation (see previous section). Using this concept of incremental cost, the cost of the program is the connectivity and the devices required to disseminate the lessons to the 15 percent or 25 percent of the student population. Using an assumption of 10 months per year of download access at $8 per month, the cost of a $35 mobile device annualized over seven years, and $50 per mobile device support for charging each year, the annual cost per participating student is $138.16. This annual cost per student results in an increase to the annual systemwide education spending of $20.73 per student for a program providing connectivity and devices to 15 percent of the students and $34.54 per student when the program supports 25 percent of the students.[77]

[75] Assuming a 180-day school year

[76] If a system had already adopted a strategy or a policy of having IAI lessons developed and implementation ready as a risk management strategy for maintaining the continuity of learning, the development costs for using the lessons to complement in-person schooling would be considered sunk costs.

[77] Once again using the assumption of a 1-million student system, 250,000 students would be 25%: (25%) * $138.16 (per student provided mobile connection and device)/1,000,000.

Table 10: Incremental cost of IAI as on ongoing complementary program

Complementary IAI Program Marginal Costs (as Per Student, 1 Million Student Population)			
		% Students Supported by IAI Complementary Program	
	Annual per Supported Student	15%	25%
Connectivity	$ 80.00	$12.00	$ 20.00
Devices	$ 58.16	$ 8.73	$ 14.54
Annual cost per student (1 million student population)	**$138.16**	**$20.73**	**$34.54**

Assessing the cost-effectiveness of IAI as a complement to regular classroom instruction requires examining marginal costs and benefits of the program for the entire education system rather than the costs and impact for a targeted group of students. One way of assessing the impact of an education strategy on the education system is to examine its effect on student repetition, promotion, and completion.[78] A handy measure for examining the impact of changes in repetition, promotion, and completion is to use a reconstructed cohort analysis[79] to calculate the number years of spending required to produce a completer at some level of the system, which in this case is primary education/grade 6. Improving repetition rates and promotion rates lowers the number of years of system spending required to produce a grade 6 completer (due to improvement in internal efficiency).

Table 11 presents a scenario for examining the potential cost-effectiveness of IAI as a complementary program to in-person schooling using a reconstructed cohort analysis. For the baseline assumption, we assume an 85 percent promotion rate, a 10 percent repetition rate, and a 5 percent drop-out rate for grades 1 to 6. Using these assumptions, the average cost of producing a grade 6 completer is 13.08 years of annual spending. If we assume that the provision of an IAI complementary program to 25 percent of students will improve the promotion and repetitions rates in the entire system by 2 percent (86.7 percent promotion, 8.3 repetition) while holding dropouts constant at 5 percent, the years of spending to produce a grade 6 completer is reduced to 11.66 years.

[78] There are of course others; most notably learning outcomes.
[79] See UNESCO Institute for Statistics, 2009.

Table 11: IAI complementary program impact on total cost of producing a grade 6 completer

Simulating Cost-Effectiveness of IAI as a Complementary Program					
		Annual Cost Baseline			
	Years.	**300**	**500**	**700**	**1,000**
Cost per G6 completer	13.08	$3,924	$6,540	$9,156	$ 13,080
		Annual Cost with IAI Complementary Program			
	Years.	**$335**	**$535**	**$735**	**$1,035**
Cost per G6 completer	11.66	$ 3,906	6,238	8,570	$ 11,660
Baseline: Promotion 85%, repetition 10%, dropout 5% With IAI: Promotion 86.7%, repetition 8.93 %, dropout 5% Marginal cost of IAI complementary program for 25% of students = $35 per student Assumed improvement in promotion and repetition rates of 2%					

We then compare the total spending required to produce the grade 6 completer without the IAI complementary program (13.08 years of spending) and with the IAI program (11.66 years of spending). This is estimated for four different education systems with different levels of annual baseline spending per primary student: $300, $500, $700, and $1,000. As presented in Table 11, the incremental cost for incorporating a complementary IAI program for 25 percent of the students is $35 per student.[80] In a system where the current spending per primary student was $300, spending the additional $35 per student reduces the overall cost of producing a grade 6 completer from $3,924 to $3,906 dollars. The impact of implementing an IAI complementary program is positive (reduces the cost of producing a grade 6 completer at all the higher levels of initial baseline spending). While the scenarios in Table 10 demonstrate how a complementary IAI program may have a positive return (produces grade 6 completers at a lower cost than it would without the program), they do not address the cost effectiveness question of whether other types of interventions, such as cast transfers conditioned on school attendance or creating additional schools or more in-service teacher training, could produce better outcomes at lower costs.

[80] As the complementary programme would be considered an integral component of education service delivery rather than as a standalone temporary initiative, the costs of the programme are expressed as the additional budgetary allocation required to provide the programme (as described). The total annualized cost of providing the materials, connectivity, and devices to an assumed 25 percent of the student population would increase total system requirements by about $35 per student (assuming a system of 1 million students).

5

SUMMARY IAI AS A RESILIENCY INVESTMENT

The goal of this paper was to present the case for IAI as a cost-effective strategy for improving the resiliency of education systems. While the COVID-19 public health crisis placed the need for more resilient approaches to schooling near the top of the global agenda, more localized disruptions were already commonplace—and increasing in frequency—before the pandemic. Millions of children experience personal disruptions of schooling even when systems are delivering business as usual, and more than half of the children in developing countries were considered learning poor before the emergence of the novel coronavirus.

We began by reviewing IAI in what has been its most typical form, namely, audio lessons supporting teachers in a classroom setting. Adkins assessed the cost-effectiveness of IAI initiatives in five countries where both rigorous assessments of the impact and effectiveness of programs as well as cost information were available. **He found IAI was more cost-effective in improving learning outcomes in reading and mathematics than alternatives that focused on provision of improved textbooks or additional teacher training (see Table 2).**[81]

The classroom-based programs assessed by Adkins were implemented in the 1970s and 1980s. The technology available for the recording and management of audio content has evolved considerably since then. To examine how new technologies might impact the cost-effectiveness of IAI, a costing model based on a classroom-based IAI initiative delivered via radio broadcast was estimated using the extant technology in the 1980s and with an updated package reflecting the digitalization of recording technology as well as the storage and management of digital—rather than analog—content. Newer technologies have vastly expanded the capacity and flexibility for remote recording of local content, and access to digital effects libraries has proliferated. **Our costing model suggests that these newer technologies have lowered the cost of program development and production while also improving quality.**

Since program development and production costs are typically very small compared to implementation costs, large savings in program development and production may translate into just a few cents per student reduction in overall total costs per participant. **The important lesson to draw from the relatively small impact of development costs on total costs is that the difference between a high-quality program producing excellent results and a mediocre or poor-quality program may be as little as a few cents per student**.

The expansion of access to mobile networks and the lowering of costs of mobile devices have also opened new possibilities for IAI as a cost-effective strategy to enhance education system resiliency. Most of the population in developing countries now reside in areas covered by mobile networks of at least a 3G capability, and the costs of connectivity and mobile devices that can store and play audio files have fallen significantly. **In a program implemented in classrooms, radio broadcasts are still likely to be less expensive, but the difference is narrowing. In our simple model of a classroom-based IAI initiative, we found that utilizing mobile networks was between 12 percent and 40 percent more expensive depending on broadcast costs and program size. In areas where radio broadcast costs are high and the population is diffusely populated, mobile networks and audio downloads to mobile devices may currently be the most cost-effective dissemination option.**

IAI has a long history of demonstrated effectiveness in its classroom-based form, and it has been assessed as a more cost-effective strategy than some other common strategies for improving learning outcomes. **However, the value proposition of IAI as an investment in education system resiliency is particularly compelling.** IAI lessons can be developed, produced, archived, and managed at a low cost. There are no requirements for investments in

[81] See Adkins, 1999.

developing the technological infrastructure—radio and mobile networks have already been deployed with private resources. **This allows IAI programs to be rapidly deployed to address disruptions in schooling whether they are widespread or localized. In a simulation of an IAI response to periodic disruptions of schooling over a 10-year period, we estimated the annual budgetary requirement to be between $0.40 to $.60 per student to develop and broadcast lessons for a system of 1 million students (see Table 9).** While decisions regarding provision of devices can raise the costs to $5 to $20 per student, those costs are not incurred unless the disruptions occur. For less than $1.00 per student, an education system can have a ready-made, high-quality contingency for deployment.

Once the investment in IAI lesson development and production has been made, those costs become what economists refer to as *sunk costs*, which are costs previously incurred and which cannot be used for alternative investment. Sunk costs are not considered when evaluating the cost of utilizing those lessons for some other purpose. As emphasized previously, many children have disrupted experiences with schooling even when schools are open and functioning. **If a policy of developing, producing, and banking IAI lessons has been adopted as a resilience and risk-mitigation strategy—providing the lessons as complementary to classroom instruction has $0 development costs.**[82] For children who already have access to devices in their households where lessons can be downloaded over mobile networks, implementation costs are also quite low for a Ministry of Education, as they comprise just the cost of the servers and basic connectivity.

Unfortunately, the children who are most *unlikely* to have access to network connectivity and devices in their households are the ones typically with the most disrupted schooling experiences. As this group of children can be widely disperse,[83] mobile networks and mobile devices may be the least costly way to reach them. Using ITU estimates for connectivity costs and mobile device costs, we calculated a per student cost of $138.16 per year for each device and connectivity provided. From the perspective of a systemwide investment in improving learning outcomes, the costs should be viewed as per student costs across the entire student population and incorporated into the annual budget. Using 1 million students as the student population, providing the mobile devices and connectivity to 15 percent of the students would add about $20.73 annually per student to the budget, while a larger program targeting 25 percent of the students would result in a budget increment of $34.54 per student.

While an increment of $20 or $35 to an education budget can be viewed as expensive—it may still be cost-effective. We simulated the results of an investment of an additional $35 per student in education spending to reach the 25 percent most vulnerable children in the system. If we assume that this investment results in a 2 percent improvement in promotion and repetition rates systemwide, it can lower the overall cost of producing a primary completer—making it an investment that pays for itself over time (see Table 11).

[82] The development costs would be considered sunk costs—resources that have already been expended and cannot be recovered and used for an alternative purpose.
[83] If this group of students is widely dispersed, the number of different radio markets that would need to participate is likely to make the cost of reaching this group via radio comparable or higher than the mobile network technology.

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