

The S-Lab's *Lab in a Box*: A Potential Game Changer for Rural Schools in the Developing World

Stephen Mecca^{1*}, Megan Skrypek², Elizabeth Degaray³, Brittany Mandeville³, Nicole Boyd³, Michelle Feely³, Jack Ricci³, Delina Auciello³, Kerry McIntyr³

¹Department of Engineering-Physics-Systems, Providence College, Providence, RI, USA

²Department of Computer Engineering, Columbia University, New York, NY, USA

³S-Lab, Department of Engineering-Physics-Systems, Department, Providence College, Providence, RI, USA

*Corresponding author: smecca@providence.edu

Abstract The S-Lab's *Lab-in-a-Box* features a computer lab hosting a rich set of educational resources (the GSAP Portal) for internet- and electricity deprived- schools. The first version of the portal prototyped in Ghana includes the Rachel initiative on a 32 GB file set. The portal has been expanded to a 64 GB drive hosted on a Raspberry Pi server, on a local dedicated file server or directly on a PC or Laptop and its elements have been mapped to the Ghana school curriculum. The original powering option which consisted of solar collector and lead-acid battery was re-designed to eliminate the 12v-to-5v conversion making use of LiPo battery packs with significant improvements in energy, costs, weight and size. The system was also extended to bring science activities to the schools using available (Android) tablet sensors and instrument- analysis- reference- simulation- APPs plus a few inexpensive instruments and components. Eighty-two schools, the most recent of the 158 recipient schools, were reviewed; seventy-two of these had connection to the grid and 4 of the remaining 10 were provided with the solar powered *Lab-in-a-Box*. Several challenges were encountered ranging from equipment theft (1 school) and interveners replacing the computer OS resulting in erasure of the drive (several schools) to staff turnover. The latter is the biggest challenge as staff trained on the systems are replaced every two years at most schools; several schools failed to train replacements. Dramatic results were realized in one district, Birim North, which moved from the lowest performing school in the region and 117th in the country prior to the intervention to 1st in the region and 17th in the country over two years following the intervention. The results demonstrate the need for commitments of the district as well as the individual schools.

Keywords: rural education, low power it lab, low power science lab

Cite This Article: Stephen Mecca, Megan Skrypek, Elizabeth Degaray, Brittany Mandeville, Nicole Boyd, Michelle Feely, Jack Ricci, Delina Auciello, and Kerry McIntyr, "The S-Lab's *Lab in a Box*: A Potential Game Changer for Rural Schools in the Developing World." *American Journal of Educational Research*, vol. 3, no. 11 (2015): 1402-1410. doi: 10.12691/education-3-11-9.

1. Introduction

The S-Lab (as it is known) has been operating in its current state for over a decade in the Department of Engineering-Physics-Systems at Providence College creating and managing meaningful research experiences for many students both in the sciences and in other academic departments. When successful, the projects can impact schools, communities and families in the developing world. This paper highlights one such effort, the S-Lab's *Lab in a Box*, which features a computer lab for internet- and often electricity deprived- schools. We begin by focusing on the context of the problem in developing rural communities; we trace the development of the S-Lab's solution as it has unfolded with the advancement of appropriate technology. The hardware components and educational content are described and the application of same to prototype systems in rural schools in Ghana are presented. Recent extensions of the technology to science lab applications are outlined. Finally,

assessment of the interventions to date are reviewed. Both challenges and positive demonstrated outcomes are discussed.

2. The Problem

For many years, a common conversation in Twi with head teachers in Ghana would be: 'Me sukuu wɔ daabi buukuu, daabi bobɔ, daabi anyinam, daabi kita tiefi ho, daabi samina na ketewa nsu.' My school has no books, no computers, no electricity, no clean toilets, no soap and little water. Imagine heading or teaching at such a school. The only physical resource is the school room and a very old, well worn scratched blackboard on which teachers write to a crowded room of students that meticulously copy every word for regurgitation on a future test. Teaching is uneven at best with some dedicated professionals struggling to make the learning experience more than a rote exercise and others going through the chalk to notebook routine brought on by years and generations of resource deprivation, under-preparation or both.

The literature is rich on the underlying problems of education in the developing world. Since its Millennium Resolution in September of 2000 [1], the United Nations has steadily brought attention to the issue in both global action planning [2] and in its Education for All campaign [3]. In her paper on international rural education policy [4], Bonnie Stelmach organizes the challenges facing international rural education into themes: out-migration, gender inequity, poverty, declining enrollment' she cites poor outfitting and understaffing and the reinforcing impacts of same as underpinnings [5]. The shortfalls in staffing and equipping of rural schools observed in the districts of Ghana where we have worked far exceeds the most basic levels Stelmach talks about.

With the initiative of the Global Sustainable Aid Project (GSAP) and help from partners including Providence College, Books for Africa and many Rotary Clubs, interventions of books with teacher and staff training were begun in 2010. To date over 200,000 books and hundreds of computers have been used to assist 158 community schools and libraries plus several colleges and universities. An average of 4-5 teachers and staff have been trained at each school in a program that includes the setup of a lending library with holdings under 1000 volumes. The used computers were refurbished with the help of students from Providence College and the University of Ghana, Radford University-College and Ashesi University in Ghana. Educational resources, known as the GSAP Portal

were installed on each system prior to setup at the recipient schools. The resources (discussed later in this paper) offered a way forward to address the problem of resource deprivation; but the lack of power or the intermittent condition of power were impediments to bringing these resources to such schools and the later condition quickly damages any computer interventions even when secure spaces are available.

3. The Lab in a Box

The S-Lab undertook this problem with an understanding that both financial and power budgets should be controlled and heavy replaceable components, such as batteries, should be available in local markets. What emerged was the Lab in a Box, shown in Figure 1.

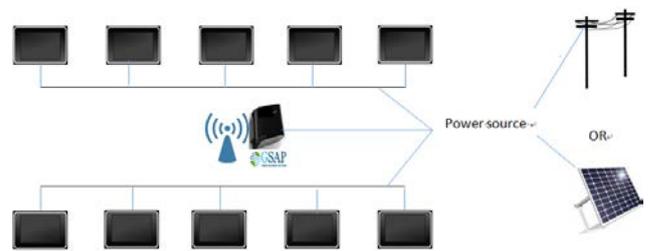


Figure 1. Current configuration of the Lab in a Box

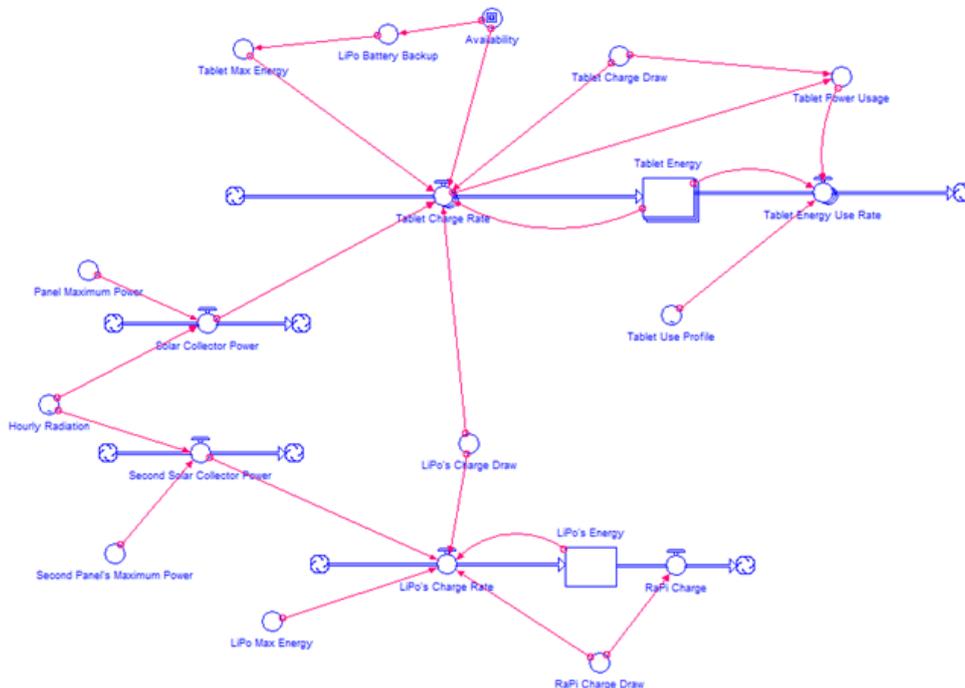


Figure 2. System dynamics of the energy-power model for the Lab in a Box

It includes a set of tablets (6-10), battery and solar charger (if grid power is not at all available) plus all necessary connections and voltage conversions. The original powering option for schools lacking connection to the grid consisted of a properly sized solar collector and 12 v auto lead-acid battery, a device available in markets serving every community. The remaining items can be shipped in a standard Fedex box though many of these components are beginning to appear in some local markets. The design variables for the system include the battery's

capacity and the peak power of the solar charger. These are impacted by the power draws of the tablets and the power conversions that are required going from 12v to the 5v required by the components. Further, the limited microSD card in each tablet has been replaced with the addition of either a Raspberry Pi A+ computer configured as a self booting wireless file server or a simple portable server for the GSAP educational portal. The Raspberry Pi, an innovative credit card sized computer, runs on less than 1 watt of power and the stand-alone file server on less

than 3 watts of power. The S-Lab has re-designed the power system to eliminate the 12v to 5v conversion and to make use of LiPo battery packs to replace the lead-acid battery component. The model used to choose the solar charger power and capacity of the LiPo for the server is depicted in Figure 2. It represents the time varying elements of the system and includes both local solar insolation rates as well as the school operating schedules.

The optimum design choice for the conditions of our prototypes for a 3w file server and the power draw of low cost 9” tablets (having 2000 to 3000 mAH LiPo batteries) is a 40w 5v solar charger and a 55,000 mAH LiPo battery (the capacity being driven somewhat by the best ‘bang for the buck’ in such batteries). The use of all 5v components has resulted in significant improvements in energy, costs, weight and size for the Lab in a Box. The performance of the system can be seen in Figure 3, which shows both the tablet LiPo’s and the server LiPo never going to zero over the course of 7 days, 5 two session school days plus continuous running of the local server.

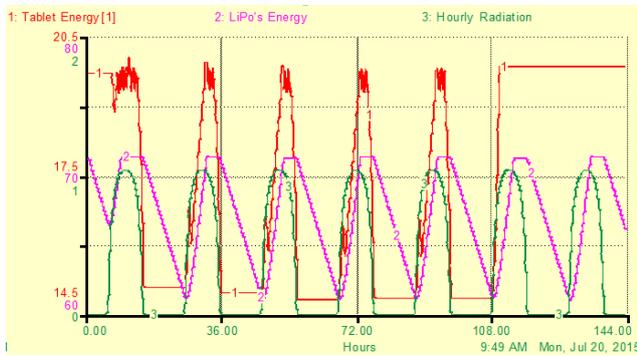


Figure 3. Tablet energy, LiPo energy and assumed hourly solar insolation for a typical two-session school day over the course of a week under optimum conditions for the Lab in a Box

4. The GSAP Portal

The most significant component of the Lab in a Box system is and has been the GSAP Portal, a rich set of off-line educational resources that includes the entire Rachel Initiative [6] and, in the most recent version, additional materials organized for primary and junior high school levels. An annotated view of the opening screen of the portal is shown in Figure 4.



Figure 4. The GSAP Portal is a rich set of off-line educational resources that includes the Rachel initiative and a number of sites organized by Primary and Junior High School levels

The portal is available on a USB drive and pre-configured on a MicroSD card for use in a Raspberry Pi or dedicated local file server. The Rachel Initiative includes:

- Wikipedia for Schools
- Khan Academy
- Health & Medicine
 - Medline Plus Medical Encyclopedia
 - Hesperian Health Guides
 - Healthcare & Medicine Videos
- K-12 Textbooks
- World Literature Books
- OLPC Educational Materials
- UNESCO’s International Institute for Capacity Building in Africa
- Math Expression
- Power Typing
- Music Theory
- School WASH Resources
- MIT Scratch.

The elements of the portal run on a browser and, while virtually all of the components can run on any client including PCs running Windows or Linux, MACs, tablets and smartphones, a few files will not function on certain devices; for example, MIT Scratch, software that teaches young children the logic elements of programming, does not function on an Android tablet.

The Primary, Junior High School and GSAP sections of the Portal are shown in Figure 5 through Figure 7.



Figure 5. Primary grade components of the GSAP Portal



Figure 6. Junior High School components of the GSAP Portal



Figure 7. Additional resources of the GSAP Portal

Many of the components of the Portal can be found online [7-30]. Permissions were sought and received for those sites that required such authorization. GSAP’s training resources and guides for the Lab in a Box are also part of the Portal.

5. Link to Curriculum

While the Portal was developed to address an absence of educational materials for teaching-learning and since the focus of the prototype was on Ghana, it was decided that we attempt to map each component of the Portal to the Ghana curriculum [31]. This was done with an eye toward assisting teachers in their use of the Portal. The authors are cognizant of a relatively recent conference that addressed the challenges of education in Ghana in the present century [32]. The themes of the papers in this work range from the need for a more indigenous education to the reality of Africa in a global society. We believe the Portal offers resources supporting the more universal needs in education; yet, we believe that more material is needed to support traditional indigenous values and to reflect local life and culture. Yet, especially in math and science, the Portal resources would appear to be universally applicable. In this regard, the effort to map the elements of the Portal to the elements of the Ghana curriculum seemed to be justified. A small segment of the mapping is shown in Table 1.

Table 1. Primary grade components of the GSAP Portal

	draw and/or colour objects/shapes	construct or model objects/shapes	copy and continue patterns made with objects and talk about them	sort out objects into groups according to identifiable attributes such as colour, shape, size, length etc.	match the objects in two groups and tell which group has less or more objects	arrange objects in order using length, area, capacity and weight
Math						
Worksheets 4 Kids						
Kids Corner						
Basic			✓		✓	
Pre-Algebra						
Algebra						
Geometry	✓	✓	✓	✓	✓	
Trigonometry						
Statistics						
How To Solve Math Test						
Grades						
Preschool						
Kindergarten						
Grade 1	✓	✓	✓	✓	✓	✓

Our efforts in this mapping indicate that the resources of the portal are indeed rich and closely support much of the Ghana curriculum in mathematics, science and social studies particularly. Going forward, these maps will be part of the resource set accompanying the Lab in a Box and GSAP Portal.

An effort is underway in the S-Lab to prepare both Spanish and French versions of the GSAP Portal.

6. Science Lab and Lab in a Box

Resource-deprived schools lack other things important in the teaching-learning process; they lack science labs – not just the physical laboratory but also the physical materials to effect hands on learning so important in teaching science. There are no instruments, components, supplies and laboratory apparatus that we often take for granted in the western world. Yet, the presence of the tablets in the Lab in a Box suggests that we have the start of a science lab extension. Thus, a major undertaking was extending the system to bring science activities, demonstrations and experiments to the schools using

available (Android) tablet sensors and instrument-analysis- reference- and simulation- APPs. Not all the desired instruments for a basic lab rest on the tablet so, with help from undergraduate research grants from Providence College and the Bauder Fund of the AAPT, we extended the *Lab-in-a-Box* resources with selected instruments and components to complement what is already available through the Android APP community and the portal. The concept is depicted in Figure 8.

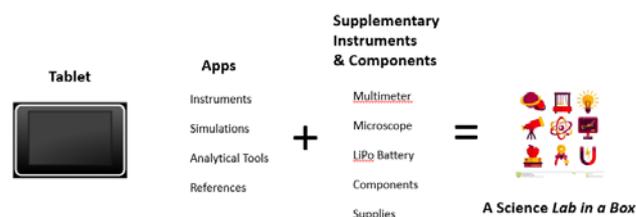


Figure 8. The tablet’s resources added to complimentary APPs and supplementary instruments extend the utility of the Lab in a Box as a Science Lab

Some of the APPs are shown in the sequence in Figure 9.

The choice of supplementary instruments to be added to the Lab in a Box Science Lab impacts the budget. Again, we have attempted to define a set of supplementary instruments that fit the rural context of the system. Table 2 shows the components that have been added and the price of each. The total is \$71, which for a 10 station lab would be \$710, affordable for a high school where tuition fees are collected but not so for public schools in rural communities. Yet, even one kit would suffice for demonstration activities,

Table 2. Supplementary items for the science extension of Lab in a Box and their cost

Items	Cost
Multimeter	\$ 5
LiPo Battery Pack	\$ 38
60x Microscope	\$ 5
Stapler	\$ 3
Components: Capacitors, Thermistors, USB to Alligator Cable, Alligator-terminated cables, Magnets	\$ 15
Supplies: #2 Pencil, Straw, Staples, Tape, Glue, Scrap File Folders, Wire, Foil	\$ 5
Total	\$ 71

What kinds of experiments and demonstration activities can be performed with the Science Lab? A small sample of a growing list of experiments includes:

- Motion experiments from exercises exploring the fundamental definitions of velocity and acceleration to constant acceleration using a homemade cart, e.g. motion of a cart rolling down a plane, cyclic motion,

real motions using the tablet’s accelerometer or video analysis of motion, e.g. collisions using the Easy Slow Motion APP, marbles and the tablet’s camera.

- Ohm’s Law and analysis of resistors (made with a pencil and index card stock) in parallel and series and basic circuits
- The 60x microscope allows the exploration and measurement of small things in the environment and opens the door to identification experiments in the Life Sciences:
 - Ant identification
 - Fabric weave analysis
 - Leaf/grass comparisons
 - Fingerprint discovery

The S-Lab has begun to compile a set of lab exercise sheets. The title headings of some are shown in Figure 10.

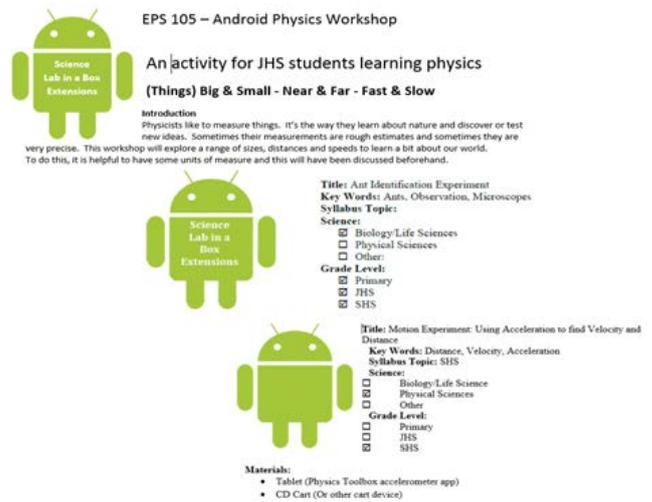
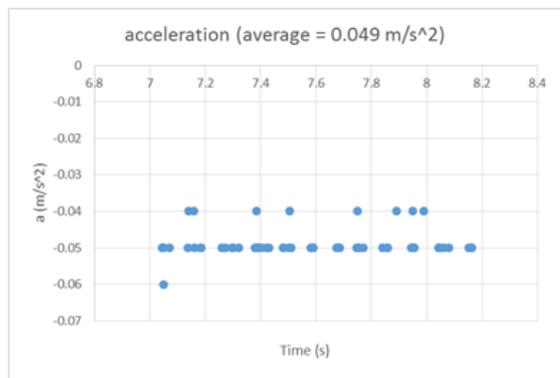


Figure 10. A few of the many experiments/activities for the Science Lab

Time	a	-a	v	ψ
7.044	-0.05	0.05	0	0
7.046	-0.05	0.05	0.0001	1E-07
7.048	-0.05	0.05	0.0002	4E-07
7.049	-0.05	0.05	0.00025	6.25E-07
7.051	-0.06	0.06	0.00036	1.24E-06
7.072	-0.05	0.05	0.001515	2.09E-05
7.137	-0.05	0.05	0.004765	0.000225
7.14	-0.04	0.04	0.0049	0.00024
7.159	-0.04	0.04	0.00566	0.00034
7.162	-0.05	0.05	0.005795	0.000357
7.184	-0.05	0.05	0.006895	0.000497
7.185	-0.05	0.05	0.006945	0.000504
7.261	-0.05	0.05	0.010745	0.001176
7.274	-0.05	0.05	0.011395	0.00132
7.296	-0.05	0.05	0.012495	0.001582
7.301	-0.05	0.05	0.012745	0.001646
7.322	-0.05	0.05	0.013795	0.001924
7.38	-0.05	0.05	0.016695	0.002808
7.383	-0.05	0.05	0.016845	0.002859
7.386	-0.04	0.04	0.01698	0.002909
7.388	-0.05	0.05	0.01707	0.002944

Figure 11. Acceleration data for a homemade simple cart rolling down an inclined plane

The quality of data from the tablet and supplementary instruments is quite good as can be seen in the following two experiments. The first, shown in Figure 11, is acceleration data taken with the tablet affixed to a homemade cart rolling down a slightly inclined plane. The negative accelerations in column 2 (due to the tablet



accelerometer orientation) have been made positive in the analysis.

The subsequent columns in the table in Figure 11 are the results of the usual numerical calculations of velocity from acceleration and displacement from velocity. These are plotted in Figure 12, where one observes the

consistency in the acceleration parameters gleaned from fits made in the plots.

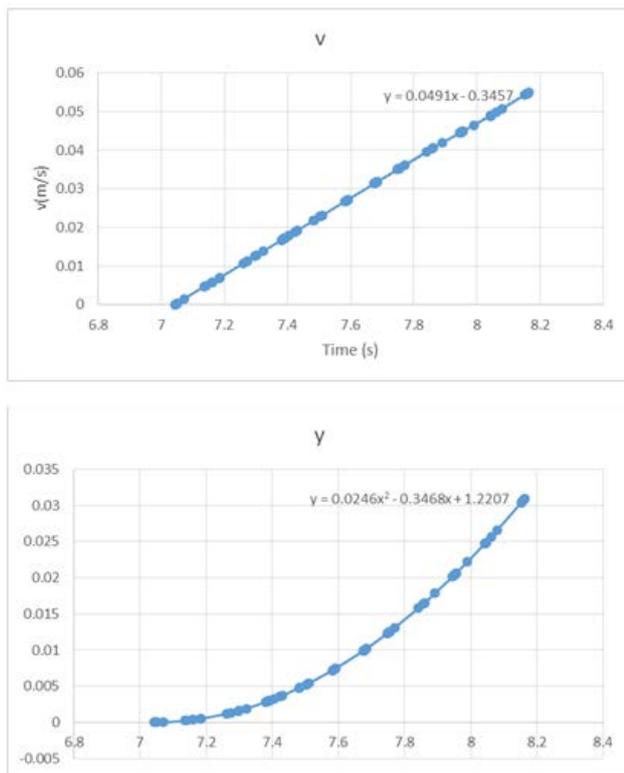


Figure 12. Trend lines for the velocity and displacement results of the motion of a homemade simple cart down an inclined plane

Consider a simple experiment to demonstrate Ohm's law. The resistors are made by densely scribbling a #2 pencil on index cards; the multimeter is used to measure the resistance, R , and current, I , when the 5.29 V LiPo battery is applied across the resistors. Figure 13 shows I vs $1/R$. The slope of the theoretical (assuming the relationship is $I = V/R$) and experimental lines shows remarkable agreement

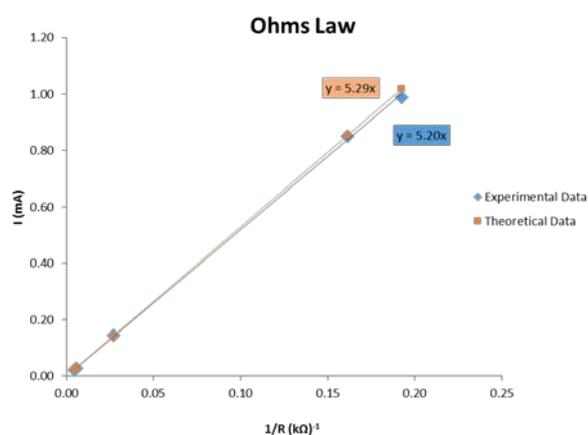


Figure 13. An Ohm's Law experiment using a LiPo battery as a 5.29 V power supply, homemade resistors and the multimeter in the Science Lab in a Box

7. Results to Date and Conclusions

Of the 158 recipient schools receiving books, computers and/or Lab in a Box interventions, we reviewed the last 82 of these (those from the last 3 years in 4

Districts – Ga West, 2 Districts in the Eastern Region and a District in the Ashanti Region) closely. Seventy-two of these schools had a connection to the grid and had a cumulative enrollment of 33,755 students. Of the remaining 10 without power, Lab in a Box interventions with solar power were made in 4 schools plus the GSAP training center. The others lacked sufficient security for the intervention.

While many schools are making good use of the interventions, some exceeding our expectations, we tended to focus on the schools where the interventions appeared to be falling short of our expectations. Our observations were as follows:

1. Approximately half of the schools have blown away the portal as a result of someone (an expert!!!) coming to the school and installing a stolen license to Windows negating ~20 hours of our setup work. We had used Ubuntu, an open source OS.
2. There is turnover in staff. Many of the staff we trained had been reassigned to another school and not trained their replacements. Early visits to schools demonstrated that recently trained staff were well underway with implementing both library reading and lending programs as well as use of the GSAP Portal in relevant subjects. Yet, some of those same schools two years out had allowed these programs to drop when a trained staff member left. The teachers we trained at these schools were moved to other schools and never trained those who did not attend the original program training. The movement of teachers every two years is common practice and needs to be considered in the training and school-qualifying process. Securing a stronger commitment and expectation at the school will help assure continuity by training new teachers
3. Some schools have inadequate storage (shelving) for books to the extent that students have to rummage through cartons and piles to find a particular book. Some schools insist on a very restrictive lending policy and protection of books in spite of training to the contrary.
4. Schools repeatedly said that a small LED projector would enhance the things they could do with the donated technology. Inexpensive small 12 v models were tested in the S-Lab against a wall mounted flat screen monitor and the latter proved far superior for the conditions found in most rural schools.
5. Some schools lack power (and everything else). As mentioned earlier, we piloted 4 off-grid schools with these systems. One is making excellent use of the technology even offering literacy programs after school to the mothers of the students. Two others are making good use of the technology and the GSAP Portal in multiple subjects. Sadly, in one school, of the 6 donated tablets, we found one with a broken screen (understandable-such things can happen, another tablet with a smashed case (not understandable), another uncharged and not connected to the solar charging system and three tablets that had been taken home (by teachers according to some staff). It should be noted that in many of the schools visited during our follow-up, it was found that PCs had failed at a much higher rate (nearly 50% in the schools sampled) than the tablet failure rate (2 in 30). The failures

usually followed power interruptions while computers were in use. Because the tablets are generally running from batteries (in both off-grid and on-grid situations, there is some protection from the effects of sudden loss of power.

The portability of the tablet makes them more vulnerable to theft. Recently, 151 tablets – part of Lab in a Box interventions – were delivered and installed at 8 schools in Tamale and Techiman as part of Rotary Global Grants. The turnover of the donation was widely publicized in the press and TV media. On the first night after taking possession, one of the schools was broken into and their tablets stolen. Such challenges are part of the process of realizing potential game changers in developing countries. We focus on these challenges to devise ways to overcome them.

At the same time, the positive results need to be recognized.

GSAP, which has been a contributing partner with the S-Lab in this project, continues to work to improve the effectiveness of its interventions in the teaching-learning of schools and on improvement of literacy rates among students. It has concluded that the commitment of school administration, PTA and teachers are vital. Yet, for many schools – indeed the neediest - the commitment is verbal and not always observed in action. When the commitment is put into action, one gets ‘model’ results.

In Ga West for example, the Mayflower School’s commitment to student learning is obvious even when there is teacher or staff turnover. We observed there an effective library lending policy where students were borrowing an average of 30+ books per term and where it was easy to see the fraction of books on loan at any time and the student lending rates and patterns. The GSAP Portal was operating on every donated computer with Math, Social Studies and Science teachers bringing their classes to the lab according to a schedule that made excellent use of the donated computers.

Commitment can help assure long term results. In Birim North in the Eastern Region for example, 5 years ago GSAP found the district to be the lowest performing district in the region and 117th in the country as a whole. Schools had no spaces for a library or computers and were sharing small local libraries which also had few holdings (40-50 books each). GSAP donated over 2000 books to 5 community libraries each being shared by 5-6 nearby schools. At the same time a new Minister of Education, Mr. Atacra, was appointed. Realizing the availability of books and the terrible state of his district’s school system, he mandated that each school would open 30 minutes early and close 30 minutes late each day and that during the morning period, every student should be reading a book – it didn’t matter the subject- and during the last 30 minutes of the day the same – each student should be reading or writing. He spends little time in his office instead visiting 2-3 schools each day to assure compliance and sacking teachers who repeatedly don’t comply. Now fast forward to 2014 when it was announced that Birim North schools moved from last place in the Eastern Region to first place and from 117th in the nation to 17th! The lesson is that books and computers matter, but commitment to change and use of these interventions is even more important. Recent grants have allowed us to expand our interventions with more books last year and

the GSAP Portal deployed on district computers. This year, Birim North is still in first place in the region and has moved up to second in the country!

Pre-intervention test scores in relevant subjects were taken from a random sample of schools; at the conclusion of a full 3-year cycles, we will acquire similar data from these schools while reckoning other interventions that may have taken place.

Acknowledgement

The authors express their gratitude to web site authors for use of their on-line sites in the off-line portal, to GSAP for deploying the Lab in a Box and Portal to recipient schools, to the teachers and head teachers of those schools and to donors who have contributed funds for the purchase of the Lab in a Box and/or for the initial resources that led to the present system especially the Rotary Clubs of Accra Airport, Old Saybrook CT, Henniker NH and Jamestown, RI. Global Grants spearheaded by Walter Hughes and his Rotary Colleagues and Clubs and The Rotary Foundation. The Bauder Fund of the American Association of Physics Teachers is acknowledged for their support in developing the science extensions for the Lab in a Box. Finally, the authors thank Providence College for their support of student research that contributed so significantly to the project.

References

- [1] United Nations. (2000, September). Resolution 55/2. Available from: <http://www.un.org/millennium/declaration/ares552e.htm>
- [2] United Nations. (2007). Education for All. Global action plan: Improving support to countries in achieving the EFA Goals. Available from: http://portal.unesco.org/education/en/ev.phpURL_ID=47377&URL_DO=DO_TOPIC&URL_SECTION=201.html United Nations. (2010).
- [3] Education for All global monitoring report: Reaching the marginalized. Available from <http://unesdoc.unesco.org/images/0018/001866/186606E.pdf> United Nations. (2010).
- [4] Stelmach, B., A Synthesis of International Rural Education Issues and Responses, *Rural Educator* 32(2), pages 32-42, Winter 2011.
- [5] Frisby, C.L., and Reynolds, C.R., *Comprehensive Handbook of multicultural social psychology*. John Wiley & Sons, Hoboken, NJ, 2005.
- [6] The Rachel Initiative, Available from: <http://worldpossible.org/rachel/>.
- [7] MightyBook, Available from: www.mightybook.com/index.html.
- [8] Kizclub, Available From: www.kizclub.com.
- [9] E-Learning for Kids, Available from: <http://www.e-learningforkids.org>.
- [10] Free Kids Books, Available from: <https://freekidsbooks.org>.
- [11] PBS Learning Media, Available from: <http://www.pbslearningmedia.org>.
- [12] Clarkness, Available from: <http://www.clarkness.com>.
- [13] Reading Hawk, Available from: http://www.readinghawk.com/Reading_Hawk/Welcome.html.
- [14] Math Worksheets 4 Kids, Available from: <http://www.mathworksheets4kids.com/index.html>.
- [15] Kidipede, Available from: <http://www.historyforkids.org>.
- [16] Astronomy Picture of the Day, Available from: apod.nasa.gov/apod/archivepix.html.
- [17] Western Cape Primary Science Program, Available from: <http://www.psp.org.za/materials/psp-materials-for-download>.
- [18] Stickyball, Available from: <http://stickyball.net>.
- [19] Science Kids, Available from: www.sciencekids.co.nz/index.html.

- [20] Fun English Games, Available from: www.funenglishgames.com/index.html.
- [21] Kids Math Games Online, Available from: www.kidsmathgamesonline.com/index.html.
- [22] Science with Mr. Jones, Available from: <http://www.sciencewithmrjones.com>.
- [23] World of Teaching, Available from: www.worldofteaching.com/index.html.
- [24] Science-Class, Available from: www.science-class.net/index.html.
- [25] Saasta, Available from: <http://www.saasta.ac.za>.
- [26] Fiction.us, Available from: www.fiction.us/index.html.
- [27] Free World Maps, Available from: www.freeworldmaps.net/index.html.
- [28] Arvindgupta, Available from: www.arvindguptatoys.com/index.html.
- [29] Environmental Education Activities for Primary Schools, International Centre for Conservation Education for UNESCO-UNEP International Environmental Education Programme (IEEP), undated.
- [30] Upper Primary Science My Natural Environment, The Southern African Development Community (SADC), 2001.
- [31] Teaching Syllabus for Mathematics, Social Studies (JHS 1,2,3), Mathematics (Primary 1-6), Citizenship Education (Primary 4-6), Natural Science Primary 1-3), Integrated Science (Primary 4-6), Republic of Ghana, Ministry of education, Science and Sports, Accra, September 2007.
- [32] Challenges of Education in Ghana in the 21st Century, Amenumey, D.E.K., editor, Woeli Publishing Services, Accra 2007.