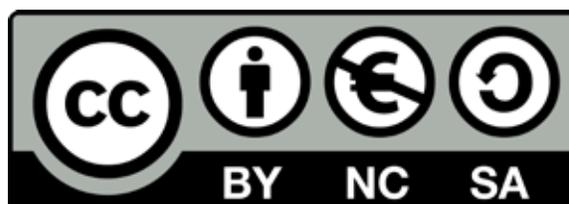


WORLDREADER DEVICE DURABILITY REPORT 2016



ACKNOWLEDGMENTS

This report was authored by Worldreader Global Insights, Rachel Heavner and Zev Lowe with significant contributions from Ryan Lew. We would like to thank Beatrice Ani-Asamoah, Wanjiku Gathoni, Ivan Koomson and Laura Ross-Perry for their contributions and assistance with data collection and analysis.



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ABSTRACT

With the goal of measuring the durability of e-reader devices and determining the cause of device failures in their digital reading programs, Worldreader conducted a survey of their projects in March 2016. They received 34 responses representing 29% of the 141 projects that were active between Q1 2012 and end of Q3 2015, and reporting on 5,575 (41%) of the 13,448 devices that were deployed during the same time period. Over that 3.5-year period, 3.6% of those devices were reported as broken or defective.

This report shows that the new e-reader models that Worldreader has been deploying over the past 3+ years stand up to hard use, with yearly breakage rates under 3% per year across projects. The deployment model was shown to be the biggest predictor of device breakage with the shared classroom model (where 3 to 10 students share each device during class time) showing instances of breakage between 1% and 10% greater than the individual model or library models. Given the analysis outlined in this report, Worldreader can predict a yearly device breakage range of 0.2% to 2% for each active project over the next 3 years for projects utilizing the more robust 2012-era Kindle Paperwhite and 2014-era Kindle 7 devices.

INTRODUCTION

Over the past 5 years Worldreader has experienced exponential growth in its e-reading programs starting with a reach of 10,000 school and library readers in 2012 to over 100,000 in early 2016. As Worldreader continues to grow and evolve as an organization, we are committed to ensuring the continued use of the ever-increasing number of digital devices and books we have placed in schools and libraries. As a part of our Partner Care and Sustainability Initiative, Worldreader surveyed 141 of our projects on the topic of "broken e-reader devices." The goal was to measure the durability of Worldreader devices in the field and understand how many of our currently deployed e-reader devices are broken, how they were broken, if device type affects breakage rate, and to estimate our year-by-year anticipated breakage rate.

The results demonstrate no clear linear trend in terms of time devices have been deployed in the field. This indicates that the majority of problems are due to physical damage rather than issues that develop due to wear with device age. **The data shows that a large majority of devices deployed since 2012 are still functional with a predicted yearly device breakage range of 0.2% to 2% for each active project over the next 3 years.** The evidence in this report thus shows that the e-reading devices are highly durable, demonstrating great promise for the sustainability of e-reading programs in Sub-Saharan Africa.

METHODOLOGY

In March 2016, Worldreader rolled out surveys to all 141 of its projects that had been active since 2012. We incentivized partners to take the survey by promising a chance to win 20 free e-books for any project that participated in the survey. There was a 31% response rate with 42 project responses. We cleaned the data to remove projects that were deployed in the last 6 months so as not to skew the breakage rate with newly deployed devices that showed very low to non-existent breakage. That brought the sample to 26% of projects (34 of 133 projects), representing a total of 5,575 devices deployed, 41% of the 13,448 devices deployed during that time.

After performing a statistical analysis to ensure the sample was predictive, we performed a qualitative analysis to code responses on what was causing device breakage. More in depth data was collected during Worldreader's 2016 Digital Reading Summit. Program partners attending the Summits were asked to bring their broken or faulty devices to a Help Desk where the devices were checked in and assessed by Worldreader team members. This process allowed for the collection of more detailed data on the kind of damage the devices sustained and how many of the problems the help desk was able to fix.



LIMITATIONS

Since this survey was conducted using an online survey platform and not through direct observations by Worldreader staff, the data is self-reported and subject to discrepancies. For example, it is difficult to assess the causes and level of breakage reported. Many of those who responded to the survey didn't give specifics on how the devices broke and some of the issues that were reported from the field may have been repairable with a proper charge and hard restart¹. Furthermore, the level of use each device has undergone has not been included as a factor since that level of data would require a much more in depth monitoring process. Finally, while direct observational data from Worldreader staff upholds these breakage estimates, there is some concern that those who were able to respond to an online questionnaire have higher levels of connectivity and perhaps lower instances of breakage than some of the less connected Project Managers. Nonetheless, the data sample is strong enough to show that a majority of Worldreader devices are highly durable and will continue to function with regular usage for years to come.

RESULTS

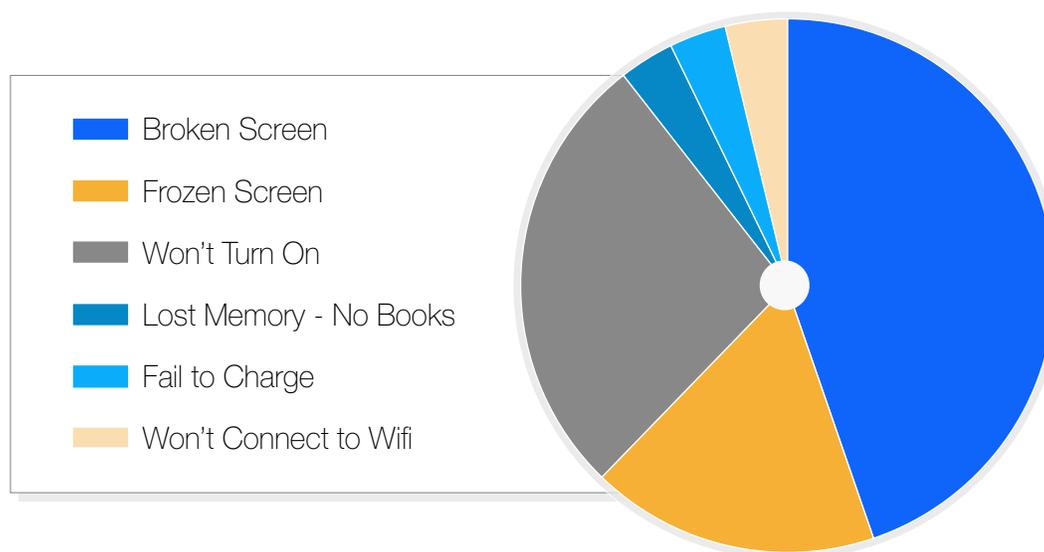
Overall the results showed low instances of breakage with much higher breakage rates among older device models. A total of 6,970 devices have been deployed to the 42 project sites from 2012 to date. Out of these 6,970 devices, 208 devices (3%) were reported to be broken or defective. Since there was under a 1% breakage rate reported for devices deployed in Q4 2015, we removed these from our sample to look more closely at devices that had been in the field for a minimum of 6 months.

Responses came from nine of the fourteen Countries where we are implementing e-reading programs. These include Ghana, Kenya, Sierra Leone, South Africa, Uganda, Tanzania, Malawi, Nigeria and Rwanda. We received 35 responses, representing 29% of our active projects between Q1 2012 and end of Q3 2015. The sample represents 5,575 (41%) of the 13,448 devices deployed during that time period with projects ranging from 6 months of deployment to 4 years. Results showed a 3.6% breakage rate overall, however when you remove the two devices we are no longer deploying from this sample – the 2010-era Kindle Keyboard model and 2011-era Kindle 4 model – the breakage rate falls to 1.1%. Using the adjusted Wald method² we calculated a predictability margin of error of just 0.5% for the total sample and 0.3% for the sample of newer devices (the Kindle Paperwhites and Kindle 7s). **These low margins of error demonstrate that the sample is accurately predictive of 96 - 99% of devices remaining durable over the next three years of Worldreader programming.**

¹ A hard restart involves pressing and holding the Power button of a Kindle device for a full 40 seconds then releasing, at which point the charge indicator light should turn on after a few seconds.

² The adjusted Wald method (also called the modified Wald interval), is a formula that calculates a confidence interval that will contain the average observed proportion of a data sample about 95 percent of the time (Sauro, J., 2005, see <http://www.measuringu.com/wald.htm>)

FIGURE I: Frequency of Different Issues



The causes of the breakage varied, with the most common problem being broken screens with some instances of frozen screens and the devices not turning on. Figure I shows a breakdown of the various problems reported in the surveys and observed at the Summit Help Desk.

When looking at the breakage rate by years of device deployment there was a much larger percentage of devices broken for projects that have been active for four years (see Table I), however this was the period when the 2010-era Kindle Keyboard model and 2011-era Kindle 4 model were being deployed. As seen in Table II, when the two devices are removed from the sample, the percentage of broken devices for 3-year active projects drops to 0³ with a maximum breakage rate of 2.4% for projects that have been active for two years and an average breakage rate of 1.1%.

We calculated a standard deviation of 0.9% year to year for the Kindle Paperwhites and Kindle 7s, thus can predict a yearly breakage rate range of 0.2% to 2% for each active project over the next 3 years (since we are no longer deploying the 2010-era Kindle Keyboard and 2011-era Kindle 4).

³ The sample of three-year active projects using the 2012-era Kindle Paperwhites and 2014-era Kindle 7s is notably small. There are likely to be higher breakage rates with larger samples of devices, but no evidence suggests it should be much higher than 3%.

TABLE I: Breakage rates by length of project activity

ACTIVE YEARS OF PROJECT	SUM OF # BROKEN DEVICES	SUM OF TOTAL # OF DEVICES	% OF DEVICES BROKEN
0.5	11	2910	0.4%
1.0	23	935	0.4%
2.0	96	1270	2.5%
3.0	65	410	7.6%
4.0	3	50	15.9%
GRAND TOTAL	198	5575	3.6%

TABLE II: Breakage rates by length of project activity without the Keyboards and 4s

ACTIVE YEARS OF PROJECT	SUM OF # BROKEN DEVICES	SUM OF TOTAL # OF DEVICES	% OF DEVICES BROKEN
0.5	10	2860	0.3%
1.0	17	810	2.1%
2.0	22	920	2.4%
3.0	0	20	0.0%
GRAND TOTAL	49	4610	1.1%

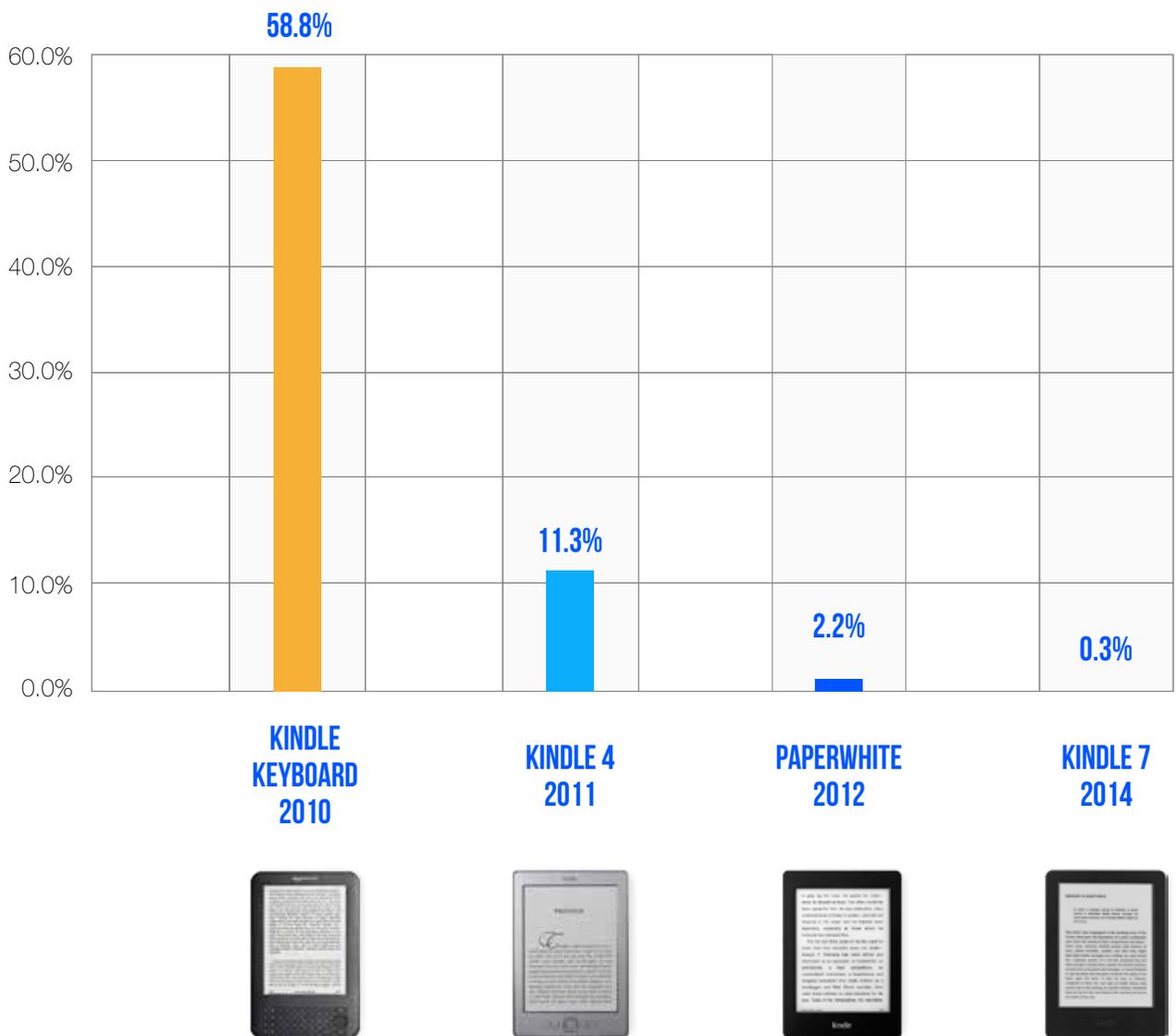
DEVICES

To date, Worldreader has deployed four different types of e-readers in the field at a large scale: The Kindle 4 (2011), Kindle 7 (2014), Kindle Keyboard (2010), and Kindle Paperwhite (2012). As outlined in Table III, data shows the lowest breakage rates among the Kindle 7s with the Kindle Paperwhite as a close second. The earlier versions of the Kindles, the Keyboard (2010) and 4 (2011), did not use touch screen technology and thus relied on a built-in keyboard in order to navigate the device. The Kindle Keyboards show the highest breakage rate at 58.8% because they had 'floating screens' that opened and were easily broken. Worldreader worked with Amazon to add adhesive to make the screen stick better, but ultimately have stopped deploying these devices due to the high instance of screen breakage. The Kindle 4 was a similar model to the Kindle Keyboard with a smaller screen that had a lot of moving parts including buttons along the bottom and an adhesive screen. These devices have thus also been discontinued in favor of the much sturdier and more reliable 2014-era Kindle 7 and 2012-era Kindle Paperwhite. The newer devices use one button and a touch screen, thus they have far less moving parts and demonstrate a lower rate of damage.

TABLE III: Breakage rates by device

DEVICE	YEAR OF RELEASE	SUM OF # BROKEN DEVICES	SUM OF TOTAL # OF DEVICES	% OF DEVICES BROKEN
Kindle Keyboard	2010	50	85	58.8%
Kindle 4	2011	99	880	11.3%
Paperwhite	2012	39	1750	2.2%
Kindle 7	2014	10	2860	0.3%
TOTAL		198	5575	3.6%

FIGURE II: Percentage Reported Broken by Device



DEPLOYMENT MODELS

While analyzing the data, we hypothesized that shared device models might have an effect on breakage rate as well. Worldreader partners use a variety of deployment models depending on how and where the e-readers are being used. These include:

- A **Classroom model** in which 3 to 10 students share each device for use during class time.
- An **Individual model** in which each student in a classroom has their own device and often gets to take it home with them.
- A **School library model** in which the devices are shared among 8 or more students each and either circulated among classes or kept in a designated library space.
- A **Community library model** for our library programs in which devices are placed in community libraries and used by library patrons or taken out into communities by local librarians to engage communities around reading. An estimated 20 people utilize each of these devices, but with less frequency than the school programs.

FIGURE III: Breakage Rate by Deployment Model: Kindle 7 and Paperwhite Only

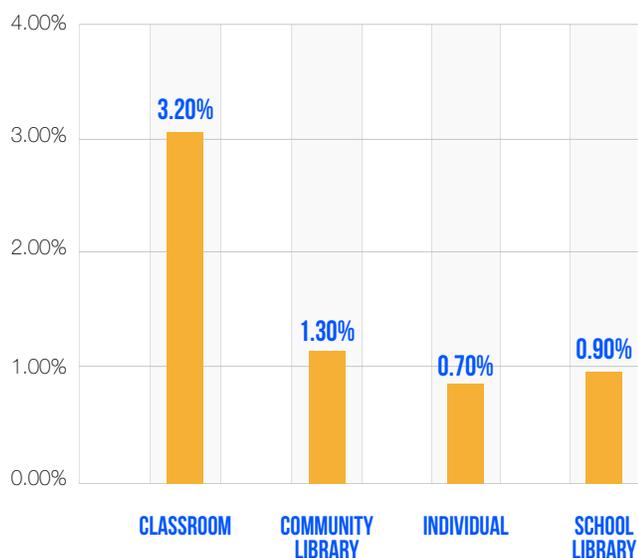
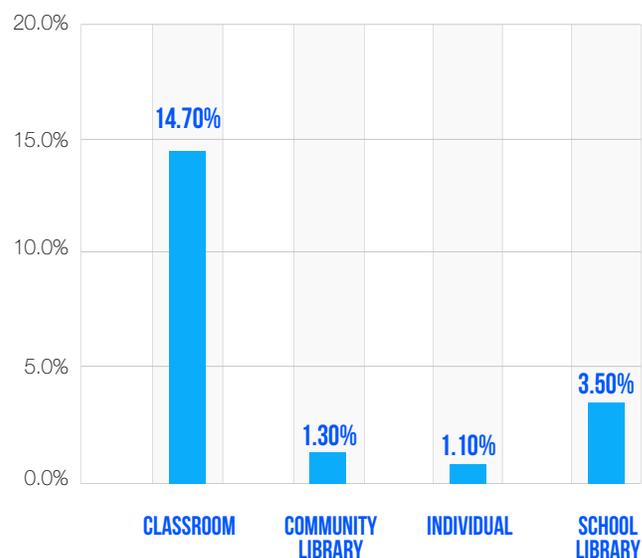


FIGURE IV: Breakage Rate by Deployment Model - All Devices



Given these models, it is not surprising that the data shows the highest breakage rates among classroom reading models since the devices are being used by multiple students with a high frequency of use. We have displayed the analysis of breakage rate by program model in Figure II for current devices only (the Paperwhite and 7) and Figure III for all devices. As you can see the findings consistently show the highest breakage rates among classroom models, with relatively low instances of breakage among the other three deployment models. Of note is that the Individual model shows the lowest breakage rate, something we have found anecdotally is that when a student or teacher is responsible for their own device they take much better care of it than if the device is shared and they cannot be directly held accountable for damage.

Spotlight: Pencils of Promise in Ghana

Worldreader's partnership with Pencils of Promise in Ghana represents one of the largest device deployments to date. The project uses an individual model where each student is given their own device loaded with 100 to 168 books each. To date Worldreader has deployed 3,200 Kindle 7 and Kindle Paperwhite e-readers to 28 Pencils of Promise schools in Ghana with an aggregate of 517,200 books. Recent device durability analysis shows that between the initial project launch in 2014 and November 2016, just 214 of those devices have come back to Worldreader for troubleshooting and of those 214, only 34 were not able to be repaired by Worldreader Operations staff in Ghana. The below table shows the issues associated with each of these 34 devices.

PROBLEM	KINDLE 7	KINDLE PAPERWHITE	UNSPECIFIED	GRAND TOTAL
Blank Screen		1		1
Broken Screen	3	6		9
Cracked Screen	3	8		11
Frozen Screen	4			4
Books Not Downloading		1		1
Not Charging	2	4		6
Not connecting to WiFi	1		1	2
GRAND TOTAL	13	20	1	34

On average the 20 malfunctioning Kindle Paperwhites had been in use for 694 days (roughly 2 years) and the 13 Kindle 7s had been in the field for an average of 319 days (just under 1 year). This sample shows that after 2 years of program implementation with children taking devices home and using them in their classrooms, 93% have demonstrated no problems or instances of breakage at all, and 99% of devices are still functional after minimal troubleshooting from trained Worldreader staff.

SUMMIT HELP DESK

While the Worldreader surveys were able to capture information on rate of breakage and general causes of broken devices, the surveys didn't capture whether a trained staff would be able to troubleshoot and fix the broken devices. However, at Worldreader's annual Digital Reading Summits in Ghana and Kenya in April, 2016, we piloted a Help Desk with the primary purpose of providing Kindle troubleshooting assistance to program partners. As established venues that annually attract Worldreader program managers, the Summits provided an opportunity for Worldreader to offer direct technical support without the added cost and complexity of deploying Worldreader staff or maintaining a reverse logistics network and allowed for the collection of preliminary data on how to scale and improve Worldreader's Partner Care and device support. As a supplementary objective, we encouraged partners to release "unrepairable" devices to Worldreader for recycling to raise awareness and reduce the e-waste footprint of our programs.



WORLDREADER'S E-WASTE RECYCLING INITIATIVE

In 2015 Worldreader began partnering with e-waste management company City Waste Recycling, a reputable e-waste management company in Ghana's capital. City Waste Recycling began operations with recycling plants in Ghana in 1999 and expanded with an e-waste recycling pilot plant in 2010. They maintain an active role in the community with over 500 employees, many of whom are women. The company dismantles the devices and transfers the metal parts to a government facility for processing and recycle the plastics through City Waste Recycling's local melting process in Accra. The plastic melted will then eventually be turned into bottle caps, chairs, or other items, depending on their density and other physical properties.

Breakage issues for devices brought to the summit were included in the analysis above. As long as a faulty device did not have a broken screen, the Help Desk treated it as potentially fixable. Although we could not fix all such devices, 50% of faulty devices had broken screens and 50% of all devices brought to the Help Desk were worth further investigation. The Help Desk completed technical reviews for 105 of the 175 devices⁴ of which 71 had intact screens and were considered potentially repairable. Consistent with the Pencils of Promise data highlighted above, after completing our review, we resolved issues associated with 64 devices (90%) and returned these to partners to bring back into service.

We found that nearly half of all potentially repairable devices could be resolved by partners without requiring Worldreader's intervention, given proper training. Recharging and applying a hard restart resolved 24% of reviewed devices that did not have broken screens. Furthermore, these hard restarts resolved devices that were otherwise slated for hardware-based repairs. Another 25% of devices had issues related to content deletion or outdated Kindle software. Assuming they have access to WiFi, partners could potentially re-download content and update software on their own. We found that remote Worldreader support would have been required to resolve a further 18% of problems including devices that were de-registered or passcode locked.

Although there are other considerations, granting more partners access to Worldreader's book database under Tiered Administration⁵ could potentially allow them to resolve such cases independently. The remaining one third of devices assessed at the help desk required a hardware fix and Worldreader technicians were able to successfully repair 70% of these devices. Hardware parts were refurbished only after all other solutions were exhausted. All activities that required technicians to physically open a Kindle were associated exclusively with devices that were categorized as either having a frozen screen or charging problems. The fixes conducted included: hard restarts, re-downloading deleted books, software updates, passcode breaking, battery reboots, battery swaps, motherboard swaps and re-registrations for accidentally de-registered devices. See Appendix II for the detailed breakdown of the frequency of each fix.

One of the more successful components of the help desk was the ability to responsibly recycle broken devices. A majority of eligible partners (15 of 18) with unrepairable devices participated in the recycling program. We acquired 33 devices for recycling, which represented 35% of unrepairable devices that were brought to the summits. Program managers that chose not to participate cited uncertainty on whether they were authorized to release devices that were unrepairable.

⁴ Technical reviews for 88 devices were curtailed because they were brought to the help desk in the last three hours of the summit leaving insufficient time for analysis.

⁵ Tiered Administration is a feature that allows Worldreader to give partners tailored access to the book database system for things like re-registering devices that have been passcode locked.

RECOMMENDATIONS AND CONCLUSIONS

As Worldreader programs begin to grow and we assess the cost-effectiveness and impact of our various implementation models, these breakage results show great promise for the durability and sustainability of digital reading programs in the Global South. With an estimated breakage average in the 1% range for current devices in use, there is evidence that e-books are a durable solution in the sub-Saharan African geographies we serve. The devices show great promise for being utilized for five years or more with a possibility of continued book top-ups to keep devices up to speed with current curricula and supporting materials.

Although devices have proven to be highly durable, there is continued room for improvement in our Partner Care Initiatives to insure sustainability of Worldreader programs. Several issues were identified with the devices including devices that will not turn on, will not connect to Wi-Fi, have frozen and broken screens, and are failing to charge. We should continue to provide help desks and Wi-Fi access at our annual digital reading summit to support the troubleshooting of these issues, and build up our systems and trainings to better support partners to troubleshoot and fix their own devices and control their own content in the field.

In order to continue efforts to reduce e-waste as a result of Worldreader programs, some work needs to be done early on with our partners to get their permissions to safely recycle irreparable devices. It is worth exploring potential funding streams to support the e-waste recycling initiative and support the sustainability of Worldreader programs through on-going device repairs and replacements.

This research has helped Worldreader identify ways to improve its trainings and manuals to teach Project Managers the necessary skill to perform easy fixes such as the hard restart and charging of devices, re-downloading deleted content, and updating software by accessing Wi-Fi. Worldreader has already begun to implement some of these policies and will continue to innovate and improve our systems and products to support our on-going mission of a world where everyone is a reader.



APPENDICES

APPENDIX I: Worldreader E-Reader Survey

The following survey was sent out to Worldreader school and library partners via Survey Monkey in early 2016.

WORLDREADER E-READER BREAKAGE SURVEY

Worldreader cares deeply about supporting your e-reading program. We are conducting a survey across our programs in Africa to help us better understand more about devices that are broken. We are conducting this survey ONLY to help us improve your experience. Your answers will be kept confidential and will not have any negative impact on your e-reading program — they will only help to improve our offerings. Thank you in advance for your truthful feedback.

****Please submit this survey no later than Friday, March 18th, 2016****

Thank you for taking the time to answer this survey - you will be entered into a raffle to win 20 free e-books for every device you have!

- *1. What is the name of your school/library?

2. What is the name of your organization, or sponsoring organization?
(If not applicable, please leave blank.)

- *3. Do you have any broken devices? **Yes** **No** **Unsure (please explain)**

4. If you answered "Yes", how many devices are broken?

5. What are the issues for your broken devices? (please fill in as many as you have.)

*If you have more than 10 broken devices, please indicate this in the comment section at the end of the survey, and we will follow up with you for more information.

	Broken Screen	Won't Turn On	Other
Device 1	Device 1 Broken Screen	Device 1 Won't Turn On	Device 1 Other
Device 2	Device 2 Broken Screen	Device 2 Won't Turn On	Device 2 Other
Device 3	Device 3 Broken Screen	Device 3 Won't Turn On	Device 3 Other
Device 4	Device 4 Broken Screen	Device 4 Won't Turn On	Device 4 Other
Device 5	Device 5 Broken Screen	Device 5 Won't Turn On	Device 5 Other
Device 6	Device 6 Broken Screen	Device 6 Won't Turn On	Device 6 Other
Device 7	Device 7 Broken Screen	Device 7 Won't Turn On	Device 7 Other
Device 8	Device 8 Broken Screen	Device 8 Won't Turn On	Device 8 Other
Device 9	Device 9 Broken Screen	Device 9 Won't Turn On	Device 9 Other
Device 10	Device 10 Broken Screen	Device 10 Won't Turn On	Device 10 Other

If you responded "Other", please describe the issue.

6. Would you be interested in purchasing a low-cost replacement device? If yes, we will contact you for more information! **Yes** **No**

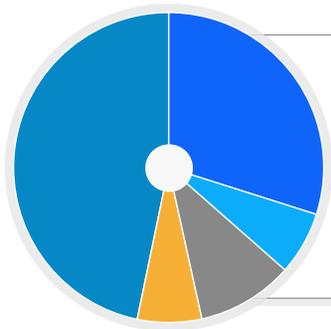
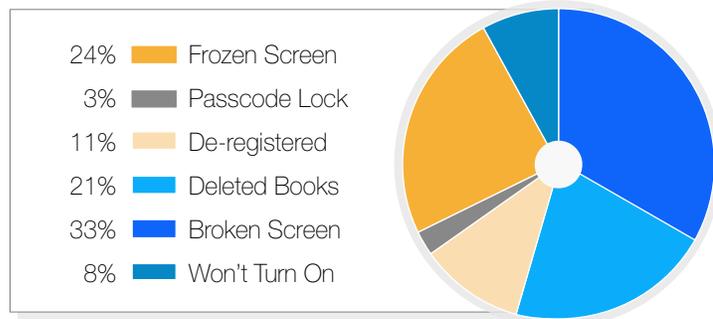
7. Is there anything else you would like to share with Worldreader about your devices, or your program?

8. If you would like to be entered into the free book raffle, please write your name and email address here. If you are selected, we will contact you via email in early March!

APPENDIX II: Analysis of Devices Reviewed at West Africa and East Africa Summits

West Africa Summit = 75 devices

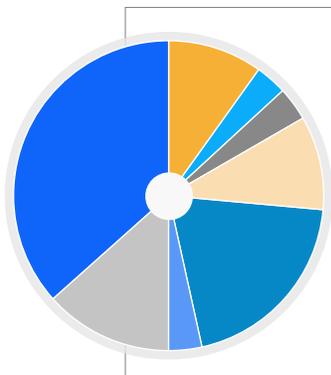
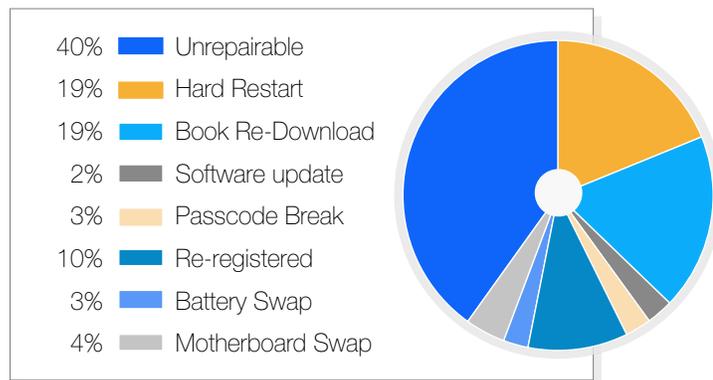
West Africa Summit Issues



East Africa Summit = 30 devices

East Africa Summit Issues

West Africa Summit Solutions



East Africa Summit Solutions