#### Braille Literacy and Tactile Learning: Developing Educational Materials for Students who are Blind or Low Vision

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Agency Background

Clovernook Center for the Blind & Visually Impaired was founded in 1903 by Georgia Trader and her sister Florence in the city of Cincinnati. Founders of the Cincinnati Library for the Blind in 1901, the sisters approached William Procter of Procter & Gamble with the idea of purchasing a home and its adjoining 30 acres of land, so that they could open a home for blind women. He agreed – and quickly, Clovernook became not just a home, but a place of employment. Initially opening a weave shop and selling crafts to the Cincinnati community, in 1914 Clovernook was gifted a printing press by a local benefactor – and thus became the first braille producer in North America to be primarily staffed by people who were blind or low vision. Today, over 50% of Clovernook’s staff in the Braille Printing House are blind or visually impaired. It remains a central part of Clovernook’s mission as a non-profit – to employ individuals who are blind or have low vision in the Cincinnati community, across all facets of the organization.

For as long as Clovernook has been a producer and distributor of braille materials, they have also been an international distributor, and approached braille as a global resource to be shared and disseminated. After receiving a printing press in 1914, one of Clovernook’s first printing projects was to emboss decks of playing cards and Christmas cards, which were sent to hospitals in the United Kingdom housing soldiers who had been blinded through exposure to munitions in World War I. Early embossing was in the then-predominant code of New York Point. Clovernook transitioned to braille embossing in the early 1920s.

Since the advent of the Library of Congress’ National Library Service (NLS) program in the mid-20th century Clovernook has been a predominant supplier. Today, about 75% of Clovernook’s production is on behalf of NLS and other federal agencies – the other 25% being a mix of private publishers and corporate accounts. As of 2023, Clovernook is the highest volume producer of braille in the world, embossing and shipping approximately 30 million pages of braille per year.

In addition to their braille operations, Clovernook also provides adaptive sport programming for youth, runs free pediatric low vision clinics in partnership with Cincinnati Children’s Hospital, and offers a variety of community living, orientation & mobility, and assistive technology supports.

Print/Braille Materials

For many years, Clovernook Center for the Blind has provided Print/Braille books for the National Library Service. These books are distributed to libraries across the United States and can be accessed on loan by any eligible patron. These books are typically for younger children, and consist of print pages that are overlaid with see-through plastic braille embossed pages. This format allows for print and braille readers to read the same materials simultaneously, which can be of tremendous benefit to student/teacher and parent/child pairings as they are able to access shared reading experiences and braille instruction.

The development and success of this format in libraries in the United States, as well as the adoption of the Marrakesh Treaty (eliminating many international copyright restrictions for accessible materials), spurred Clovernook to explore the feasibility of bringing this type of resource to schools and classrooms outside of the NLS program. Specifically, Clovernook wished to explore the development of materials for educational centers that lacked reliable access to early reading materials – which led to the development over time of a targeted pilot focused outside of the United States. The initial focus of this pilot - Clovernook’s “Tactile Literacy Initiative” - was the provision of culturally relevant early reading books in print/braille format.

The first step in developing this program however was to redesign the product. Producing books to the standard that we produce for the Library of Congress was not feasible from a cost perspective – so Clovernook developed an alternative format which provides the same reading experience for a fraction of the price. The following design changes were implemented, resulting in a 95% drop in production costs:

* Replacing the hardcover binding with a sturdy cardstock cover
* Replacing the interior riveted page clasp with a strong plastic coil binding
* Printing print pages of books on Canon Imagepress at Clovernook, rather than purchasing books and cutting out the pages
* Embossing clear plastic braille pages on an Index Everest, rather than on a plated press

Notably, the development of Everest embossing for braille insert pages provided improvements across the board, such that Library of Congress products also migrated to this method after successful sustained usage in the Tactile Literacy Initiative.

African Storybook Initiative

When selecting titles to develop for the Tactile Literacy Initiative, one of the primary considerations was to ensure that the stories selected were culturally relevant to the target audience. In observing what kind of materials are typically received by schools in African nations from American and European sources, it was noted that the books they receive are invariably Euro/Western-centric narratives, and not necessarily stories that their students and/or educators can relate to. For this reason, it was a deliberate choice to focus solely on storybooks rooted in the cultures, languages, and storytelling of the target regions/schools.

With this in mind, Clovernook decided on using the African Storybook Initiative database for the launch of its program. The African Storybook Initiative is a multilingual literacy initiative that works with educators and children to publish openly licensed picture storybooks for early reading, available in numerous African languages. To date they have shared nearly 6,700 storybooks in 222 languages across their digital platform. This database provides Clovernook with a wealth of culturally relevant storybooks.

3D Models

Early in the design phase of this initiative, supplemental tactile materials were identified as a key addition. For early print readers, storybooks are filled with engaging illustrations and representations of the world within the narrative – and these provide not only enjoyment to the child, but also a variety of educational impacts. By replicating objects found within the storybooks, Clovernook aimed to provide a similar sense of engagement and learning for braille readers (and also provide some fun!). Several different tactile formats were explored, including the traditional tactile materials of thermoform and swelltouch graphics – and from both a cost and experiential standpoint, it was decided that 3D printed models would be the most effective method of representation.

The cost of 3D printing equipment and materials has vastly decreased over the past decade – reliable printers can be purchased for under $200, and models can typically cost under $1 to print. This is significantly cheaper than most forms of tactile representation. There also exist vast databases of “free-to-use” models that are already designed, which provides Clovernook a variety of models that were ready to print without any design work needed.

Models selected for tactile representation are typically objects found within the storybook. A book that tells the tale of an elephant and a rabbit becoming friends would be paired with a kit that contains a model elephant, and a model rabbit. However, model development isalso focused, whenever possible, on interactive model pieces or model designs that could enhance a learning concept.

For example, the book “How Far” tells the story of a spear throwing contest that is held amongst the animals of the jungle to see who can throw it the farthest. Various animals take their turn, throwing the spear increasingly farther distances (“Far”, “Farther”, “Farthest”) – providing educational instruction on distance terminology through the narrative. For this model kit, a custom playing field was designed that allowed students to replicate the spear throwing contest as it occurred, and reinforced the concepts of distance found within the story.

2021 Exploratory Pilot

Initial distribution of materials consisted of a single title “A Very Tall Man”. This book told the story of a man who was too tall for everyday materials –his bed was too short, he hit his head on the doorframe, and his farming implements were too small for him to use effectively. Halfway through the story the tall man has an epiphany – everything just needs to be bigger! He gets a bigger bed, builds a bigger door, and acquires a larger furrowing tool. Models paired with this book were designed by the Mountain Lakes Makerspace, based in Mountain Lakes, New Jersey, under the supervision of Ian Matty. These models included:

* A Tall Man
* Short/Long Beds
* Small/Large Doorframes
* Small/Large Farming Hoe

The models allowed students who are blind or visually impaired to experience the narrative in a tactile format, as well as reinforce basic learning principles concerning size and spatial awareness.

In October of 2021, Clovernook distributed copies of “A Very Tall Man” to select school groups in East Africa, at a small scale (200 books, and 20 model kits). Book kits were received by groups in Kenya, Rwanda, Uganda, Tanzania, Ethiopia, Burundi, and Somalia.

2022 Pilot Phase I

After the initial findings of the 2021 exploratory distribution phase, additional titles were selected for development from the African Storybook Initiative database, utilizing the same format. In addition to English titles, stories in Kiswahili and Kinyarwanda were also selected – reflecting one initial finding that support of non-English languages in braille was a significant resource gap in the classroom.

For the expanded pilot, Clovernook partnered with the University of Cincinnati’s DAAP School – primarily through a co-op that provided Clovernook with a Masters of Design student (Henry Levesque), who had highly proficient skill sets in 3D design and printing. The co-op provided Clovernook with both original models, and models sourced from free-to-use online databases. Models were mostly printed by partner organization See3D, with some additional printing services provided by the University of Cincinnati Makerspace.

In September and October of 2022, Clovernook’s Director of Braille Production & Accessible Innovation - Samuel Foulkes - traveled to schools in four East African countries to distribute and assess the use of the newly developed materials. Schools were located in the following locales:

* Nairobi (Kenya)
* Mombasa (Kenya)
* Jinja (Uganda)
* Soroti (Uganda)
* Kigali (Rwanda)
* Dar-es-Salaam (Tanzania)

Over the course of several weeks, 2000 books were distributed, along with over 100 model kits (each kit containing as many as 10 distinct models). Feedback was solicited from staff and students regarding the efficacy of this particular resource (i.e. book kits) as well as general needs assessments to research what other types of particular items these educational centers needed.

Resource Specific Findings

* **Model Durability** – Perhaps the most significant finding was to ensure the durability of 3D models by avoiding thin model parts. Several model types met sad ends either in transit, or at the hands of a small child in the classroom. Notable examples included a model chicken that had thin spindly legs extending from its base. Most of these snapped upon relatively slight pressure, leaving a multitude of chicken feet behind. Goal nets for “Chicken and Millipede” would also break easily, as the “net” lattice was too thin to withstand normal handling. For this reason, a slight philosophical shift in the model design occurred – a certain amount of model “reality” (i.e. the exact replication of an object) would be sacrificed if it would allow for a significantly more durable model. Clovernook established a minimum width for any part of a model, to ensure the durability of the resource.
* **Contracted Braille** – All books distributed during Pilot Phase I contained uncontracted (Grade 1) braille, as the resources were intended to provide learning supports and reading experiences for young students who are just beginning to learn braille. However, educators shared that having versions of the books in contracted (Grade 2) braille – or even having both in a single book – would help as a teaching tool for students who are beginning to learn braille contractions.
* **Larger Print Size –** Increasing the font size of the print pages in the books would allow for easier reading of the materials by low-vision students.
* **Reading Comprehension and Vocabulary Questions –** Educators shared that these books would provide additional educational value if they contained vocabulary definitions before the narrative, and reading comprehension questions afterwards. All existing storybooks within Clovernook’s program have now been updated, through partnership with Northern Kentucky University, to include this content.

During each school visit, interviews were conducted with educators and administrators to better understand the needs of schools and the resources that would be of use in their locations.

2023 Pilot Phase II

Design

Following the results of Pilot Phase I, Clovernook entered into a partnership with Northern Kentucky University (NKU). Under the supervision of Samuel Foulkes and Dr. Tamara O’Callaghan of the English department, classes of students collaborated with Clovernook on the development of book kits – both for African Storybook Initiative titles, and for new titles outside of that database. Students also developed vocabulary and reading comprehension guides for both new and already existing books in the Clovernook program. Other individuals in the classes pursued the development of stand-alone kits, and curriculum-aligned STEM support model kits.

Thanks to an NKU alumna who had worked with Clovernook, Samuel connected in early 2022 with Dr. O’Callaghan, a professor of English who also works in the digital humanities – that is, the application of technology to humanities disciplines. She was planning to launch an undergraduate course on creating multimodal tactile books for STEM and technology students in NKU’s Honors College.

The timing could not have been more perfect. Dr. O’Callaghan first taught HNR 330: Community & Humanity on the topic of “Build a Better Book” in the fall of 2022 to 19 Honors students. NKU is a teaching-intensive university with a strong community-outreach mission. HNR 330 is a course that requires students to explore ideas in the humanities and arts and to apply those ideas to experiential learning in local, regional and/or national communities. The course needed a community partner to fulfill that student learning outcome, and Clovernook was an ideal match.

Using the newly opened makerspace in NKU’s main library, the students considered how to build a better book, not just for themselves but for others who may benefit from an enhanced and/or completely redesigned reading experience. Drawing on the humanities and arts for inspiration, the students explored constructionism, critical making, universal and co-design, and studio-based instruction to build a book that can not only be seen but also touched and heard.

The pilot course was extremely successful. As a result, Dr. O’Callaghan has offered it for both the Honors College and English department in subsequent semesters. The students work with a range of technologies, including 3D modeling, 3D printing, 3D scanning, and laser cutting, available in the library makerspace. Existing 3D model designs readily available online are typically used and adapted, thanks to the generosity of the 3D printing and laser cutting communities. These communities allow their designs to be shared and often adapted with certain conditions, such as appropriate attribution to the original creator and no selling of derivative designs. Consequently, the students do not need any expertise with the technologies in order to take the course.

In each Build a Better Book course, the students design, fabricate, test, and refine multimodal prototypes that incorporate tactile and audio features for blind and low-vision individuals as well as for others with physical and learning disabilities. In some cases, the students work with narratives from the African Storybook Initiative (ASI) to create suitable 3D artifacts. For example, one group 3D printed an articulated snake for the storybook Behre and the Snake, a narrative that tells the story of a snake that asks a man named Behre to carry him on his head across a river. The students found a suitable 3D print file for an articulated snake, but they had to print a number of versions before they had a 3D snake of a suitable length for a child reader of the book to coil and wear on their head.

Another group adapted existing 3D files of a rocket, astronaut, satellite, and telescope to accompany the ASI storybook Andzani, the Astronaut. Blind and low-vision staff members at Clovernook were the early testers of these 3D objects, providing essential feedback on which ones worked well and which ones did not. The initial design of the telescope was particularly problematic; the testers found that it felt like a flashlight. As a result, Clovernook’s tactile coordinator, Quentin Roa, revised the initial design until it met the testers’ specifications.

This collaboration between Clovernook and NKU has been mutually beneficial. NKU’s students have not simply supported Clovernook’s original concept of the initiative, but expanded it beyond the production of 3D toolkits for selected ASI storybooks by supplementing the narratives with vocabulary lists and discussion questions to support the teaching of the braille texts in the classroom. And perhaps more significantly, the students have grown the initiative to include STEM-dedicated lessons with suitable 3D objects, such as the planets of the solar system labeled with braille and a tactile puzzle teaching the phases of the moon. Several students have even written their own short stories and designed appropriate 3D objects that, in combination, teach a variety of STEM concepts, including mathematics, geometry, and density and mass.

From the students’ perspective, they learn about co-design/participatory design, a process involving all stakeholders to ensure a fully usable and accessible end-product; ICT4D (Information and Communication Technologies for Development), the application of technology to support socio-economic development and human rights in developing nations; and social justice and globalism, both of which foster a deep and authentic understanding of differences across communities and cultures. They also gain essential digital literacy and technology skills for the 21st-century workplace as well as a published physical artifact (book and 3D toolkit) that they can use for a professional portfolio. It has been a win-win partnership for both the students and Clovernook.

During this process, Clovernook also established its own 3D printing makerspace at their Cincinnati location, to allow for internal production and development of tactile models. This resulted in the purchase of six 3D printers, an Einscan 3D scanner, and a variety of filaments and printing materials. Clovernook also hired Quentin Roa, a graduating NKU student, to manage the space.

Distribution & Community Printing (2023)

In October of 2023, Clovernook distributed over 1000 new books and model kits to educational centers in East Africa. On-site visits at schools near the Kenyan cities of Nairobi and Mombasa provided more insight into how tactile elements can align with classroom goals. This visit also saw the launch of the next phase of the program - the setup of a community printing center in Nairobi. Clovernook’s long-time consultant, Dominic Kiamba, is based in Nairobi - and has now been provided an office space with two 3D printers. This allows for quick testing and printing of completed designs and kits, and eliminates the need to print and ship models from the USA - it also has begun to establish 3D printing skill-sets in the targeted community. This concept of community-based printing partners is one that Clovernook continues to explore.

Next Steps

The next phase of growth for Clovernook’s Tactile Literacy Initiative includes the further development of learning materials, exploration of additional partners and funding sources, and the creation of an ordering platform [currently referred to as the “Clovernook Catalogue”] that will allow school partners to select the materials for their particular institution. The current structure of this catalogue is planned to permit schools to order a certain amount of materials each term – providing choice allows them to prioritize classroom needs, which can vary.

The catalogue will also hopefully include materials that partner organizations can provide, such as white canes, which will allow us to strengthen and broaden the reach of the program and what it can offer. The amount of materials that schools can select will be linked to the amount of funding that Clovernook is able to dedicate to the program.

Further steps include the continued work to ensure tax exemptions for shipments to partner schools, so that the receiving organization is not required to pay an import tax or custom fee on received materials. Currently, Clovernook reimburses these expenses when they arise – but securing these exemptions will allow for reduced program costs, and for additional materials to be distributed.

Other areas of development include:

* Specialized packaging for learning materials, so that books and tactile kits can exist in secure environments.
* Exploration of how people who are blind/low vision can operate 3D printing equipment and design software.
* An intuitive stand-alone computer application that will allow individuals to input text and receive an accurate braille translation in the form of a 3D braille label file. This label can be applied to 3D model files before printing, to provide additional information/context for braille readers. Particular attention and testing is focused on the accuracy of the translation, and the quality of the braille dot height and sizing. The application will allow for toggles between contracted and uncontracted braille.
* Exploration of a “Write Your Own Story” program piece, currently underway with a school in Kenya in partnership with the African Storybook Initiative. This pilot explores the feasibility of collecting creative stories from students who are blind, and publishing them in print/braille formats along with 3D models.
* Expansion of the Clovernook Makerspace – additional 3D printers and equipment.
* Providing customized training to organizations or schools that have braille production equipment or 3D printers.
* Testing audio enhancement of storybooks – embedding QR codes that provide audio recording of narrative, as well as other audio content related to narrative (e.g. animal noises).
* Exploration of other partner locations - exploratory shipments have been sent to South Sudan, Nigeria, Sierra Leone, and Bhutan. First step is ensuring that materials can arrive via Free Matter shipping. This first shipment consists of a test box, typically containing braille paper and several book titles.

Clovernook’s goal is to provide enriching learning experiences for young braille readers through the exploration of stories and tactile models – and it is in this spirit that the initiative continues to evolve!