Wakayima: a multimodal literacy companion for any age and ability.

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Abstract*—In Uganda, like many parts of the world, education is barely available, affordable, nor accessible. Schools are dilapidated and teachers are underpaid. The children and mainly co-laborers in the homestead and part-time pupils if circumstances allow. With these large gaps in the current education delivery, Wakayima is an idea that seeks to bring this urgently-needed education to the children when they can't go to school or have none to go to. The battery-powered device leverages visual, audio, and tactile interactivity to deliver reading and arithmetic lessons to the next generation. Its collaborative and modular approach to study encourages group work and high customization to make learning "affordably accessible" when children are differently-abled and/or learning communities have different needs. Since early childhood education is a key factor in later success, Wakayima seeks to bridge that gap.

I. Introduction / Background (Sytle: Heading 1)

Human beings have always lived and thrived best in community. A particular benefit of this is that the young learnt everything from their community. With the urbanisation of human living, education has been reframed around institutions like nurseries, schools, and universities to standardise the learning, and provide skills outside the communities' knowledge.

Unfortunately, in developing countries like Uganda, such standardisation often clashes with the needs of daily survival. Entire communities are constantly engaged in manual labour such as herding livestock or tending to gardens in to feed the home. The children are often needed to contribute to this and therefore can't spend entire school days away from home. They miss out on the rigorous academic activity that builds their hearts, minds, and communities – potentially their best chance at breaking the communities' poverty cycle.

In these same communities, a folk tale is told of *Wakayima*, a little rabbit, that defeated a menacing lion that had set out to eat all the animals in the jungle! Wakayima did this using his wit, learning the lion's weakness and planning appropriate tricks to defeat it. This folk tale inspires the Wakayima prototype presented in this paper. It's a device that aims to empower the next generation with literacy tools they need to solve the problems around them. The key question we're answering is; "If the kids can't go to school, how can we bring school to them?"

The prototype proposes a literacy companion that children can use to learn reading and arithmetic through audio, visual, and tactile senses. It can also be used collaboratively where they engage with its content together, exploratively where a child can self-direct their learning or revision, and accessibly where children with disabilities can also utilise it effectively.

II. Related Work

What if we waited for the children to grow up, and have them attend school later? The research has consistently shown the benefit of early education in the lives of children. Nola et al. [1] write that "In fact, the years from birth to age 5 are viewed as a critical period for developing the foundations for thinking, behaving, and emotional well-being." Wakayima also solves the problem of lack of access to literature which is a large limitation for low-income children [2]. Moreover, this early childhood learning has a long-lasting impact on their lives, being a good predictor for less involvement in crime and better employment opportunities [3].

Why not just teach them to read? Splashlearn defines multimodal learning as "an educational approach that integrates various methods of learning, such as visual, auditory, and hands-on activities, to cater to the unique learning styles of each student." [4]. This approach to learning ensures that a wide variety of learning approaches is used to maximise learning adaptations and preferences, as well as increasing accessibility of learning [5]. Inevitably, even learning performance is significantly improved by taking this approach [6].

Why burden them with education in a language (English) they don't know? Wakayima, being a digital-brained product, can be programmed to deliver learning in whatever language the children are familiar with. Reference [7] noted that "children acquire linguistic and cognitive skills more readily in their home language." This platforms their innate intelligence and lowers the barriers to academic information. It also allows them easily pick up further languages such as English to gain access to the already-present body of work in that language.

Therefore, Wakayima draws on these key markers to propose a literacy companion that helps children pick up many necessary skills in many learning styles, using many senses and in many languages.

III. IMAGINGED OR EXISTING PROTOTYPE SKETCHES/DRAWINGS/PHOTOS

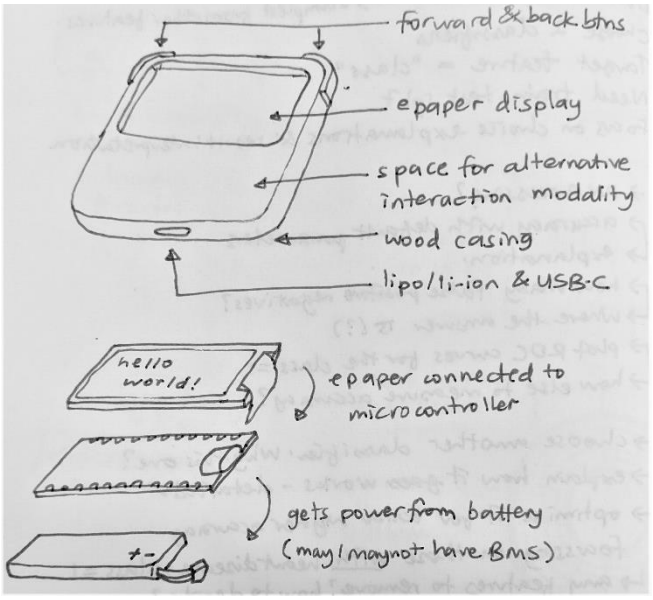
A. Components and assembly

The Wakayima project aims to use items that are off-the-shelf, easy to assemble, repair, and replace. They also should be robust given the varied working conditions of the device. Wakayima consists of a hard plastic housing that is home to three tactile buttons, a battery and microcontroller board. The final prototype will also have a plug-and-play swappable bay, which can house different sensory interactive surfaces.

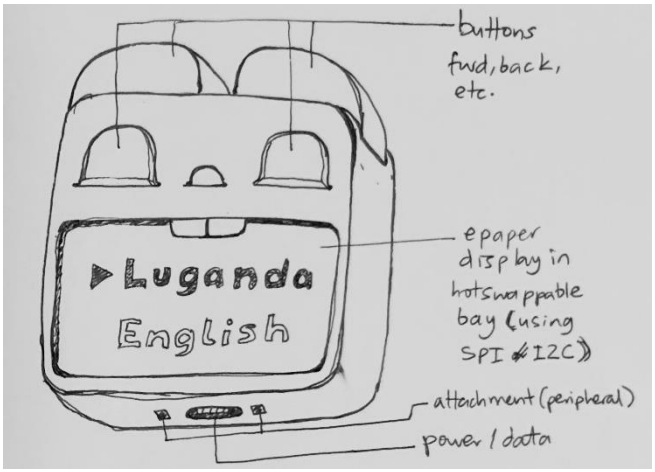
The plastic choice used in housing and buttons is recyclable PET that can be reused when the product is at its end of life. We hope to 3D print this. An alternative material is wood given its durability and natural feel. The microcontroller board of choice is the Pico Lipo from Pimoroni [8]. It runs an RP2040 microcontroller capable of running programs written in C/C++ as well as Micropython. It also has 16MB of storage, a battery management system necessary for charging a connected LiPo battery, and lots of connection pins(GPIO) to interface with different sensory hardware. One such hardware is a 2.13-inch ePaper display from Waveshare Electronics [9] used in the prototype. It's run by an ePaper HAT module (version 2.3) from the same manufacturer. This is a passive display that is very power-efficient, only consuming power when updating, and great in outdoor use-cases. The prototype also features buttons used for standard user input. Information on material choices and their contribution to recycling and waste management is included in the Responsible Innovation section later in this paper. Wakayima measures about 8cm on each side, with a depth of about 1.5cm. The protruding parts such as the 'ear' buttons, will add an extra 0.2 to 0.5cm of height.

B. Prototype sketches

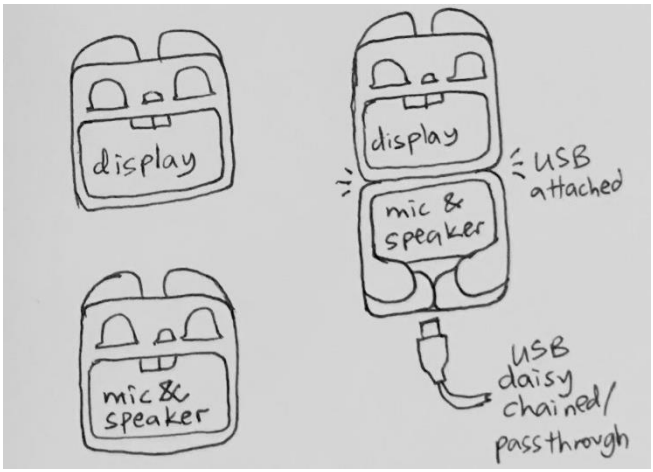
Below is a sketch of the first prototype's proposed construction, featuring ideas for button placement and component arrangement within the housing.



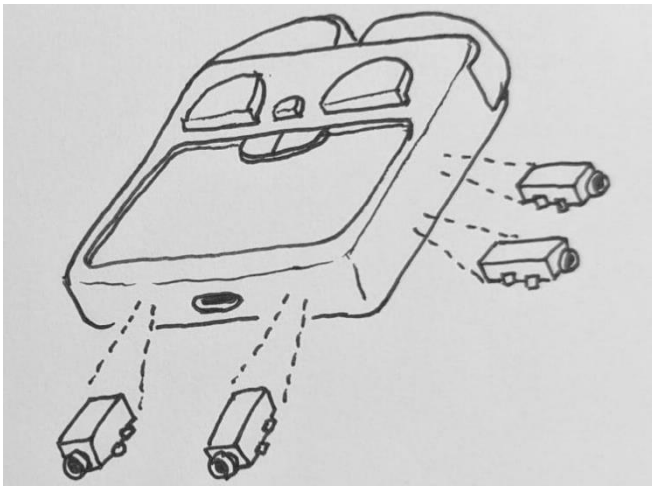
The current prototype sketches feature a more children-friendly design, inspired by Wakayima's rabbit features. It will feature USB-C charging and data at the bottom, alongside attachments holes.



The next sketch shows different modes of operation catering to different senses, and one that utilises a second component attaching via USB-C to extend Wakayima's functionality.

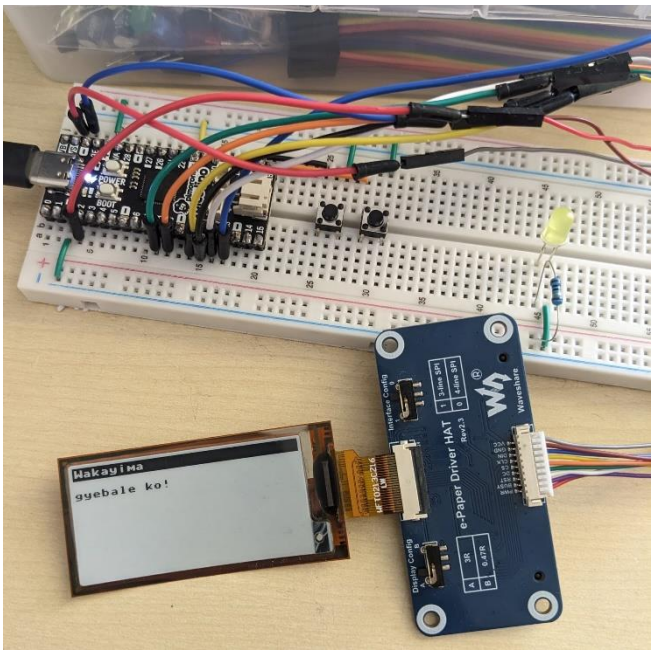


Moreover, the 'nose' part will be a status LED that easily communicates feedback as the child learns with Wakayima. The modular design helps components fit in both Wakayima and the attachment which can also be manufactured to be identical in functionality to Wakayima. Its sensory components are also swappable. An alternative linking interface is a pair of 3.5mm stereo audio ports placed on the side or bottom of Wakayima. These can do audio output for two users interacting with the device. Also, the six connection lanes can be used for charging, data transfer, and even Serial Peripheral Interface (SPI) slave attachments as a USB-C alternative.

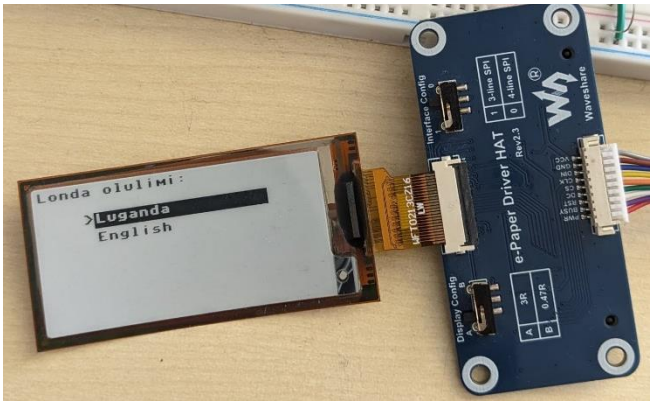


C. *Prototype photos*

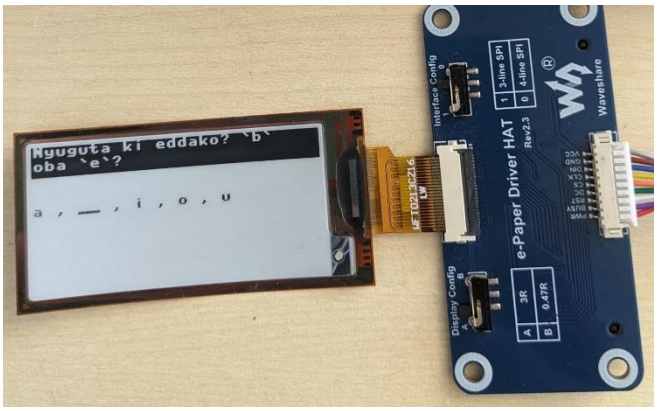
Below are some pictures of the current progress with Wakayima. The parts are running on a bread board to speed up coding and testing with different parts. The housing will be constructed after this. The setup currently runs off USB power through the microcontroller as there are no batteries currently attached.



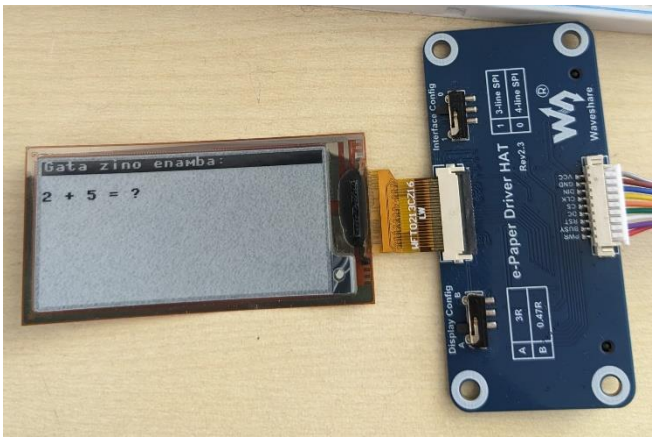
A sample menu select screen for a child to choose which language they want to learn and interact using.



An example literacy question testing for participation and recall using English vowel order. The child can respond using the inbuilt buttons since they are given two options, *b* and *e*. This display language is Luganda.



Finally, an example mathematics problem for a child to interactively learn. With inbuilt buttons and LED, they can respond intuitively by counting the answer with button presses.



IV. Responsible Innovation

Wakayima is a product designed with the low-income high-potential population in mind. It is a tool that bridges the information gap so that people and communities can be empowered to solve their challenges and build better lives for themselves.

A. *Component choices*

The component choices reflect this resilience amidst a difficult time and the hope of a better future by making good use of available resources, and innovating ways to reuse and reduce waste out of necessity.

1) *Housing*

The PET plastic chosen works well with the already-present Ugandan plastic recycling industry [10] and promotes employment for the marginalised [11]. This prolongs the life of broken device housings, but also opens up opportunities for artisanal replacement housing makers. For basic water-proofing, the prototype will be assembled with a glue gun, but the final device can utilise water-proofing button and port designs, as well as rubber linings.

2) *Battery*

Wakayima will be powered by the industry-standard Nokia BL-5B Battery [12] whose form factor fits well within the housing, holds enough charge, and can be recharged by the Microcontroller board. This battery model powers many low-cost devices in peri-urban and rural Uganda, has high availability and versatility, and can be recharged in and out of the device, for example, using common solar lamps with inbuilt phone-charging.

3) *Microphones, speakers, buttons and displays*

Input and Output (IO) attachments will be similar to those used in locally-sourced phones. The large electronics repair industry in Uganda spans both urban and rural areas, and this means cheap spares and repair services will help prolong the device's life.

4) *Device programming*

Setting up, programming, and adding/editing data on the device will be done using computers. Since Wakayima uses a

standard USB-C connection, any typical computer that has USB ports can be used to update it. Moreover, these port repairs are widely available at fairly low cost. All this pushes Wakayima's life and utility. Regarding the software, learning programs can be written, tested, and audited free of charge by several stakeholders to ensure quality, relevance, and appropriateness. This is because the Microcontroller can operate with programs written in C, C++, and Micropython.

B. *Societal participation*

Given its design, different parts of society can actively participate in the manufacture, distribution, and maintenance of Wakayima. Below are some ways this can happen.

a) Innovation and repair industry

Since Wakayima is assembled from components, and has swappable parts and attachments, this is an opportunity for the repair industry. They can work to maintain the devices already in circulation, recycle parts from used or broken ones, and even invent new attachments and versions that are task-specific.

b) Ugandan-led lessons

Wakayima being an open platform can attract the attention of practitioners that create lessons catered to their audiences. A rural education board can design children's science lessons that work in tandem with their planting and harvest seasons, and a peri-urban Cooperative can design math lessons for their children as they deliver food in the local market.

c) Scalable from young to old

As is often the case, many well-meaning solutions are deployed every year to low-income locations like Uganda that aim to serve the communities. Unfortunately, it is also commonly the case that these innovations are never taken up by the same communities. Wakayima aims to garner community adoption by being a tool for not only childhood literacy but interactive information dissemination. Non-Governmental Organisations (NGOs) who are the biggest players in this space could adopt Wakayima to diversify their sensitization efforts among communities for example in Teen and Adult Sexual and Reproductive Health, Adult Education, Business trainings, etc. Wakayima can be a learning-on-demand tool that allows even the least-represented to access high-quality education in a way that works for them.

d) Scalable from low-income to high-income

Another societal benefit of Wakayima's versatility is the ability to work in both high-income and low-income contexts. This is because of the ability to customise learning input and output, and the ability for the users to schedule their own learning. This widespread popularity increases the availability of free learning content and collaboration that would normally not happen between rural and urban schools and communities.

V. Author bio(s) / experiences

In between job-hunting and doing freelance gigs back home in Uganda, I volunteered with a youth-pioneered and youth-led NGO called 40-40 [13]. One of our outreach programs was a literacy program at local school in Kubuli, one of Kampala's peri-urban areas. The school was understaffed and we spent Friday afternoons reading stories and practicing English with 4-12 year old pupils. Some never made it to school if they were needed to help out back home. The same was the case in my local market where I bought food, a mother served, and her children did the food delivery as she took other orders. All this happened, and continues to, during school-going hours. While the children have time, they have it in small chunks, and not in the larger consistent ones a typical school education would require. Wakayima is an attempt at bring the learning to them in those pockets of time they have during the day.

VI. Acknowledgements

I'd like to acknowledge Dr. Shawn Flemming who first introduced me to Microcontrollers in his 2021 module, and opened my mind to the possibilities of building devices as tools. I also would like to acknowledge Prof. Matt Jones of the Centre for Doctoral Training at Swansea University who shared this opportunity with us over email. Last but not least, I thank my wife who listened to my wacky ideas and encouraged me still.

VII. References for formatting instructions

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