Dynamic Flash Card Device for Learning to Write Chinese Characters: Project Proposal

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Abstract— *Learning to write Chinese characters remains the greatest source of frustration for beginner L2 learners. Immersive mobile applications have generally proven effective in motivating learners as well as exposing them to broader vocabulary and applications. Despite their richness and ease of use, these tools may not effectively address younger learners who, whether due to economic conditions or parental design, do not have access to smart mobile devices, reliable Internet connectivity, or funding for paid subscription plans. This paper proposes the development of a simpler, embedded device to assist younger, more easily distracted, and low-income community learners of Chinese as a Second Language to learn how to write Chinese characters.*

Link to video presentation: https://youtu.be/_6ZkpBNCtys

1 INTRODUCTION

The shift to online-centric language learning presents several challenges for second language (L2) learners, who without in-person feedback may struggle with more nuanced aspects of the language. This can be ameliorated to an extent with dedicated course content (Prichard, 2022) as well as recorded feedback (Xu, 2017) to retain certain beneficial in-person aspects while retaining the flexibility and scalability of online models.

Immediate, personalized feedback is difficult to provide at scale for learners practicing writing Chinese characters. While CFL instructors of learner groups without goals to apply writing skills may opt to forgo writing practice beyond the basics of stroke order and character components, dedicating more time to character recognition and other topics (Lu et al., 2019), handwriting remains the most effective method for building an understanding of characters' orthography and being able to use it, and is a necessity for learners seeking to progress to intermediate or advanced levels (Lyu et al., 2021).

CFL beginner learners benefit immensely from routine, timely feedback on their performance (Hsiao et al., 2013). As beginners may benefit most from basic writing practice to reinforce the meaning of characters, more frequent writing (character copying) practice should be encouraged (Xu et al., 2013). Techniques eliciting deeper, concentrated thought, such as student-generated mnemonics and character writing exercises, improve character writing and performance and semantic accuracy over other coding and translation-based exercises (Kuo et al., 2004; Hsiung et al., 2017).

While first language (L1) Chinese learners have ample exposure to learn and practice writing new characters through basic immersive methods, and quickly move on to chunking, L2 learners outside of Chinese-speaking environments do not have the same volume and frequency of exposure to such vocabulary, whether written or spoken (Anderson et al, 2013). With the support of interactive writing practice interfaces, L2 learners feel more encouraged to study (Xu et al. 2019). Interactive learning tools for teaching Chinese writing that include animations of writing the character in the correct stroke order, while removing practical obstacles to the learner practicing writing the characters and showing verbal-visual cues, are particularly effective in improving both learner engagement and reducing learner frustration (Olmanson et al., 2021).

Mobile devices, which provide ample contextual learning opportunities for learner immersion in reading, listening, speaking, and to a lesser extent, writing, have been introduced in classroom and online courses to improve learner engagement as well as social interaction (Luo et al., 2016; Wen, 2018). However, learning and troubleshooting Chinese handwriting input methods for countless student-owned mobile devices may be less intuitive for instructors and beginner learners.

While writing cannot be entirely ignored throughout the beginner levels, an overemphasis through interactive learning technology can also have a negative effect on performance. While incorrectly written characters due to miswriting of their components is the most common mistake made by learners at all levels (Deng et al., 2022), too much emphasis on stroke order and radicals can lead to adverse learner performance in character recognition (Hou et al., 2022). Thus, a balance must be achieved where the appropriate amount of attention is given to writing the characters properly without overloading the learners. L2 learners may see increased benefit from *non-intrusive* technologies that introduce these characters with routine frequency beyond the classroom and allotted study sessions (Anderson et al, 2013), and must be taken by online teachers to make writing experience as close to in-person practice as possible (Deng et al., 2022).

TikTok and similar social media are gaining traction as supplementary education platforms, and have been implemented to improve student learning outcomes (Jacobs et al., 2022) as well as encourage student participation (Radin et al., 2022). Integrated properly, TikTok can be a powerful tool to improve student engagement, promote knowledge and innovation, and increase overall educational reach. However, these apps can also promote dependency on the platform, leading to distraction from studies and even greater psychological repercussions (Zhang et al., 2019). When used in moderation, these platforms could be excellent affordances for beginner learners to build orthographical knowledge of Chinese characters through character animations and verbal-visual coding, but they also are a slippery slope that detracts from student handwriting practice.

Learning Chinese characters is hard; learning to write them is even harder. Among the four main components of language learning – listening, speaking, reading, and writing – CFL students from various cultural and linguistic backgrounds tend to have the most difficulty learning to write Chinese characters.

While computer and mobile assisted instruction methods have proven very effective in enhancing learner performance across all facets of the target language, learning with content-rich technology can also deter from learners' focus and self-study discipline. Learning to write Chinese characters requires a significant time commitment from the learner to sole study. Robust mobile apps for language learning often contain more content than is necessary or helpful for beginner learners, and short video apps, in their ability to easily browse unrelated content, can pose a significant distraction. On top of this, younger learners do not always have access to desktop computers, smart phones, or internet bandwidth to leverage these rich tools.

Should instructors rely too heavily on rich digital experiences to teach Chinese, they also lose the ability to precisely track the students' Character writing development. Even worse, learners risk falling prey to the myriad of distractions posed by short video apps and even gamified language learning apps, sacrificing valuable time and energy from their studies.

The CFL community lacks a simple, interactive self-study tool that is learnable by students of all ages, accessible to learners of lesser means, acceptable to parents of distracted young learners, and easily updated by instructors and learners. By addressing this need, the barriers to learning to write Chinese characters – the generally accepted most difficult aspect for beginners – can be lowered, students can practice more efficiently, and CFL instructors will be able to arrange more productive online curriculum; these improvements can all assist in making the Chinese language more accessible to learners from all backgrounds.

2 RELATED WORK

Before the introduction of smart phones, hardware devices have been adapted for Chinese language learning. Electronic dictionaries, with full keyboards and styluses – such as Besta (Besta, 2023) and BBK (BBK, 2023) were also mass-produced as electronic dictionary and translation devices for the Greater China markets.

Pleco, arguably the most popular Chinese dictionary mobile app for L2 learners, was originally developed for the Palm IIIx in 2000 (Pleco, 2023). The app now includes OCR for documents and interactive handwriting guidance. To their merit, the developers have managed to keep the app free to use, with optional paid add-ons.

With the increasing accessibility of smart mobile devices, more and more educational applications are being designed from a technology-first perspective, as well as gamifying the language learning experience through goal setting and tracking. JinBuPal, developed by a Georgia Tech alum, analyzed a massive corpus of online Chinese language materials to provide learners with more exposure to a greater breadth of Chinese characters – much broader than traditional curricula – and tracks learner progress (JinBuPal, 2023).

Skritter is another all-encompassing Chinese learning app, first for the web in 2008, then with an iOS version in 2012, eventually adding handwriting correction and analytics based on learning progress (Skritter, 2023). Despite the approachable, interactive interface and content richness, the app is a paid product, and currently without any free options for learners.

As more education and technology experts as well as experienced L2 learners develop more targeted, interactive tools and technologies for learning Chinese, learners are able to immerse themselves in rich multimedia on smart devices. However, having access to such a broad variety of functions and other applications also presents a potential source of distraction, especially for younger students with the inability to focus, while at the same time proving a source of consternation for teachers and eager parents of students learning to write Chinese characters, an innately applied skill requiring a large volume of repetition. Mobile and web applications also require reliable Internet infrastructure and reliable computing devices, which may not be widely available in economically challenged regions to where teachers and cultural diplomacy resources are being deployed.

This calls for a complementary product dedicated only to learning to read and write Chinese characters – one that can be cheaply mass-produced, simple to learn and operate, and easy for administrators such as teachers to update with relevant content. By excluding any features that are not directly related to teaching Chinese character writing, such a device would allow learners to focus without the distractions of their smart devices for intensive and extensive practice sessions as well as quickly review while on the go. Limited functionality also allows the developer to reduce the bill of materials to make the device an economically viable solution for low-income community Chinese language programs.

3 PROTOTYPES

This project entails designing a focused interface for a low-power hardware device, curating dynamic content of Chinese characters and their correct stroke order, and developing a program for learners to study several individual characters in a format similar to two-sided flash cards.

Two hardware prototypes using integrated development boards purchased from Adafruit.com, were developed in parallel to test the different form factors and display characteristics. Both devices contain an integrated screen and hardware buttons for the user to interact with the system. Initial iterations used Adafruit PyBadge and MagTag dev boards (Adafruit, 2023) to focus more on interface display, content design, and integration. The PyBadge a 1.8″ color TFT display, 8 control buttons – 2 up/down, 2 left/right, and 4 auxiliary, 5 color LEDs, and several other sensors. The MagTag has a 2.9″ grayscale ePaper display with similar dimensions to an index card, and 4 control buttons positioned underneath the display. Both devices will be powered by a 400 mAh lithium polymer battery, which can be charged via Micro-USB.

The Adafruit MagTag includes a wider display more closely resembling the shape and dimensions of an index card, and its ePaper display is easier on the eyes while consuming significantly less power. I also have more storage capacity to ft more characters into the prototype.

3.1 Wireframes

First, a prototype is required to show how the user will interact with the device to, at a minimum, select an individual character, toggle individual brush strokes, and play the entire sequence of brush strokes for selected character

To achieve this, initial wireframes were based on a miniaturized form factor reminiscent of the handheld gaming devices of the 1990s. The directional buttons Up and Down cycle through the bank of characters, while Left and Right buttons play previous and next strokes. Two buttons on the right side of the device activate an automatic play through of all brush strokes of the currently displayed character, as well as classify characters as “to learn” or “learned”. The stroke number and character ID are displayed at the top of the screen.

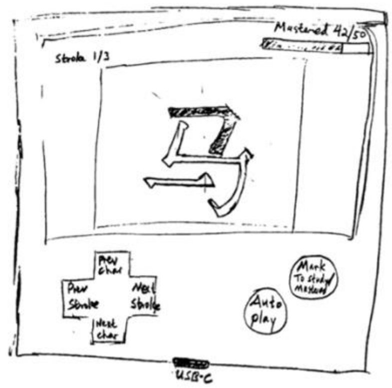

Figure 1 – Wireframe of sample character “马 ma3” (horse).

Shortly after drawing the initial wireframes, I came across an integrated dev board designed by Adafruit called PyBadge, which closely resembles the form factor I had in mind when drawing the wireframes. Thus, I used PowerPoint to create more visually appealing, interactive wireframes for a higher fidelity testing experience.

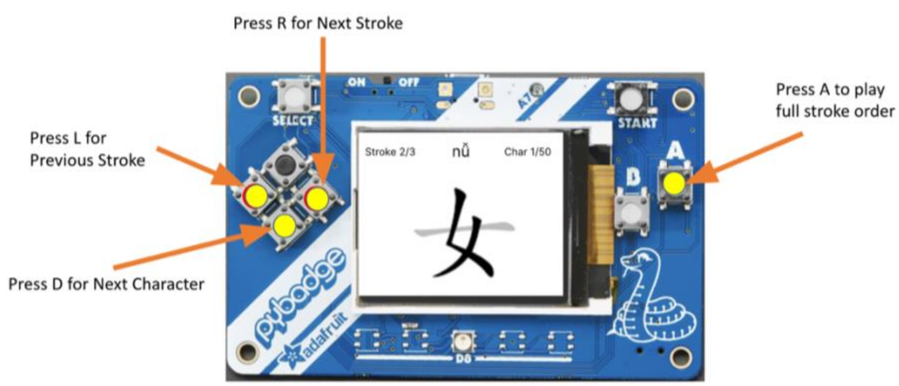

Figure 2 – Adafruit PyBadge. Source: Adafruit.

3.2 Platform

CircuitPython (CircuitPython) was used for initial development due to its relative ease of use – Python instead of C or C++ for Arduino (Arduino) – and the ability to quickly modify and run the code – the libraries and code live on the board and do not require additional compilation to run, a major advantage over other frameworks using Arduino. The platform also supports programming using MakeCode Arcade (MakeCode Arcade) and Arduino frameworks.

A major constraint to implementing additional features within the PyBadge and MagTag is its limited memory, as the bitmap images take up too much space. Initial plans were for the prototypes to display the pronunciation and stroke-by-stroke demonstration of 3 to 10 characters similar to a set of two-sided flash cards; however, due to severe device storage constraints, only 2 characters could be fit on each device as a proof of concept.

3.2.1 *Content*

The front side of each card requires both an outline and filled in brush stroke of the character, broken down by each stroke. To allow the user to manually play each stroke, this requires several BMP frames per stroke, adding up to several files per each character. Although GIFs would consume less space, the

Figure 4 **-** PyBadge hardware implementation.

CircuitPython framework is only compatible with BMP images.

Aside from designing a useful and appealing interface, sourcing and organizing content proved an interesting topic. After some searching, I located a set of full stroke order GIFs on Wikimedia Commons that I was then able to split into individual frames. The frames were resized to 100x100 pixels and converted to BMP for the device screens. Initial BMPs were not entirely visible on the grayscale display of the MagTag, and required indexing the different shades of gray and black and increasing their contrast to show properly on the MagTag display. Further color gamut and resolution limitations were tightened to reduce the memory footprint on device flash storage.

The prototypes initially included examples of usage for each character, but they did not have enough device storage to hold the Chinese font files. This will be left for a future implementation as after loading the stroke frame files, the devices lacked sufficient storage capacity to hold the required font data for full sentences using Chinese characters.

Character details, including pronunciation, definition, and number of frames per brush stroke of each character, are organized in a single JSON file that is accessed by the main script.

***Figure* 5 -** MagTag hardware implementation.

3.2.2 *Interface*

At the front (PyBadge) and right (MagTag) side of the card sits the outline of a specific character. The top-left (PyBadge) and bottom-right (MagTag) corner indicates the number of the stroke alongside the total number of strokes making up the character, with the pronunciation at the center (PyBadge) and left (MagTag), and the definition on the back (PyBadge) and bottom-left (MagTag) of the display.

For the PyBadge, the back face of each card holds the definitions of the character, while on the MagTag, the front face contains all the relevant information for the selected character. Both devices include hardware buttons for the user to cycle through the flash cards, brush strokes, and access additional settings.

To improve the appearance and feel of the devices for subsequent user testing, simple device enclosures were 3D printed in the Makerspace on campus in Shenzhen.

Table 1 – Device controls

	PyBadge	**MagTag**
Play next stroke	R	C
Play previous stroke	L	B
Play next character	D	D
Play previous character	U	A
Autoplay	A	Not implemented
Flip card	B	Not implemented
Toggle traditional/simplified script	Not implemented	Not implemented
Toggle "to learn"/"learned" status	Not implemented	Not implemented

4 FUTURE WORK

4.1 Improve processing speed

While similar code runs without issues on the PyBadge, the current MagTag implementation event updates load slower than the animation speed. The code requires refactoring, and perhaps a fresh implementation using a faster framework, to get the bitmap frames to load faster without refreshing the screen.

While the bitmap format is the only known compatible image format for CircuitPython, alternatives, such as SVG vectors, tend to be much smaller and faster to load, and deserve further exploration.

4.2 Store more characters

Both devices lack the capacity required to store a meaningful amount of character images in their current bitmap form. The storage capacity will need to be increased to hold a meaningful amount of character images as well as the font files required to include examples of character usage in Chinese text.

Character content can later be categorized into "card decks" or accessible via tags to allow students to practice more efficiently. Subsequent iterations will include curated "bundles" of characters based on the learner's curriculum or study goals. This can be addressed once the storage constraints are alleviated.

4.3 Productization

The first step to making this device accessible is to launch a crowdfunding campaign to gauge market interest, collect broader feedback from interested potential users, and acquire the funding needed for further prototyping and test production.

Subsequent iterations will strive to lower the bill of materials by replacing the color LCD with e-Ink, using a smaller controller, and removing superfluous sensors to produce an even more lightweight board.

5 CONCLUSION

A low-cost and low-power, handheld device is an effective supplement to existing learning materials and online tools for learning to write Chinese. The flash card device shows promise for beginner and intermediate learners without access to high-end mobile devices or reliable internet connectivity, as well as students seeking to eliminate the distractions presented by content-rich mobile technologies. Further development is required before making this tool accessible to the broader Chinese language learning market.

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7 APPENDIX: IMPLEMENTATION PLAN

Week	Completion	Category	Task
-	Mondays	Communication	Report progress weekly
0	2/27/23	Platform	Order Adafruit PyBadge
1	3/6/23	Platform	Explore PyBadge dev environment
1	3/6/23	Interface	Produce 3 wireframes of interface
2	3/13/23	Content	Create GIF files for 3 characters (single file per char)
3	3/20/23	Interface	Conduct cognitive walkthrough of wireframes
3	3/20/23	Communication	Deliver first intermediate milestone
4	3/27/23	Platform	First draft of program logic – char by char function
4	3/27/23	Content	Format pronunciation and GIF data for 3 characters
4	3/27/23	Content	Split character GIFs by stroke
5	4/3/23	Platform	Revise device logic – stroke by stroke function)
5	4/3/23	Evaluation	Test program on device
5	4/3/23	Platform	Order additional components as needed
6	4/10/23	Platform	Revise device logic – flip front/back function
6	4/10/23	Evaluation	Test program with users
6	4/10/23	Communication	Deliver second intermediate milestone
7	4/17/23	Content	Curate images and data for additional 3 to 7 chars
7	4/17/23	Platform	Order enclosure or design for 3D printing
7	4/17/23	Interface	Complete MVP
8	4/24/23	Evaluation	Gather user feedback
8	4/24/23	Interface	Revise as needed
8	4/24/23	Communication	Begin project report and presentation
9	5/1/23	Interface	Continue to revise as needed
9	5/1/23	Communication	Finish project report and presentation

Total time commitment: 100~120 hours.