Kanak: Automating the Generation of Accessible STEM Materials for Blind and Low-vision Students

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Abstract

Blind and low-vision (BLV) students face significant barriers to timely access of visual STEM materials. Accessibility practitioners, such as braille transcribers and teachers of the visually impaired (TVIs), rely on manual and labor-intensive processes to produce accessible formats (e.g., braille, tactile graphics) of visual educational materials. To complement this effort and address ongoing accessibility gaps, we developed Kanak, an AI system that leverages generative intelligence to automate the generation of accessible STEM content, including text, math equations, and graphics. Through a comparative study with seven practitioners, we examined how Kanak supports traditional transcribing workflows and augments expert judgment. Our findings reveal how generative tools could complement practitioner expertise by providing context-aware formatting, proofreading support, and on-demand graphics generation. We conclude with design considerations for human-AI collaboration in transcribing work, positioning generative intelligence not as a replacement for expert insights, but as a catalyst for expanding equitable access.

CCS Concepts

• **Human-centered computing → Empirical studies in HCI**; **Empirical studies in Accessibility**.

Keywords

Accessibility, STEM Education, Blind and Low-Vision (BLV), Human-AI Collaboration, Generative AI, Tactile Graphics, Inclusive Design

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1 Introduction

In STEM education, visual educational materials (such as equations, diagrams, and charts) serve as foundational tools for conceptual understanding, problem-solving, and communication. However, blind and low-vision (BLV) students often face significant challenges in accessing these visual educational materials [22, 41, 66]. Achieving access to educational content for BLV students requires not only classroom accommodations but also systemic efforts to produce accessible instructional materials in formats such as braille, Nemeth or UEB math expressions, tactile graphics, audio descriptions, and accessible digital documents [3, 5, 23]. Producing such accessible materials involves the collaborative efforts of a range of accessibility practitioners, including braille transcribers, teachers of the visually impaired (TVIs), mainstream educators, and publishing institutions [16, 17, 35, 36, 38, 62]. However, these accessibility practitioners continue to face numerous challenges, including delays in educational material delivery and inconsistent quality of tactile resources [6, 16, 46, 76]. Further, while braille remains an important medium for accessing educational content in BLV education [3], there is a persistent shortage of certified braille transcribers, which often results in delays in delivering textbooks and other instructional materials to students [2, 16, 36, 77]. In many cases, braille textbooks are distributed incrementally (e.g., one chapter at a time) because the transcription process remains ongoing. These delays are exacerbated when teachers change course materials mid-semester, which leaves students without timely access to updated content [36]. These existing issues in the production of accessible educational materials negatively influence the learning experience of BLV students, often leaving them without timely access to educational content that their sighted peers receive in real-time.

While prior research [9, 16, 29, 56] has explored the strategies provided by accessibility practitioners to enhance accessibility in BLV education and the challenges they face, limited studies [40, 48] have captured the accessible material production workflows from the perspective of these practitioners. Further, we know considerably less about how technological interventions, such as generative AI tools, could be integrated into transcribing workflows to augment practitioner expertise and streamline accessible content creation. Responding to this gap, our study explores how generative tools could collaborate with accessibility practitioners to automate and reshape accessibility workflows for educational materials. To study this, we developed Kanak, a prototype AI system that extracts, converts, and generates accessible STEM content from visual formats, with flexible delivery across different platforms. We then conducted a user study involving seven accessibility practitioners, including braille transcribers, tactile graphic designers, and TVIs, to examine how Kanak supports the transcription of visual educational content into accessible formats [49, 53].

The purpose of our study is twofold. First, we identify the challenges in the current process of accessible educational material production and how accessibility practitioners perceive the design of an AI-powered generation tool, Kanak, in their transcribing process, extending prior work [16, 46, 61, 76] on accessibility practitioners' strategies on adapting academic content for BLV students. In doing so, this study provides in-depth empirical evidence of practitioners' step-by-step transcription workflows and their multi-tool ecosystems, which reveal how practioners strategically select each tool based on the content type of educational materials and formatting needs. Second, we systematically evaluate the usability and efficacy of Kanak to support the generation of accessible educational materials through both qualitative and quantitative evaluation. This approach enabled us to capture and assess how an AI-powered generation tool like Kanak could be integrated into—and potentially streamline—current transcribing workflows. Based on our findings, we rethink the accessible educational materials' transcribing workflows and discuss design considerations to support accessibility practitioners, including providing context-aware formatting suggestions, supporting content verification and proofreading, enhancing the generation of accessible graphical components, and promoting human-AI collaborative interventions.

The remainder of the paper is organized as follows: Section 2 reviews related work; Section 3 describes the design and development of the tool; Section 4 outlines the evaluation method; Sections 5 and 6 present findings from the user evaluation; and Section 7 provides a discussion of the results.

2 Related Work

Our study is informed by prior research on accessible educational materials generation for BLV students and the practices of accessibility practitioners to support accessibility of educational materials for BLV students.

2.1 Accessible Educational Materials for BLV Students

A growing body of research has highlighted the accessibility challenges of BLV students when interacting with visual materials [14, 57, 61, 76]. For instance, Prakash et al. [57] found that BLV students often invest substantial time in accessing information from visual diagrams like bar charts. In response to these accessibility issues, there has been increasing research to improve the accessibility of visual educational materials for BLV students [5, 8, 23, 28, 42, 45, 60, 70, 75]. For example, Giudice et al. [23] introduced a tool that allows learners to explore visual graphics through vibration patterns and auditory feedback triggered by touch interactions. Similarly, Zhao et al. [80] developed TADA to enable BLV students to access node-link diagrams by engaging in open-ended touch-based exploration, node search, and navigating between nodes.

Relatedly, researchers [22, 31, 44, 59, 73] have also focused on improving accessibility for discipline-specific content. For example, in the domain of mathematics, Ge and Seo [22] developed an equation editor using spatial audio cues to support intuitive navigation for BLV students. Likewise, Knaeble et al. [31] created AutoChemplete, an interactive tool for generating accessible representations of chemical structural formulas. Others [28, 64] aimed to improve accessibility of data visualizations. Sharif et al. [64] proposed VoxLens, which enables BLV learners to explore visualizations through voice-activated commands and obtain holistic summaries of the data. Hoque et al. [28] designed Susurrus, a sonification-based tool that integrates keyboard interaction and text-to-speech feedback to present data through natural sounds. In addition, to support access to various chart types, Moured et al. [45] introduced Chart4Blind, an intelligent interface that converts bitmap images of line charts into accessible digital formats (e.g., SVG, CSV). Zhang et al. [79] developed ChartA11y to provide accessible interaction techniques for making line charts, bar charts, and scatter plots.

While impactful, much of the existing work has centered on making specific types of visual content accessible in isolation, such as charts or discipline-specific graphics. In contrast, accessibility practitioners must routinely transcribe entire documents containing diverse visual elements, such as charts, diagrams, equations, and more, which requires a more holistic approach. Our study addresses this overlooked need by examining the end-to-end workflow of practitioners and exploring how an AI-powered generation tool can support the holistic transcription process of educational materials as they occur in real-world contexts.

2.2 Practices of Accessibility Practitioners

Inclusive education continues to face challenges when teaching methods in classrooms fail to address the diverse needs of all learners. This is often due to the inadequate teacher preparation and a lack of both human and material resources [25]. Among the key stakeholders of BLV education, teachers of the visually impaired (TVIs) face several challenges in providing accessible learning experiences to BLV students due to the inaccessibility of mainstream learning resources, which often rely heavily on visual representations and are not designed with non-visual accessibility in mind [4, 29, 30]. For instance, Stefik et al. [68] noted that when adapting a computer science curriculum, TVIs expressed concerns about the heavily visual learning materials, the absence of braille-compatible practice exams, the omission of visual graphic-based exam questions, and the implications of such omissions on educational equity for BLV students.

To address these inaccessibility challenges, TVIs provide considerable effort by adapting academic content to meet the accessibility needs of BLV students [9, 56, 61]. In doing so, they consider strategies to enhance the accessibility of learning materials for their students [21, 65], such as the use of tactile resources for interpreting visual information non-visually [56]. Hayes and Proulx [26] showed that TVIs consider classroom adaptations, such as hands-on activities and increased lesson time, important for topics like science and mathematics. Rosenblum et al. [61] found that TVIs provided a range of strategies to help students access and understand information presented in graphics. These included aligning instructional language with that used by general education teachers, simplifying complex visuals, for instance, by reducing data points in scatter plots, and tailoring instruction to meet students' individual learning needs. Likewise, Zebehazy and Wilton [76] reported that TVIs faced numerous challenges related to the preparation and instruction of tactile graphics to support accessibility for BLV students, including limited time for material production and lack of standardization in how tactile graphics are designed. TVIs expressed concern that learning materials often arrive late for timely transcription or modification into accessible formats [36]. In addition, classroom support staff were sometimes unfamiliar with how to properly convey graphical information or felt rushed to keep pace with the lesson, further hindering the delivery of accessible learning experiences [76]. Corn and Wall [16] found that braille production systems often rely on volunteers, which leads to inconsistencies in the availability and quality of accessible educational materials. As such, there is no guarantee that students who use braille will receive the appropriate quantity or quality of accessible materials corresponding to the mainstream educational curricula.

Extending this prior scholarship, our study captures the current transcribing workflows of accessibility practitioners and their challenges, investigating how AI-powered tools can be integrated into this transcribing process, and identifying opportunities to optimize workflows for efficient and effective production of accessible educational materials for BLV students.

3 Tool Design and Development

To explore how generative AI can be embedded into practitioners' workflows for generating visual educational materials (e.g., worksheets, handouts, quizzes) into accessible formats (e.g, braille, tactile graphics), we developed Kanak, a web-based tool that supports automation with human-in-the-loop control. As an initial use case, we developed and deployed a prototype version of Kanak that focused on SAT test preparation materials, which enabled practitioners to generate accessible equivalents of the visual SAT paper (in scanned PDF format) that can be instantly delivered to students as accessible versions, such as BRF for braille and DOCX for screenreader access. The tool enabled users to generate accessible materials through a range of integrated features and supported flexible delivery of the accessible content across multiple hardware and software platforms, which we describe below.

3.1 Dynamic Visual-to-Tactile Transcribing and Editing

We designed Kanak to support end-to-end transcribing of visual documents into accessible formats. The tool begins with a document upload interface similar to file-management systems like Dropbox, which allow users to manage multiple uploaded documents, preview and edit contents, and download outputs. After the file upload, the backend engine of the tool processes the uploaded document and initiates a visual-to-tactile transcribing process. The tool automatically extracts (Figure 1 (d)) textual, math, tabular, and graphical elements into editable blocks from the uploaded document. It provides users with an in-browser editor (Figure 1 (e)) where different content types (e.g., text, table, math equations, graphics) are made interactively editable.

3.2 Inline Editing for Multiple Content Types

To provide accessibility practitioners with flexible and intuitive editing methods, Kanak incorporates a multi-pane preview editor that presents the original and transcribed document contents side-by-side. Users can directly edit all extracted document contents, such as text, math equations, tables, and graphics, within the interface. Users can also rearrange the editable blocks to customize the flow and order of the content as needed (Figure 1 (d)). These features enable practitioners to correct the content extraction errors across diverse content types and refine content within a single platform, which eliminates the need to switch between multiple tools. For example, when users click on a text block, it activates a standard text editor. When they interact with a math equation, it launches an equation editor. Likewise, tables open in a dedicated spreadsheet-style table editor, which allows users to perform cell-level modifications. For graphical content, such as bar and line graphs, users can adjust data labels, axis values, and other visual attributes through a built-in graphic editor.

3.3 Custom Graphic Redrawing Feature

Kanak allows users to manually revise or recreate graphical content, given that automated graphics extraction is still evolving and often inaccurate [15, 71]. This feature enables practitioners to retain control over the tactile interpretability of visual graphics. Users can use a built-in graphic editor within Kanak that supports drawing with different shapes and line textures. For instance, users can specify properties, such as line style (solid, dashed) and line width.

3.4 Output Generation in Multiple Accessible Formats

Recognizing the diverse range of assistive technologies used by BLV students, including notetakers, refreshable braille displays, and screen readers [6, 21, 43], Kanak supported the export of transcribed documents into multiple device-compatible formats. While audio-based output is under development for future iterations, the supported output formats include BRF (braille ready format) for embossing or use with braille displays and DOCX for further editing or embossing. The prototype also supported Nemeth[1] codes for mathematical content. Additionally, users have the option to specify if they require contracted braille[2] or not in the transcribed document.

3.5 Prototype Architecture and Workflow

The Kanak prototype was designed to align with the structural and content-specific ways of standardized assessments, particularly the SAT, which comprises four distinct sections: reading, writing, math with calculator, and math without calculator. Implemented as a web-based application, the tool used ReactJS for the frontend interface and NodeJS for backend operations. Kanak leveraged computer vision and deep learning techniques to analyze visual documents and automate their transcription into accessible formats, facilitating non-visual access for BLV learners. The underlying models and backend services of the tool are proprietary to UNAR Labs [32]. The tool architecture consists of five key modules, each focusing on a specific stage in the accessibility conversion pipeline, which we describe below:

[1] Nemeth Code is a braille code which is developed for writing mathematics and scientific notation in braille [1].

[2] The shorthand combinations of braille characters, that are used to represent common letter groups, syllables, or whole words to make braille compact and efficient, are called braille contractions [18]

(a) User login page

(b) Dashboard page

(c) Document upload page

(d) Content preview and editing page

(e) Table editor page

(f) Output download page

Figure 1: Steps of Kanak's workflow: (a)–(f)

- **Pre-Processor:** Extracts embedded images and text from PDF documents and stores them as temporary assets for modular processing.
- **Text Processor:** Parses, formats, and semantically classifies the extracted text to ensure compatibility with non-visual consumption tools.
- **Graphic Processor:** Uses custom scripts in conjunction with OpenCV's EAST text detector to isolate graphical elements (e.g., charts, diagrams), identify their spatial attributes (type, size, color, and location), and convert them into structured spatial objects.
- **Reconstruction Module:** Translates these spatial objects into perceptually optimized representations for tactile access, such as braille and raised-line graphics, guided by tactile perception research [12, 23] and compliance with BANA guidelines [52].
- **Cross-Platform Delivery Module:** Compiles the structured accessible content into platform-specific output files (e.g., BRF for embossers, tagged HTML for screen readers, SVG for tactile rendering systems). This module ensures that content is tailored to the technical and usability constraints of target devices, including embossers, notetakers, refreshable braille displays, smartphones, and tablets.

Through this modular pipeline, Kanak could automate the task of transcribing diverse visual educational materials into standardized accessible formats for real-world educational use. By supporting the accessibility of multiple content types, including text, mathematical expressions, and graphics, Kanak addressed the core components of most educational materials, which provides an approach that could be expanded to support accessibility in other contexts (e.g., workplace, professional certification).

4 Tool Evaluation: Method

To uncover the challenges in current accessibility workflows and assess the usability of Kanak in generating accessible educational materials, we conducted a comparative and within-subjects study with seven experienced accessibility practitioners, with approval from the institutional review board of our university.

4.1 Participants

We recruited seven participants (1 Male, 6 Female) who had prior experience in transcribing visual educational materials into tactile formats. Participants were recruited with a study announcement distributed through an organization that works with blind or low-vision individuals. All participants were from the US. Two participants belonged in the age range of 45–50 years, two were 51–55 years, and three were 60–65 years. The sample size is considered reasonable in this context, as prior literature [63, 67] demonstrated that five to six participants are sufficient for assessing the usability and identifying the majority of issues in novel human-computer interaction (HCI) systems. Table 1 provides details about each participant's occupation, years of experience in material conversion, and the tools they currently use (e.g., Word, Firebird, Duxbury Braille Translator) for visual-to-tactile conversion.

4.2 Materials

For our study procedure, we prepared four sample PDFs (included in the supplementary materials), each consisting of modified version of the freely available SAT test preparation materials. Each document comprised four sections: reading, writing, math with calculator, and math without calculator. The documents were four pages long and included a range of content types (Figure 2 and 3), such as textual questions, bar plots, tables, mathematical equations, and graph-based math problems. We selected these sample documents because they reflect real-world learning materials commonly encountered in educational settings. The material's breadth of content and multimodal structure made it an ideal testbed for evaluating the system's ability to address varied visual and textual formats across academic contexts. The math sections included various difficulty levels of math questions ranging from quadratic to linear equations, as well as graph-related questions, geometrical figures, and tabular data. This diverse set of questions aimed to represent the typical content encountered in educational settings and provided a comprehensive way to evaluate the usability of the Kanak in converting different types of graphical content into accessible formats when compared to existing methods.

During the evaluation sessions, participants also completed three questionnaires: two System Usability Scale (SUS) [34] questionnaires to assess their experiences with Kanak and existing methods, and one Technology Acceptance Model (TAM) questionnaire [39] specific to Kanak.

4.3 Procedure

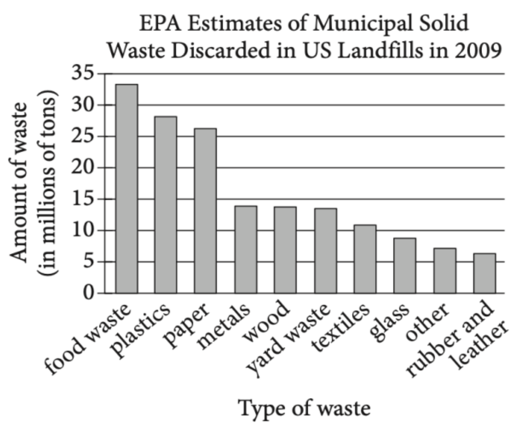
Prior to the study session, we emailed each participant two modified SAT test papers as PDF. The evaluation sessions had two conditions: a control condition and an experimental condition. In the control condition, participants walked us through their existing workflow by transcribing one of the provided PDFs into a tactile equivalent format. In the experimental condition, participants used the Kanak tool to transcribe the other PDF. At the beginning of each session, we obtained verbal consent from all participants. We first asked them to describe the tools they typically use for transcribing visual content into accessible formats. We then requested them to walk us through their process of transcribing visual materials using one of the provided sample PDFs that we sent via screen sharing. This live demonstration included copying content from the sample PDF, pasting it into different platforms such as Microsoft Word or Duxbury Braille Translator, and transcribing graphical elements, such as graphs, bar plots, and geometrical content. Participants also provided approximate estimates of the time they would typically need to complete the full conversion of the PDF contents. Throughout the demonstration, we probed participants for deeper reflection on the challenges they encountered during the transcribing process.

Following the demonstration of participants' existing transcribing workflows, we introduced participants to the Kanak tool via screen sharing. Using a separate trial sample PDF, we provided a demonstration of Kanak's core features, including how to rearrange content, edit textual elements, modify tables, and update graphical content such as bar plots using the tool's built-in editors. We also showed participants how to export the transcribed materials in accessible formats such as BRF and DOCX. After this demonstration, we provided participants access to Kanak via the website URL and login credentials. We then requested them to use the tool to transcribe one of the PDF documents into an accessible equivalent. Throughout the session, we offered reminders to participants as needed about Kanak's available features. As participants shared their screens and walked us through their use of the tool, we prompted them to interact with various features, including content rearrangement, text and math equation editing, table formatting, and plot editing through the built-in graphic editor. We asked them to share their thoughts on these features and whether they found them useful in their workflow. After the conversion, we requested participants to download the transcribed files in both BRF and DOCX formats, open them, and discuss their opinions on the transcribed materials. Further, similar to the earlier part of the session, we asked participants to estimate the time they might need to transcribe educational content in the PDF using Kanak.

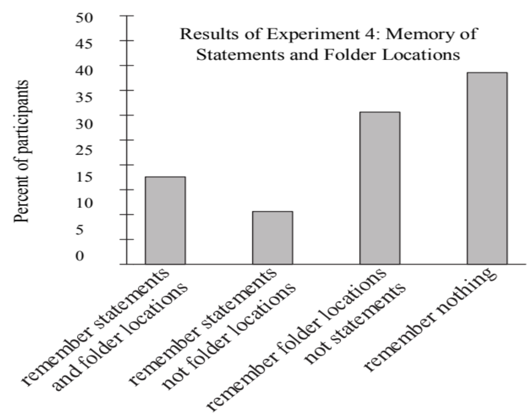
Next, we asked participants to reflect on their experience using Kanak for the visual-to-tactile conversion process and probed for any changes and challenges compared to their typical conversion workflows. Finally, we collected their feedback through the questionnaires that included Likert-scale items from the System Usability Scale (SUS) for both Kanak and existing methods, and the Technology Acceptance Model (TAM) specifically for Kanak. Each evaluation session lasted approximately 90 minutes. Participants

Table 1: Details of participants (n=7). All participants were sighted.

ID	Occupation	Experience with Conversion (Years)	Existing Tools Used for Conversion
P1	Braille Transcriber	25	Word, Braille2000
P2	Braille Transcriber, Tactile Graphic Designer	20	Adobe Illustrator, Viewplus Rogue, Word, Duxbury Braille Translator
P3	Braille Transcriber	5	Tiger Software Suite, Duxbury Braille Translator
P4	Braille Transcriber, TVI	36	Word, Duxbury Braille Translator
P5	TVI	20	Magic Paper, Tactile Image Enhancer, Braille Blaster, Firebird, Tiger, Duxbury Braille Translator
P6	TVI	7	Word, Duxbury Braille Translator, Raised papers
P7	TVI	8	Word, Duxbury Braille Translator

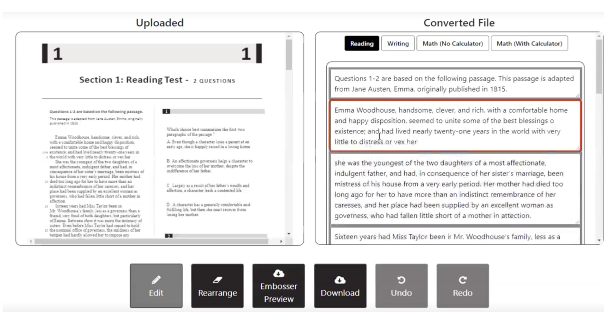


(a) Bar plot from one sample PDF

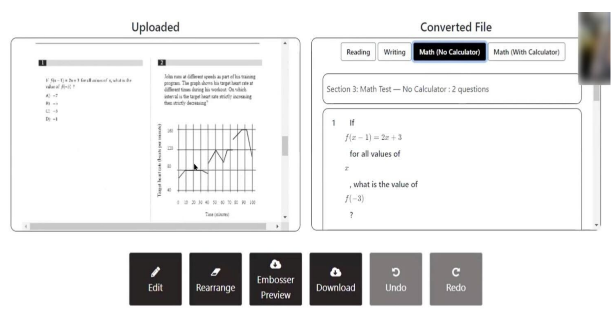


(b) Bar plot from another sample PDF

Figure 2: Example bar plots from sample PDFs used in the study



(a) Desiring to combine editable content blocks (observed in the right pane)



(b) Encountering blurry math equation in uploaded PDF (pbserved in the left pane)

Figure 3: Kanak's user interface

were compensated with US$50 per hour (prorated) Amazon gift cards. For analysis, all sessions were video recorded and transcribed.

4.4 Analysis

We analyzed the qualitative data from the user evaluation sessions using a reflexive thematic analysis approach [11]. The first and second authors open-coded all transcripts line-by-line. This was followed by weekly research team meetings to discuss and refine codes and themes. Our analysis focused on understanding participants' reactions to the features of Kanak and how they interacted with the tool during real-time visual-to-tactile generation tasks. In particular, we captured how participants perceived the role of AI-powered generation in facilitating access in BLV education, and how such technology might support their transcription work. This analysis was informed by prior research on the practices of accessibility practitioners in transcribing visual educational materials into accessible formats [9, 56, 61] and existing challenges in the preparation and delivery of accessible educational materials [6, 16, 46, 68, 76].

To analyze the quantitative data, we followed statistical analysis techniques. We reported the mean and standard deviation for each item in the questionnaire (Table 2 and Table 3). Further, we used non-parametric tests (i.e., Wilcoxon signed-rank test) to evaluate differences in response frequencies, given our within-subjects questionnaire design comparing participants' responses for Kanak versus existing methods, small sample size, and non-normal distribution of data. All statistical analyses were performed in Python using the SciPy and Pandas libraries [19, 20].

5 Tool Evaluation Findings: Qualitative

Our analysis of the user evaluation revealed how participants used existing tools in their accessible content generation workflows and how they reacted to the design of Kanak. We further uncovered participants' needs for control and customization while working with diverse content types.

5.1 Managing Multifaceted Strategies at Each Step of the Existing Transcribing Workflows

Participants applied a wide range of strategies in their existing transcribing workflows, which were mostly influenced by the type of content they were transcribing, such as literary text, mathematical equations, tables, or graphic plots. This content-specific approach required participants to frequently switch between multiple tools to complete transcribing a single document.

5.1.1 ***Multiplexity of Tool Use and the Role of Formatting***. A common first step in most participants' existing transcribing workflows involved manually selecting and copying text from PDFs into other tools to begin transcription. For instance, participants reported using Braille2000 (P1), Microsoft Word (P2), and Duxbury Braille Translator (DBT) (P4, P5) as part of this process. However, when documents contained embedded or image-based text that could not be directly selected, participants adopted alternative strategies. P2, for example, mentioned that she *"run it through ABBYY FineReader [an OCR utility] and do an OCR on it"* to extract the text. Similarly, P1 used Adobe Acrobat's OCR features, while P4 and P5 manually retyped the textual content. In contrast, after experiencing how Kanak automatically addressed text extraction without requiring manual intervention and OCR tools, participants appreciated how it streamlined this initial step, as P5 noted:

> *"So, the fact that it translated it [the PDF], brought it into the system without me having to worry about copy and paste not working... that's really amazing."*

Some participants used an intermediate tool in their existing workflows, such as Microsoft Word, to prepare documents before importing them into specific transcription software, such as DBT or Braille2000. After extracting the text from the original PDF, participants carefully reviewed and curated the content on Microsoft Word to ensure its accuracy, as P2 mentioned:

> *"When I'm working in Word, I read through it carefully to make sure everything is making sense because sometimes OCR does unexpected things."*

Through this step, participants curated and formatted the extracted texts so that they would be correctly interpreted by the braille transcription software. For instance, participants described adding structure markers and layout adjustments, such as skipping lines before paragraphs to reflect the visual separation present in the original document (P4, P5) and omitting words like "continue" at the end of a page (P1). Participants also performed additional formatting in the braille-formatted document before embossing. This step was necessary to ensure structural clarity, especially when managing meaningful groupings of content for students, as P2 explained:

> *"... It's just a point of going through and making sure that things like a question and all of its answer choices, if they fit on one page, need to be kept together. If that grouping is too large to fit on one page, then the answer choices need to be kept together."*

Using their familiarity with content and formatting conventions, participants also reorganized content to improve clarity, for instance, P2 moved the table to precede related questions when the table was essential to understand the questions in the sample PDF. During document preparation, participants often used transcriber's notes [50] to clarify contextual elements for the braille reader. Participants added these notes based on their own understanding and familiarity with the content and the needs of the intended reader. For example, P1 and P2 highlighted the need to add a transcriber's note to explain the presence of item numbers embedded within a paragraph *"in case the student is not familiar with it"* (P2).

Participants also made layout-specific curation in the braille-formatted document to preserve corresponding visual cues of the original document. For instance, P1 and P2 added box lines [51] in braille to represent table borders. P1 added blank cells to represent the start of new print lines, saying: *"Three blank cells tells the braille reader that this is the start of a new print line"*(P1). Thus, formatting was an important part of participants' existing transcribing workflows, which was further reflected in their opinions of Kanak's formatted DOCX and BRF outputs. Some participants discussed several formatting issues, for instance, P2 observed dropped letters, missing punctuation, inconsistent capitalization, and improperly formatted section headings, and mentioned: *"This should be a centered heading... [It] looks like it's trying to be a paragraph... that just messes with the flow."* P4 pointed out the missing underlines and line numbering in a paragraph in Kanak's formatted outputs, which were necessary for maintaining the corresponding reference structure of the original document in the tactile equivalent.

5.1.2 ***Formatting Strategies Based on Diverse Content Types***. Another important aspect in participants' exisiting workflows was their formatting approach based on specific content types. For example, participants used mathematical content indicators, such as Nemeth code [1], to differentiate math from literary text. Their process involved carefully reading through the document and identifying which parts required Nemeth code, as P2 noted: *"... I'd go through it all, and the parts that need to be in math, I would add the Nemeth codes to them."* For graphical content (e.g., bar graphs), participants' practices varied based on the tools they preferred and their individualized workarounds. For instance, P2 used Adobe Illustrator to redraw bar graphs and relied on visual estimation rather than precise measurements and explained: *"I kind of eyeball it... it's my way... I just look at it and draw it."* While working on transcribing the bar graph in the sample PDF, P2 started by adding the heading, labeling axes, making grid lines, and then drawing the bars in Adobe Illustrator. Likewise, P5 redrew the bar graph in

Firebird. Participants also had to come up with workarounds while transcribing the bar graph, for instance, while dealing with long labels. Unlike print, where labels can be angled along the horizontal axis to save space, braille requires linear formatting and does not support angled text [55]. To address this constraint, most participants created abbreviated keys, for instance, using two-letter codes to represent each bar label. P3 explained:

> *"There's no way that this would fit across the board in braille... so we'd have to shorten things and make a key, for example, 'FW' for 'Food Waste' (Figure 2 (a))."*

Most participants highlighted that the most time-consuming and challenging parts of the existing transcription process were creating and formatting the graphics, particularly coming up with keys for long labels and aligning different graphical components. Referring to a specific graph in a section of the sample PDF, P5 estimated the graphic alone could take about *"five or six minutes."* Likewise, P1 stated that the hard part for him was not the textual content, rather transcribing the graphical parts. Participants also shared their challenges while creating graphics using existing tools, for example, P5, who used Firebird for plot creation, encountered difficulties during how to adjust numerical labels when the y-axis skipped the value 20 (Figure 2 (b)). She also mentioned that she could not *"resize anything once done... it's almost like an outdated program... you don't have any advanced options."* Conversely, while using Kanak, P1 found potential in Cartesian graph formats, especially in automatically generating line placement for users and explained: *"I could see some real benefit for this, especially if it puts the lines on there for me automatically."* Likewise, P2 found the usefulness of the features of Kanak, such as previewing the original image, flexibility of editing titles of the axes, and adding customized keys, noting: *"I could change the keys [bar labels] right away... that looks good."*

Overall, these findings reflect the fragmented nature of existing transcription workflows, involved efforts, and the reliance on tool-specific workarounds depending on content type and output constraints. From navigating unreliable OCR to redrawing graphics manually and encoding domain-specific structures like Nemeth math or braille tables, practitioners' transcription workflows required both technical skill and in-depth content familiarity. Within these workflows, while Kanak showed promise in automating discrete steps, such as text extraction and graph structuring, participants also called attention to the importance of retaining control over formatting and layout decisions.

5.2 Desiring Control and Customization Support Across Diverse STEM Content Types

While participants appreciated the side-by-side user interface with original and editable content (Figure 1 (d)) in Kanak, they called attention to the need for proofreading features during the transcribing process, particularly when working with mathematical or graphical content. P4 highlighted the challenge of proofreading mathematical content without access to the zoom-in feature, mentioning:

> *"... it's (Figure 3 (b)) still blurry on my screen... I wouldn't be able to proofread these or to scan them for accuracy... if I could have a way to blow this up."*

Likewise, P1 shared the challenges in redrawing graphical components in Kanak without a persistent and clear reference to the original image. Further, he expressed the need for moving beyond rigid templates toward more adaptable design environments. He desired overlaying graphics from original documents for accurate tracing, as he described:

> *"It'd be nice if I could actually pull it [original document] over here and actually draw right on top because some of these get pretty intricate... if I had a flower or a space shuttle or whatever I'm creating."*

P1 desired to add line textures and weights while creating graphical content. P4 also expressed interest in editing capabilities within the embosser preview of Kanak to make adjustments before finalizing the output without repeating her entire workflow.

Participants highlighted the importance of having control over formatting and layout decisions to deal with nuanced transcription rules and layout elements. For instance, while using Kanak, P2 expressed her desire to manipulate layout elements directly, such as combining the content boxes and controlling line flow for easier understanding by students and noted: *"Can I combine?... I'd like to combine these two boxes (Figure 3 (a))... these things need to stay on the same line."*

Collectively, these findings indicate that participants appreciated Kanak's capabilities and its side-by-side interface for accessible content generation; yet, they also highlighted the importance of accuracy and control, especially when handling mathematically dense or visually complex materials. The inability to zoom-in, trace over original images, and preview embossing outputs in detail limited participants' confidence in Kanak's outputs. These challenges point to the need for generative tools that not only automate tasks but also provide opportunities for customization that align with the nuanced needs of accessibility practitioners. Complementing these findings, our quantitative data analysis provided additional insights into participants' reactions to Kanak.

6 Tool Evaluation Findings: Quantitative

Participants' responses to the SUS items (Table 2) reflected a general preference for the Kanak tool over existing methods. Notably, the item "I think that I would like to use this system frequently" received a mean score of 4.43 (SD = 0.53) for Kanak, compared to 3.43 (SD = 1.27) for the existing method. Participants also mostly agreed on Kanak being as less complex ("I found this system unnecessarily complex": Kanak Mean = 1.86, Existing Methods Mean = 2.57), and showed higher confidence in using it ("I felt very confident using the system": Kanak Mean = 4.14, Existing Methods Mean = 3.57). However, other items showed minimal differences, such as "I thought the system was easy to use" (Kanak Mean = 4.14, Existing Methods Mean = 4.29) and "I needed to learn a lot of things before I could adapt it to my process" (Kanak = 1.86, Existing Methods Mean= 2.00). To determine whether these observed differences between Kanak and the existing method were statistically significant, we conducted Wilcoxon signed-rank tests for each item. The results showed that none of the item-level comparisons were

Table 2: Participants' (n=7) system usability scale (SUS) item ratings for existing Method and Kanak. (Response scale: 1=Strongly Disagree, 5=Strongly Agree)

Statements	Existing Method		Kanak	
	Mean	SD	Mean	SD
I think that I would like to use this system frequently.	3.43	1.27	4.43	0.53
I found this system unnecessarily complex.	2.57	1.27	1.86	0.69
I thought the system was easy to use.	4.29	1.11	4.14	1.07
I think that I would need the support of a technical person to be able to use this system.	2.29	1.38	1.57	1.13
I found the various functions in this system were well integrated.	4.14	1.21	3.86	0.90
I thought there was too much inconsistency in this system.	1.57	1.13	1.71	0.49
I would imagine that most people would learn to use this system very quickly.	3.43	1.27	4.14	0.69
I found the system very cumbersome to use.	2.29	1.70	2.00	1.00
I felt very confident using the system.	3.57	1.62	4.14	1.07
I needed to learn a lot of things before I could adapt it to my process/approach.	2.00	1.41	1.86	1.07

Table 3: Participants' (n=7) technology acceptance model (TAM) item ratings for Kanak. (Response scale: 1=Strongly Disagree, 5=Strongly Agree)

Statements	Mean	SD
A. Ease of Use		
It is easy to use.	4.57	0.53
It is simple to use.	4.71	0.49
It is user friendly.	4.71	0.49
It requires the fewest steps possible to accomplish what I want to do with it.	3.86	1.21
Using it is effortless.	3.57	0.53
I can use it without written instructions.	4.43	1.13
I don't notice any inconsistencies as I use it.	3.57	1.27
Both occasional and regular users would like it	3.86	1.07
I can recover from mistakes quickly and easily.	4.14	0.90
I can use it successfully every time.	4.00	0.82
B. Ease of Learning		
I learned to use it quickly.	4.71	0.49
I easily remember how to use it.	4.71	0.49
It is easy to learn to use it.	4.71	0.49
I quickly became skillful with it.	4.43	0.79
C. Satisfaction		
I am satisfied with it.	4.14	1.07
I would recommend it to a friend.	4.29	0.76
It works the way I want it to work.	3.71	0.95
I feel I need to have it.	3.71	1.11
It is pleasant to use.	4.14	1.07

statistically significant at the $p < 0.05$ threshold. The small sample size might have limited our ability to detect statistically significant differences. These findings showed a clear trend favoring Kanak over existing methods, particularly in perceived frequency of use, simplicity, and user confidence. However, none of the differences reached statistical significance, likely due to the small sample size. Despite this, the findings highlight Kanak's potential and suggest user receptiveness, indicating a need for further evaluation in larger and more diverse user settings to fully assess its impact.

Participants' responses to the TAM items (Table 3) indicated positive perceptions of the Kanak tool across all three categories: ease of use, ease of learning, and satisfaction. Within the ease of use category, items such as "It is simple to use" and "It is user-friendly" received a mean of 4.71 (SD = 0.49) and "It is easy to use" received a mean of 4.57 (SD = 0.53). This reflected participants' perception that the tool is intuitive. Further, participants mostly agreed on being able to use Kanak independently, as shown in their scores for "I can use it without written instructions" (Mean = 4.43, SD = 1.13), "I can recover from mistakes quickly and easily" (Mean = 4.14, SD = 0.90), and "I can use it successfully every time" (Mean = 4.00, SD = 0.82). In the ease of learning category, participants agreed on across all items, such as "I learned to use it quickly," "I easily remember how to use it," and "It is easy to learn to use it" received a mean of 4.71 (SD = 0.49), and "I quickly became skillful with it" received a mean of 4.43 (SD = 0.79). These findings suggest that participants found the Kanak tool easy to learn. The satisfaction category also received mostly positive ratings. Participants indicated that they were satisfied with Kanak (Mean = 4.14, SD = 1.07) and would recommend it to others (Mean = 4.29, SD = 0.76). However, slightly lower means for "It works the way I want it to work" and "I feel I need to have it" (both Mean = 3.71) suggested the tool might not yet be perceived as personalized to individual workflows.

While these findings highlighted the usability and learnability of Kanak, they also provided implications for further iteration of the tool that supports a more personalized transcribing workflow. Together with qualitative feedback, these survey results showed the tool's promise and provided insights for its future iterative design and deployment.

7 Discussion

Based on our findings, we rethink the transcribing workflow for accessible educational materials and discuss design considerations to inform the development of future technological interventions to support STEM accessibility for BLV students.

7.1 Rethinking Transcribing Workflows for Accessible Educational Materials

Prior research [9, 56, 61, 76] called attention to how accessibility practitioners (e.g., TVIs) often adapt educational materials to meet the accessibility needs of BLV students. Our findings extend this by capturing empirical insights on how accessibility practitioners are currently performing their transcribing work through developing their step-by step workflows and multifaceted tool use ecosystem, each selected based on content type and formatting need. However, transcribing content was not merely a procedural task; it required nuanced considerations that was learned through years of expertise and situated knowledge of practitioners. Practitioners relied on their expertise to estimate how much time and adaptation certain content might require [61, 76], and to determine which formatting standards (e.g., Nemeth vs. UEB) were appropriate [16, 76]. While their practices reflects years of expertise and adaptation, it also demonstrates how practitioners provide additional effort to repeatedly switch between tools or manually copy and paste content to move between steps. Consequently, their experience with Kanak, where participants could edit different content types in the same space surfaced the potential to rethink their multi-tool pipeline. Our findings suggest that, rather than relying on a fragmented toolchain, a more integrated workspace that allows direct curation and formatting without leaving the platform has the potential to support the transcribing work for accessibility practitioners.

In parallel, this shift requires careful consideration of what it means to move away from a well-established workflow of experienced transcribers, as our findings showed that practitioners are satisfied with their current workflow. Therefore, generation tool like Kanak should not aim to replace expert judgment or expertise, but rather to support it by offering flexible layout control, editable previews, and seamless transitions between content types. These needs align with other expert domains, such as knowledge workers [10, 74], journalism [37], and architectural design [78], where domain experts benefit from all-in-one environments that support precision, customization, and expert oversight. As such, developers should consider designing for expert-in-the-loop workflows by incorporating more control and decision-making support to make transcribing work both adaptable and scalable.

7.2 Design Considerations for Generating Accessible Educational Materials

Building on prior work [26, 61, 69, 76] on the implications of delays in the timely generation and adaptation of educational materials into accessible formats in BLV education, our study provides in-depth insights into the transcribing workflow of accessibility practitioners and their needs. Based on these findings, we provide practical design considerations for developers to support the transcribing work of educational materials.

7.2.1 ***Providing Context-Aware Formatting Suggestions.*** Our findings revealed that practitioners provided significant effort into applying correct formatting throughout their transcribing work [16, 76]. For this, they currently depended heavily on their own memory and personal understanding of formatting conventions. In addition, these formatting rules are highly context-sensitive; for instance, formatting the start of a new line differs from using box lines in braille to indicate table borders [51] and mathematical notation differs from literary text [1, 13]. Likewise, deciding when to insert a transcriber's note is based on contextual understanding [50]. Some participants also recalled how it took considerable time and practice to become proficient with these formatting rules, implying a steep learning curve for novices. To address this, we recommend implementing context-aware formatting suggestions that provide real-time, relevant suggestions to assist users during their transcribing work. Such a system could allow users to accept, reject, or revise suggestions [7]. For example, when encountering a paragraph that includes embedded item numbers, the system could display an inline hint to insert a transcriber's note to clarify the context of the numeric markers.

7.2.2 ***Supporting Content Verification and Proofreading.*** Practitioners provided substantial effort in re-verifying both text and graphical elements at every stage of their transcribing workflow, from OCR extraction to DOCX conversion to the embosser preview. In addition, during the use of Kanak, proofreading was their main concern. For instance, some participants expressed frustration when they were unable to zoom in on the original document for comparison. These findings extend prior work [54, 74] that highlights domain experts' desire for design features that support accuracy and precision. As such, there could be opportunities for content verification and proofreading [33, 47] in transcribing tools. For example, enabling zooming into side-by-side original and converted document views and highlighting differences between the original input and the transcribed output (e.g., missing punctuation, extra or missing lines). Further, there could be opportunities to flag parts of the output for review, add inline comments, or suggest edits without directly changing the content, which could support self-checking or proofreading before final embossing or export.

7.2.3 ***Enhancing the Generation of Accessible Graphical Components.***

We found that transcribing graphical components is the most effortful and time-consuming aspect of accessibility practitioners' work. Prior research [23, 28, 42, 45, 79, 80] mostly focused on making isolated graphical components accessible for BLV students, such as bar graphs, node-link diagrams, or plots. We extend this research by uncovering practitioners' current strategies for generating accessible graphics, often manually redrawing them in separate tools. In this regard, while practitioners appreciated that Kanak's design features for previewing and editing different types of graphical components (e.g., bar plots, mathematical diagrams) within a single tool, they also expressed a desire for additional capabilities, such as overlay-based tracing tools and customizable graphic primitives (e.g., line textures). In addition to these features, we propose that design approaches should be more aligned with transcribers' workflows for making content accessible, for example, supporting automatic key generation for longer labels since angled text could not be represented in braille. Similarly, opportunities to redraw components by providing a base layer or partial rendering of the original graphic that practitioners could draw over would streamline their graphic generation workflow.

7.2.4 ***Promoting Human-AI Collaborative Interventions.***

Our study highlighted that automating the generation alone cannot capture the nuanced decision-making of expert transcribers, extending prior work on accessibility practitioners' efforts on adapting academic content for BLV students [16, 21, 65, 69]. While practitioners appreciated Kanak's automatic text extraction and graphic templates, yet consistently overrode or refined these outputs to align with discipline-specific conventions. These behaviors point to a negotiated workflow in which the system and practitioner iteratively co-produce [27, 58, 72] the final tactile artifact. Therefore, future design should provide opportunities to turn accessible content generation into a collaborative partner [24, 58] that would preserve practitioners' agency while still streamlining mundane steps. For example, the system could explain its decisions in plain language (e.g., *"Used Nemeth for Math Notations"*) and provide *"why"* and *"undo"* controls so that users could understand and revise AI-based decisions without disrupting their workflow.

7.3 Limitations and Future Work

Although our exploratory study provided valuable insights on practitioners' transcribing workflows, the sample size of seven practitioners limited the generalizability of our findings. Future work should include a diverse participant pool by centering on a wider range of practitioner roles, institutional contexts, and transcription practices. Another limitation is the lack of direct evaluation with BLV students, the intended end-users of accessible learning materials. Future work should include usability studies with BLV students to assess their comprehension and learning outcomes from STEM materials while using Kanak. Relatedly, using sample SAT PDFs allowed us to examine how participants interact with varied content types. However, this approach may not fully represent the scope and complexity of real-world materials encountered in everyday transcription workflows, particularly as the current evaluation primarily involved relatively simple diagrams and equations. Future work should examine how Kanak could address more complex STEM content types, such as 3D graphs, multi-layer circuit diagrams, and chemical structures.

Given that Kanak is an evolving prototype, participants engaged with an early-stage system that lacked several features identified as important during the study. Thus, feedback from users reflected interaction with an early-stage tool, and future development should prioritize the integration of customizable formatting controls and proofreading capabilities. We also recommend longitudinal and in-situ deployments to evaluate Kanak in real-world work settings to gain a deeper understanding of how generative tools could support practitioner workflows. Further, no systematic user evaluation has been conducted to assess the compatibility of Kanak's outputs with assistive technologies such as screen readers or braille displays. Future work should investigate how BLV learners perceive and interact with the generated accessible learning materials across these platforms.

8 Conclusion

Our study uncover the iterative and expert-driven nature of the visual-to-tactile transcribing workflows of accessibility practitioners. These workflows involve navigating the use of multiple tools and applying contextual knowledge to produce accessible materials. While generative AI tools like Kanak show promise in reducing manual effort, our findings reveal the importance of aligning system features with practitioner goals by complementing, rather than replacing, human judgment. We identify key design considerations, including context-aware formatting suggestions, enhanced proofreading support, and adaptive graphic generation tools. By centering the lived experiences and practices of accessibility practitioners, our work calls for a human-AI collaborative approach that supports practitioners to maintain control, efficiency, and ensure the timely delivery of accessible STEM content for BLV students.

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