Beadwork Bridge: Understanding and Exploring the Opportunities of Beadwork in Enriching School Education for Blind and Low Vision (BLV) People

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ABSTRACT

Tactile perception is a crucial channel for education in individuals with blindness and low vision (BLV), and beadwork is a low-cost and widely adopted tool in their educational practices. In this paper, we aim to explore what the field of Human-Computer Interaction (HCI) can learn from beadwork practices in relation to educational somatic experiences and tangible interaction. To understand how beadwork practices are enacted, we conducted in-class observations, semi-structured interviews, and focus groups with BLV students and teachers. Our results suggest that beadwork is an effective tool to foster personal development (e.g., mathematical and creativity skills) and social engagement (e.g., career development). Based on our findings, we offer insights into how beadwork can serve as a cost-effective material for HCI, particularly in the context of embodied cognition and soma design. Finally, we propose how state-of-the-art technology could be integrated to optimize the overall process.

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CCS CONCEPTS

• **Human-centered computing → Empirical studies in accessibility**; *Empirical studies in HCI*; • **Applied computing → Interactive learning environments**.

KEYWORDS

Blind and low vision, beadwork, soma design, embodiment cognition, tactile materials, school education

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1 INTRODUCTION

Pedagogical research has highlighted the importance of tactile experiences for Blind and Low Vision (BLV) students in formal schools [7]. Indeed, many tangible, low-cost, and non-digital educational instruments have often been used in BLV classrooms

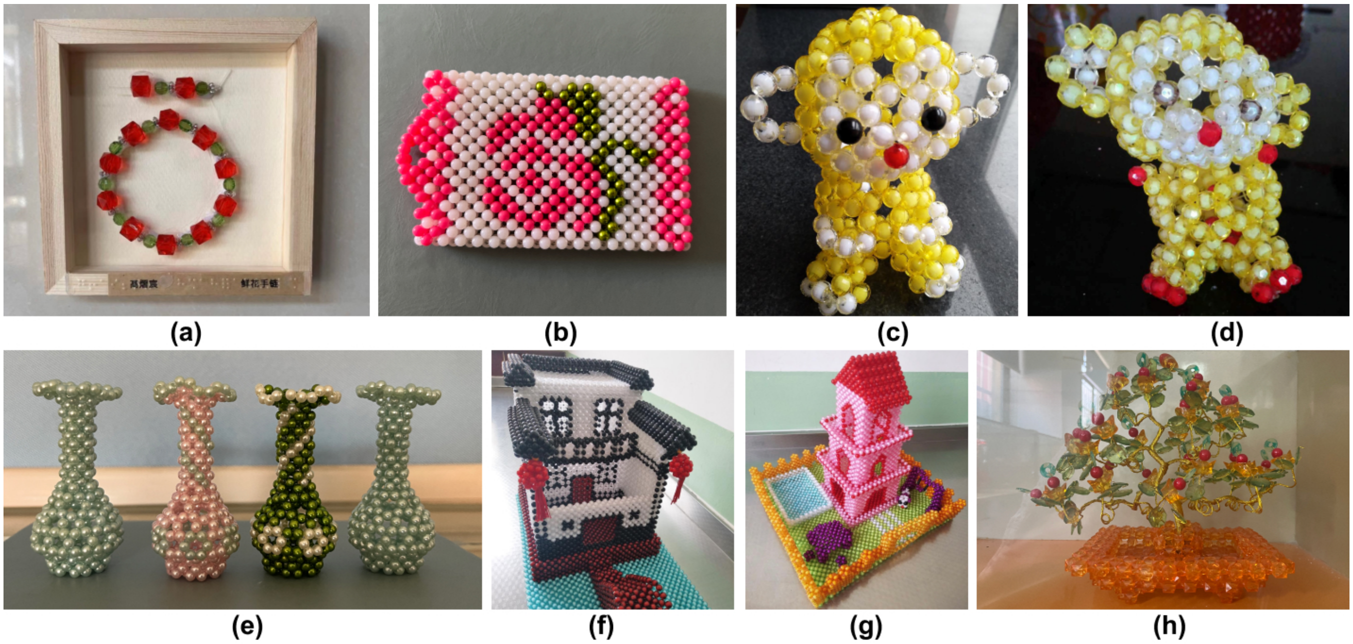

Figure 1: Beadwork created by BLV students. (a) A plane bracelet beadwork. (b) A plane cardholder beadwork. (c) A symmetrical 3D monkey beadwork. (d) A distorted monkey beadwork. (e) A series of vases with the color and pattern changing. (f) A symmetrical 3D traditional house beadwork. (g) An asymmetrical 3D beadwork. (h) A beadwork incorporates additional handicraft materials. Moreover, these figures show the progression from the simple to the difficult that teachers follow when teaching beadwork.

[66, 67, 81, 95]. HCI researchers focusing on BLV education have also focused their endeavors on the development of tangible prototypes [1, 13, 20, 26, 42, 50, 56, 58, 67, 75, 83, 90], and tangible computing systems have been used for BLV education [3, 13, 50, 56, 58, 70]. Overall, investigating tangible tools is a crucial aspect that needs to be accounted for while developing accessible technology for BLV students.

Tactile experiences and tangible devices can be fruitfully investigated through the lens of embodied cognition. Embodied cognition is the term used to describe how bodily interactions with the environment shape cognitive processes and mental representations [15]. Embodied cognition has been used to ground the design of tangible computing systems [9, 51], and tangible computing has been used for embodied cognition training [26, 67, 75, 83]. In the recent endeavor to look at how to design technologies with and for the body, soma design has emerged. Soma design suggests accounting for the entire body (the soma) as a central aspect in shaping interactions and *"entail a distinct manner of making space shutting out the outside world"* while also allowing *"users to turn their attention inwards, and they rely on articulation of bodily experiences to encourage learning and increased somatic awareness"* [33].

During our initial exploratory research on BLV education, we discovered a generalized and affordable tangible educational instrument - beadwork - currently overlooked by HCI researchers. Schools for BLV students across China conduct beadwork creation education. In this study, we aim to understand what HCI researchers can learn - in terms of somatic experiences and tangible interaction - from the practice of beadwork creation courses in schools of BLV students. We look at this general aim from two complementary perspectives. On the one hand, inspired by the research on soma design [33, 51, 79], we want to look at the tangible relationship between BLV students and beadwork to discover new insights on tangible interaction for education. On the other hand, by looking at a real school scenario we also aim at identifying problems that interactive technology can help to solve. Thus, we decided formalities our research aim into two research questions:

- RQ1) What kind of insights for tangible interaction design for BLV education can we learn from beadwork?
- RQ2) What are the main issues currently in the BLV beadwork class, and how can ATs help to solve them?

To answer our RQs, we conducted observations in two classes (N=29), semi-structured interviews with teachers (N=8) and BLV students (N=9), and focus groups with teachers (N=12) and BLV students. The main highlights of our results suggest that beadwork can support personal development (from mathematics to creativity) to social development or career possibilities. We also highlight practice and issues in beadwork creation education. In the discussion, we connect our findings to literature and uncover the practice and issues of beadwork creation in the education of BLV students, articulating two main contributions: (1) we contextualize beadwork educational practice within the current HCI debate, highlighting design insights in relation to somatic experiences for BLV students in relation to personal and social development; (2) we discuss current issues in beadwork pedagogical practice in light of state-of-the-art interactive technologies highlighting possible solutions.

2 BACKGROUND AND RELATED WORK

This literature review is articulated in four main sections. Firstly, we outline the use of tactile material in BLV education scenarios. Second, we provide an overview of embodied cognition related theories. Third, we present related work that focuses on beadwork creation. Finally, we provide an overview of beadwork creation used in Chinese schools.

2.1 Education of BLV Students

Formal school education plays an important role in BLV students' learning [2], as it provides BLV students with a learning environment and social connection through conducting structured activities [71, 94], training basic and professional skills [55], and offering academic knowledge [41]. Studies on BLV formal education have highlighted some challenges and difficulties in accessing information [4, 5, 36], gaining spatial intelligence [65], and using non-visual educational instrument[4]. Among the possible strategies to overcome these challenges, tangible and auditory interaction proved to be particularly useful [10, 29, 47, 66]. Given the frame of this paper, we will primarily focus on tangible interactions.

Tangible educational instruments - including tactile graphics, 3D models, and real objects - proved to be welcomed by teachers and BLV students in formal school education [66, 67, 81, 95]. In previous pedagogical research, tangible educational instruments can be applied to different disciplines in actual teaching practice. For instance, 3D models help BLV students understand the untouchable features of cells [34], chemical molecules [19], skeleton models [84] and geography [7]. Additionally, tactile graphics enhance learning mathematical formulas [25, 45] and images[29].

The aforementioned studies come from the field of pedagogy and educational studies. As such they did not focus on developing computational tools with these materials. Tangible research prototypes in the HCI field have been designed targeting specific disciplines, such as construction toys for programming languages[1, 13, 20, 42, 50, 58], tactile models for chemical concepts [56, 90], and tactile graphics for mathematics classes [3, 70]. Additionally, tactile educational instruments can be used to foster specific abilities such as spatial intelligence, motor abilities and spatial sense [26, 67, 75, 83]. While all these research works align in suggesting that tangible representation of teaching material has huge potential in BLV education, all the aforementioned studies were tested in controlled conditions and are yet to be tested "in the wild" in real classrooms.

In this study, we will analyze BLV classrooms from an HCI perspective, looking into this practice to distill design insights and directions. As such, we position our effort in between controlled lab conditions often adopted in HCI studies and the observation of the real world of BLV schools (usually done in pedagogic literature).

2.2 Embodied Cognition and Soma Design

In light of the central emphasis of this research paper on the investigation of tangible interaction, we position our endeavor within the contemporary scholarly discourse on tangible computing in relation to embodied cognition and soma design. Embodied cognition refers to the cognitive processes and mental representations shaped by the body's interactions with the environment [9, 15]. This includes how the body influences perception, attention, and decision-making in the context of using external artifacts [86]. Generally, researchers have relied on embodied cognition to design for people's bodily position, physical form, and interactive behavior according to the external artifacts [15, 22, 39, 40]. We can see from the previous study how the theory of embodied cognition has been used to ground the design of tangible computing systems, such as multisensory activities (e.g., tourism, learning and reading) [64, 73, 78] and gestures and postures in collaborative working environment [72]. Tangible computing systems have been introduced for BLV education [3, 13, 50, 56, 58, 70] and focusing on embodied cognition [26, 67, 75, 83]. Despite the engagement of embodied cognition in designing for accessibility [16, 52], there is a notable absence of literature specifically addressing the relationship between embodied cognition and beadwork.

In recent years, soma design has emerged as a way of designing technology centering on bodily experiences [33]. Soma design focuses on creating subtle and intimate interactions that encourage bodily inquiry, require feedback that follows the body's rhythm, and promote increased somatic awareness through the articulation of bodily experiences [51, 79]. While Soma Design often addresses the importance of different bodies - particularly in relation to the discourse on feminist HCI [30] - it has not thoroughly engaged with the design for BLV people. We argue that soma design is important for BLV people as tactile perception is particularly relevant to their everyday life activities.

2.3 Beadwork

In this paper, we analyze BLV classes using beadwork; we provide an overview of how different types of beadwork have been used in related literature. Beadwork is the art or craft of stringing beads together with threads to form flat images or 3D shapes. The styles of beads and the ways of beadwork creation are very diverse, which makes the complexity of beadwork also different. As a kind of handicraft widely practiced all over the world[8, 23, 37, 77], beadwork offers great creative spaces because of the diversity of materials and making methods[54]. Additionally, beadwork materials are primarily affordable and recyclable.

Some prior work has explored the value of beadwork in different domains for different groups. Researchers have highlighted that beadwork can be a valuable tool for craft women living with HIV/AIDS, providing them with a means for creative expression, making a living and fostering a sense of pride[21, 91, 92]. Furthermore, educational content (e.g., mathematical concepts) can be embedded in beadwork artifacts through activities for students to improve learning effects[61].

Beadwork is a low-cost handicraft generalized worldwide that can offer opportunities for interaction design as a cheap and tangible material. In the planning and system of primary and secondary education (including schools for BLV students) by the Ministry of Education, national standardization of school teaching hardware facilities and teaching methods has been carried out [62]. The government has facilitated technological support in primary and secondary school classrooms, including both ordinary schools and schools for BLV. The standard classroom is equipped with smart large screens, blackboards, projectors, electronic whiteboards, computers, TVs, mobile devices, and stereos in primary and secondary schools in China [63]. Additionally, according to the guidelines and sample courses provided by the Ministry of Education, the structured activity of beadwork creation courses in formal school education primarily involved three stages, which are preparation, instruction, and creation [62] Specifically, the teaching requirements for beadwork creation courses required teachers to prepare teaching aids and courseware in advance during the preparation stage. The instruction stage and creation stage typically occurred during the 45-minute classroom teaching and learning process, where teachers were required to integrate courseware and the functions provided by the smart classroom to instruct and guide students. In contrast, students engaged in creation and problem-solving.

Overall, beadwork is generally used as a tangible educational instrument in China's formal education of BLV. Thus, we propose that beadwork creation courses are worthy of investigation from the perspective of the previous HCI research as an affordable tangible material, and that design insights can be subsumed from such an investigation.

3 METHODS

The goal of our research was to investigate the teachers' and BLV students' practice and issues of beadwork creation in a real formal education scenario. By understanding teaching and learning practice involving beadwork, we can explore the opportunities of better leveraging beadwork as an educational instrument in the future. Additionally, probing the issues associated with beadwork creation can assist teachers in effectively teaching BLV students to engage in beadwork creation proficiently.

As shown in Figure 2, we conducted a study with two phases: (1) In-class observation and (2) semi-structured interviews and focus groups with teachers and BLV students. In classroom observation, we went to a school for BLV students to observe smart classroom settings and teaching processes in two classes' beadwork creation course. Then, we interviewed teachers and BLV students to acquire instructional approaches, teaching and learning preferences and outcomes. At last, we conducted focus groups to investigate the issues in formal school education and teachers' and students' expectations to address these issues. The university ethics review board approved this research.

3.1 In-class observation

We conducted on-site observations to obtain a comprehensive understanding of the classroom settings and instructional interactions of beadwork for BLV students.

3.1.1 Participants. The naturalistic behaviors of 29 BLV students and one teacher, who is responsible for the beadwork creation courses in these two classes, have been observed. These students are distributed across one Grade Four class with 14 students and one Grade Nine class with 15 students. In China, students in Grade Four are typically 11 or 12 years old, while those in Grade Nine are usually 15 or 16 years old. The observations were carried out with the explicit permission of the school catering to BLV students and the participants themselves.

3.1.2 Procedures. We used a covert observation technique to avoid disrupting the students' natural behavior in the beadwork creation course. Two observers (coauthors of this paper) conducted the observations. Both observers sat at a distance of approximately 3-5 meters, but on the opposite side of the classroom, having a clear overview of the students and their desks. We negotiated the method of observation with the teachers. The teachers informed the students of our presence before the beginning of the class; but, in order to minimize disruption of the usual activity, the class was not interrupted to present us during the class. The observers documented four distinct perspectives utilizing pens, notebooks and cameras as instruments: 1) The classroom settings, 2) the manner in which the teacher and BLV students interacted with the equipment and educational instruments,3) the interaction between the BLV students and teacher, and4) The interaction among the BLV students.

3.2 Interview and Focus Group

To understand why and how beadwork creation was introduced to formal schools from an empirical perspective, we conducted semi-structured interviews with teachers and BLV students about the beadwork practice. Additionally, issues and associated hopes to address the issues in beadwork creation were investigated in a focus group to reveal the future improvement in accessibility.

3.2.1 Participants. As shown in Table 1, eight teachers (N=8, six females and two males), and nine BLV students (N=9, five females and four males) were recruited using prior contacts and snowball sampling across various regions of the country. The teachers were full-time or part-time teachers of beadwork creation for BLV students currently employed at an educational institution. The teachers' experience ranged from one year to ten years.

All aforementioned participants (N=17) participated in semi-structured interviews. Among them, twelve participants (N=12), including three female teachers and all students, were recruited for the focus group discussions. Each focus group engaged with one teacher who guided the three students in recalling the creation steps and beadwork creation class experiences. Teachers and students were grouped together according to the composition of the real classes (teachers have been instructors of the students participating in the same focus group).

3.2.2 Procedures. For the observation data, two members of our research team compiled the notes and photographs taken by the observers in the classroom environment and settings.

Concerning the interviews, we began our interview by posing open-ended questions to the teachers and BLV students, spanning from inquiring about their perspectives on skill cultivation in the beadwork creation course, the structure and progression of the class, and any noteworthy technological use in the teaching of beadwork creation. We conducted interviews in person and audio recorded them. The participants were compensated 100 RMB per hour. The interviews lasted 1 to 1.5 hours, with an average of 1.25 hours.

Regarding the focus group to discuss the issues and hopes of beadwork creation practice, nine students and three teachers were

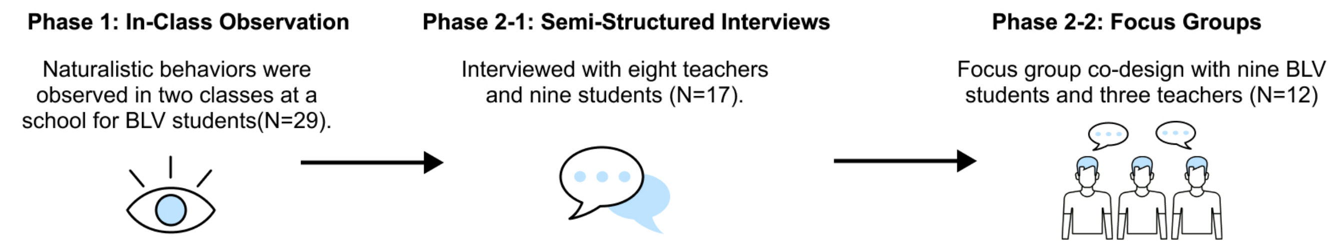

Figure 2: Mixed-method user study design and procedures with two phases: (1) In-class observation and (2) semi-structured interviews and focus groups with teachers and BLV students.

(a) (b)

Figure 3: (a) General BLV classroom settings and environment at school for beadwork creation course. (b) Students create their beadwork to recall the creation processes.

divided into three focus groups, each consisting of three students and a teacher. Focus groups were conducted in person at schools after the semi-structured interviews. We document the focus group using video and audio recordings. The teachers supplemented and elaborated upon the students' responses as necessary. After the focus group, the participants were compensated 150 RMB for every focus group. The duration of the focus groups ranged from 1.5 to 2 hours.

3.3 Data Analysis

We employed a thematic analysis method [11, 12] to analyze the data collected from the observations, semi-structured interviews, and focus groups. The data were coded using open coding using an inductive bottom-up approach by two researchers. The researchers then discussed and harmonized the codes. Thematic analysis was deemed the most suitable approach for our research questions, as it enabled us to identify recurring themes in the participants' behaviors and perspectives [11, 12, 80].

Two researchers independently coded the interview, focus groups, field notes, and photos using Miro [1] then discussed and harmonized their codes, creating a shared annotated version where both were in agreement. During the weekly meeting of the research team, the codes were presented and discussed by researchers. The codes were consequently recursively clustered themes and sub-themes through affinity diagramming. The process continued until the researchers who engaged in the discussion agreed on the emerging codes and their themes. Overall, in this process, we obtained 52 codes clustered as five themes and sixteen sub-themes.

4 RESULTS

According to the interview and focus group, we found that while all students participated in formal school education scenarios, only those with expertise and a desire to explore engaged in after-class education. Students have more freedom to create after class than they do in structured activities in formal school education. Our interview not only reconfirmed the results observed in the class but also summarized three themes about beadwork creation: Embodiment cognition in beadwork creation, issues and reactions of beadwork and teachers' and BLV students' expectations. To present intriguing quotes from participants, we used "T#" to represent the teacher and "S#" to represent the student.

For the sake of readability, before outlining the themes emerging from the analysis we briefly outline the main characters of Beadwork classes. Beadwork fabrication courses are widely offered in

[1]... is an online annotation service platform which supports collaborative working, such as coding, brainstorming and designing.

Table 1: Teachers' demographic information for the semi-structured interviews and focus groups. All teachers participated in the semi-structured interviews, while T1, T7, and T8 were the three teachers who participated in the focus group.

ID	Sex	Age	Teaching status	Beadwork Teaching Experience
T1	Female	49	Full-time	10 years
T2	Female	40	Part-time	3 years
T3	Female	33	Part-time	1 years
T4	Male	50	Part-time	1 years
T5	Male	54	Part-time	1 years
T6	Female	57	Full-time	3 years
T7	Female	50	Full-time	10 years
T8	Female	36	Full-time	10 years

Table 2: BLV students' demographic information for semi-structured interviews and focus groups. CP=Color Perception, CS=Contrst Sensitivity.

ID	Gender	Age	Vision Level	Blind Onset	CP	CS	Beadwork Experience
S1	Female	18	Totally Blind	Born	No	No	4 years
S2	Female	16	Totally Blind	Born	No	No	2 years
S3	Male	16	Totally Blind	Since 6	No	No	6 years
S4	Male	16	Low Vision	Since 5	Yes	Yes	4 years
S5	Female	17	Low Vision	Since 7	No	Yes	2 years
S6	Male	15	Low Vision	Born	No	Yes	1 years
S7	Male	19	Low Vision	Since 10	Yes	No	2 years
S8	Female	18	Low Vision	Born	Yes	Yes	9 years
S9	Female	18	Blind with Residual Vision	Born	No	No	9 years

Chinese BLV schools as a course, and beadwork is integrated into the formal school education of BLV students as important teaching material. Different schools offer beadwork creation courses at various grade levels (grades 1-9, 4-5, or 7-8). Each class usually consists of one instructor and 13-14 students. Beyond formal education classes, teachers and students also tend to establish clubs for extracurricular beadwork creation activities and entertainment. In formal school education beadwork is structured in three stages, which are preparation, instruction, and creation. The instruction and creation typically occur during the 45-minute classroom teaching and learning process.

4.1 Theme 1: Personal Development: Embodied Cognition and Learning

Embodied cognition emerged as a key element in the process of understanding and learning beadwork creation by manipulating the beadwork. Beadwork creation can cultivate and foster BLV students' intelligence and mathematical skills and creativity. We identified four sub-themes related to the embodied process which we outline below.

4.1.1 Understanding through Tactile perception (Subtheme 1.1). All students reported that tactile perception is their primary channel for discovering and learning the shapes and features of the different beadwork. Indeed, many creation processes and classes start by touching tangible beadwork samples. All teachers provided students with beadwork samples as an alternative channel for communicating visual characteristics (e.g., shape and structure).

BLV students memorize the learned beadwork by repeatedly touching the beadwork in order to understand its shape and features. Teachers (T1, T2, T3, T5 and T6) have observed that BLV students can develop a high level of precision in perceiving small objects by exploring them by hand. Acquiring precision is a gradual process that requires continuous usage of tactile feeling to gather information. Indeed, this process is not always smooth, S4 articulates, "Sometimes it is hard for me because beadwork creation is free and sometimes beadwork subjects share the same characteristics." Thus, it introduces challenges that require BLV students to constantly focus on their tactile perception in order to be accurate and minimize errors. The learning process experienced via tactile perception is generally easier and faster for young children (T1, T2, and T5). For instance, T5 reported, "At first, students struggle to find the holes in the beads, so getting familiar with beads of different materials and sizes and locating the holes is something that needs to be practiced repeatedly."

Improving tactile skills is particularly relevant for BLV life in general, improving their abilities in several activities, spanning from reading braille scripts to eating. For instance, T1 reported that peeling an egg is difficult, and by improving tactile perception, BLV students can gradually get acquainted with this. Additionally, this is useful for finding objects in any environment.

4.1.2 *Learning Modular structures and Mathematics(Sub-theme 1.2).*

Based on the information acquired via tactile exploration, BLV students are taught to construct beadwork using individual modules in their minds to comprehend the structure. At the same time, mathematical abilities are also trained in the processes of memorizing, counting, and calculating the modules of each beadwork that recombine the two simple geometric primitives of beadwork: circles and lines. Lines are composed of beads one after another, while circles could be composed of five, six or seven beads. For instance, S7 stated, "Based on the beadwork structures we've studied, I like to start feeling from the top of a physical example and then count the number of beads. For example, if it uses circles instead of lines, I'll count how many beads make up each circle." Since single modules are limited and regular, students only needed to remember some spatial algorithms that can be combined for (re)constructing and (re)assembling complex structures. Consequently, teachers adopt a progression in the complexity of the subject represented in the beadwork, starting with the simple construction of plane beadwork (e.g., bracelets and cardholders), symmetrical 3D beadwork (e.g., vases, plants and animals), and reaching complex asymmetrical 3D beadwork (e.g., architectures). Still, the more complex asymmetrical 3D beadworks are always composed of several smaller and simpler modules 1.

BLV students need to connect the mental representation of beadwork models to the physical tangible reality of manual work. In this process, students improve several aspects of spatial intelligence, such as spatial memory and 3D re-making abilities combined with mathematical and logical skills. For example, S8 stated, "I touch a beadwork example from top to bottom and from left to right. If the example is too large, I might even lose my sense of direction. So as a beginner, our teacher gives me a stick to help guide us along the example, assisting us in finding the top, bottom, left, and right directions." Furthermore, teachers told us that this finetuning of skills is particularly valuable and beneficial as it can be applied to other disciplines. For instance, T7 stated, "The design of a house will involve the calculation of angles, such as the angles of bridges and stairs. So, it will be hard for primary school students. But secondary school students can try."

4.1.3 *Learning of Chinese traditional architecture 1.3.*

By practicing beadwork creation, BLV students also learn some characteristics of Chinese traditional architecture. Indeed, traditional buildings are too big to be explored by touching and it is difficult to understand their shapes and features. By reconstructing the shapes of traditional buildings, students can engage deeply with their structure, familiarizing themselves with this important aspect of Chinese culture, which would otherwise be inaccessible. "Students can not tell the exact shapes and features of many traditional architectures because they are too big and rarely seen in our daily lives. But they can learn and recognize these traditional architectures through beadwork, such as the Great Wall and the Forbidden City, by memorizing the shapes and features they touched before (T7)."

Thus, tactile exploration of the beadwork model of traditional architecture functions as an alternative way for BLV students to discover the shapes and features of traditional Chinese architecture. In this way, beadwork becomes an informative tool providing BLV students with cultural information that sighted people usually access through images and videos.

At the same time, the features of Chinese traditional architectures are both symmetrically and asymmetrically composed of various modules, these types of beadwork offer a particularly challenging pattern for testing spatial intelligence and modeling (connecting this sub-theme to sub-theme 1.2).

4.1.4 *Fostering Creativity (Sub-theme 1.4).*

Under the guidance of teachers and through their own exploration, BLV students can develop creative expression in different ways. The main approach used is a recombination of beadwork modules previously learned. Students recombine beadwork modules in different patterns with their comprehension and association of beadwork's features. A quote from T1 gives a very interesting example, "Students self-generated the desire to create during the process of recreating beadwork which is learned from class. They usually reduce and add modules, such as vases and pineapples. In beadwork, the biggest difference between vases and pineapples is the upper green part." Additionally, BLV students integrate previously acquired knowledge of other manual crafting techniques, incorporating additional handicraft materials with greater variability and simpler application, such as ropes, wires, and modeling clay, into their creative endeavors. Lastly, teachers note that occasional errors lead to serendipitous creative discoveries of distorted shapes. Finally, only low vision students creatively explore color.

4.1.5 *Familiarising with colors (Sub-theme 1.5).*

BLV students engage in creative endeavors based on their understanding of color, albeit employing distinct learning and comprehension approaches. Students with low vision often retain sensitivity to color, enabling them to make instinctive choices of color combinations. Conversely, blind students with no color sensitivity primarily learn about colors through semantic contexts (e.g., associating white with snow and yellow with bananas). Additionally, blind students occasionally lack interest in colors (S3, S6).

Overall, BLV students need to get to know the proper colors for the different objects that they want to make with beadwork, in order to have realistic color matching and cultural aspects represented by color. In order to achieve this color matching, students need to acquire basic knowledge of colors and color relationships. They tend to acquire this knowledge in everyday experiences and continuous feedback from teachers or other mentorial actors. For instance, S8 told us, "I have a tutorial for making a blue purse. However, I wanted to use pink as the main color to give it to a sighted girl. I modified the color matching during production and used pink, white, red, and black. However, I could not do it alone, so I asked my mother to help me choose the color of the beads."

Interestingly, students also tended to create new beadwork by altering the color of the beadwork. Thus, color contributes to creativity development (connecting this to sub-theme 1.4). For instance, BLV students made a series of vases by changing the colors and patterns 1.

4.2 Theme2: Engaging with Society: Future Jobs and Visibility

Teachers reported that the beadwork creation is deeply rooted in the socio-cultural and economic context, underscoring outreach to the local community and the potential for increased employment opportunities (T1, T2, T4, T5, and T7).

4.2.1 Lifelong career and market expectation (sub-theme 2.1). Beadwork can have a very positive impact on the life of BLV, helping them to develop a personal job career. Handmade beadwork is usually priced between 100 RMB and 1000 RMB (almost exclusively sold in charity contexts), while the beads cost as low as 20 RMB and are easy to purchase. As a result, teachers (T1 and T5) have suggested that students could potentially establish their own businesses or start-up companies after graduation. For this reason, the potential buyer's preferences for specific types of beadwork may influence and guide the focus of student learning. Students aspiring to work in the field of beadwork creation are likely to place greater emphasis on the types of beadwork they produce. For example, many students (S4, S5, S8, S9) reported that everyday items (e.g., bracelets, cardholders, and tissue boxes) are easy to sell (and also easy to make), which motivates them to build these types of beadwork. S3 said, "The content of creating beadworks tends to be useful in day-to-day life, and I like items with high practicality, such as tissue boxes and card holders. I think there are even some handicrafts men create these kinds of stuff and sell them."

4.2.2 Social Visibility of BLV Students and Work (sub-theme 2.2). Oftentimes, beadwork created by BLV students can be exhibited and sold in charities which represent the primary source of visibility for BLV students. However, teachers have also identified an issue of public visibility (T2, T5, T7, and T8) regarding beadwork. BLV students' beadwork is rarely noticed by the public, while students aim to enhance public visibility and inclusivity by showcasing their work in exhibitions and online platforms. According to information provided by teachers, the largest current beadwork exhibition by BLV students is set to be displayed at the Shanxi Province Museum, featuring traditional architectural beadwork (T7). Large-scale provincial exhibitions are not frequently available, and there is limited financial support for small private exhibitions. Furthermore, the accessibility of students' beadwork on the Internet is also limited.

4.3 Theme 3: Practices and Issues in the Classroom

The third theme that we highlight is teachers' and students' practices and awareness of current issues and limitations, while teachers and BLV students have attempted several strategies to try to overcome them.

4.3.1 Resources (sub-theme 3.1). BLV schools feature assistive technologies, touch-based educational instruments, and smart classroom tools (e.g., smart large screens, blackboards, projectors, electronic whiteboards, computers, TVs, and mobile devices), and specialized teachers and are overall trained to accommodate the unique needs of visually impaired students. In addition to specialized tools and spaces, teachers in these schools undergo training and are prepared to utilize specialized touch-based educational instruments. BLV students can easily access teaching content through specific touch-based educational instruments in schools for BLV students. However, as teaching beadwork requires specialized skills that take time to acquire, the number of teachers capable of providing BLV with these types of courses can be limited (T1, T2, T3, T4, T5, and T6).

4.3.2 Time and Efficiency (sub-theme 3.2). Two primary factors contribute to time and efficiency issues in beadwork creation and preparation. Firstly, in class, a lot of time is taken in repeating instructions and correcting errors, oftentimes actually creating beadwork with individual students. All teachers reported that grouping instruction is more time-saving as it reduces the need for repetition. However, group instruction fails to meet the needs of all students, "Each class has different expertise levels of students, and there is a situation where some students are not guided by me (T8)." Additionally, both teachers and students invest a significant amount of time and effort in repeatedly correcting errors. According to T5, "In my class, few students can identify correcting errors and correct them independently, half can identify them but not in a timely manner and lack the ability to rectify them on their own. Some students are unable to identify errors at all". In beadwork creation, BLV students make many errors, a minor mistake in the placement of a single bead can result in the distortion or failure of the entire work.

Secondly, during class preparation, teachers are often overwhelmed. All teachers have expressed concerns about the time spent on calculating and sorting beads. Some students with low vision have assisted in sorting colors, shapes, and materials, while blind students have been able to help with shape sorting. Nonetheless, teachers still find themselves spending significant amounts of time. According to the teachers (T1, T3, T5, and T8), counting and sorting the beads with different colors, shapes, and materials consumes approximately one hour per class, which is particularly broadening as there are 5 to 7 classes per day. Furthermore, all teachers have reported that recycling the students' in-class beadwork at the end of the semester takes around two weeks. The beadwork created by students needs to be dismantled into individual beads, sorted, and stored in small boxes until the new semester begins.

4.3.3 Smart technology in class (sub-theme 3.3). In all classes we observed that the ordinary smart classroom could not effectively offer all students in an optimal manner. Teachers use smart classroom technologies to display courseware and explain definitions, characteristics, and contextual information about the beadwork. For example, a beadwork sample featuring plant and animal representations may be introduced by discussing its shape, structure, and color, with related stories and children's songs played through the smart classroom to enhance immersion and engagement. However, for most BLV students who are totally blind and have unclear residual sights, the magnified visual content on the big screen is still inaccessible. As T5 reported, "There are pre-recorded audio lessons, and the videos are accessible to people with low vision. So I prefer to play only audio in my class now." Overall, for blind students, touch and hearing serve as the only means of understanding beadwork samples in the classroom.

Additionally, mobile devices (mobile phones and tablets) serve as a source of inspiration and assist students in reviewing and exploring the beadwork creation. Although mobile devices can provide more personalized teaching assistance, T3, T4 and T8 told us that in their experience, during the class, there is a risk that mobile devices screen readers' volume would be too high, causing mutual disturbance. Thus, teachers do not encourage the use of mobile devices in class. S5, S7, S8 and S9 reported that they will use mobile devices for reviewing after class and finding tutorials.

4.4 Theme 4: Self-Teaching and Autonomy

Students conceive novel shapes of beadworks by drawing inspiration from their personal experiences and the knowledge acquired in class. However, students often face issues with finding and accessing preparations and tutorials in students for these shapes having problems with these self-teaching activities.

4.4.1 Smart technology in self-teaching tutorials (sub-theme 4.1). Mobile devices can help with searching sources of inspiration for new subjects and tutorials online. BLV students use screen readers as assistive technology to access these tutorials. Additionally, low vision students can also access this material by using magnifiers. However, most students (S1, S2, S8 and S9) reflected that online tutorials were designed for sighted people with numerous visual information, using visual instruction (e.g. flow charts with instructions) and including words that become unclear without reference to the visual content (e.g., "this", "that", "the red one"). Overall, students usually choose to look for external help from mentors, such as parents or teachers, to effectively access the tutorials, highly reducing their autonomy. For example, when faced with issues related to purchasing, sorting materials, and viewing tutorials during the current self-study period, students would ask their parents or remotely call their teachers for help.

4.4.2 Material organization(sub-theme 4.2). Independently acquiring the material for independent beadwork creation is problematic for BLV students. Indeed, students needed to start by purchasing and sorting materials which is usually done by teachers at school. During the self-teaching, BLV students need to classify the color, material, and location of scattered beads. From our interview, most BLV students asked for parental help. Otherwise, they will purchase the materials already classified in several small bags to avoid the issues of material organization.

4.5 Theme 5: Hopes for improvements in learning processes

BLV students and teachers primarily expressed four general diseases and hypothesized some ideal technological tools for improving beadwork. In addition to reflecting on the existing educational methods, educational instruments, and assistive technologies, teachers and BLV students expressed expectations based on integrating technologies and lifestyle habits used in the current industry.

4.5.1 One-to-one guidance (sub-theme 5.1). Additionally, to enhance the accessibility and efficiency of manufacturing in the recreation process, they envisioned a teaching assistant-like tool to provide one-on-one knowledge to students. S6 said, "Similar to a reminder robot, it should always be available." The teaching assistant must be impartial, patient, knowledgeable, and able to respond to repeated student inquiries and rapid switching of beadwork techniques while avoiding embarrassing students when asked repeatedly. Students aimed to avoid seeking help from others during the creative process and wished to have a device that they could independently use to assist with color matching and work structure analysis. Additionally, they would like a device to help them autonomously sketch beadwork models. Additionally, BLV students imagined multi-sensory stimuli, such as using scent or music to guide color matching while adding an element of fun that would also be helpful in autonomously navigating tutorials. For instance, "I wish to smell the corresponding scent when I get a bead. The color and scent should be the same. Then, tell me what it is using audio so that it becomes fun, and I can remember the color (S6)."

4.5.2 Error correction (sub-theme 5.2). To better accomplish beadwork, technical assistance is required to promptly correct errors during production. Students preferred simple synthetic sounds or tactile vibrations for error correction prompts instead of clear and natural language reminders. In contrast to the instruction of creating beadwork, more straightforward and simpler prompts in the error correction ensured that the fun of manual exploration in beadwork creation and the quietness of the classroom were maintained.

4.5.3 Material Preparation (sub-theme 5.3). As we have seen (theme 3), there is a series of time management and low-efficiency problems. In the discussions of our focus group, BLV students and teachers have proposed a vision to improve efficiency and reduce workload in teaching and creative activities, which permeates the preparation and execution of teaching and creative activities. Firstly, the teacher hoped to introduce a tool that could aid in material preparation, particularly concerning sorting things that cannot be sorted by relying on tactile feedback (e.g., color and texture).

4.5.4 More examples (sub-theme 5.4). Teachers hope to have more tangible beadwork samples that could guide BLV students. They believe that tangible models of beadwork could facilitate personal exploration of them, and ultimately aid to better understanding how to recreate them. Additionally, with more samples, students could explore these with a higher degree of autonomy and therefore contributing to time-saving.

5 DISCUSSION

In the study, we observed the practice of beadwork creation, highlighting various positive aspects, including personal development and societal engagement (themes 1 and 2), alongside the existence of certain challenges within the practice (theme 4).

In the first part of the discussion, we articulated insights for interaction design for BLV education that we learned from beadwork. First, we deepen our discourse on the first two themes resulting from our thematic analysis that highlighted the positive aspects of beadwork practice connecting them with recent literature. Then, we analyze beadwork per se by focusing on beadwork and the somatic experience of beadwork practice (combining several themes and sub-themes). Finally, we look at the current challenges and propose how state-of-the-art technology can solve them. Overall, the first three sections of our discussion focus on RQ1 (What kind

(a) (b) (c)

Figure 4: (a) Before the beadwork creation course, teachers sorted beads and put them in different boxes. (b) Different colors, shapes and materials of beads. (c) A blind with residual vision student was creating a beadwork, and tried to recognize the color with residual vision.

of insights for tangible interaction design for BLV education can we learn from beadwork?) and the remaining focuses on RQ2 (What are the main issues currently in the BLV beadwork class, and how can ATs help to solve them?).

5.1 Beadwork: Tangible Exploration for Personal Development

Based on our results (especially theme 1), we found that BLV students can develop a number of skills and knowledge by touching through creating beadwork, such as mathematics (subtheme 1.1), spacial and 3D mental modeling (subtheme 1.2), creativity (subtheme 1.4), cultural heritage (subtheme 1.3).

The use of tangible interactions for personal development in the STEM area is not a novelty per se; as we have seen in the background, many studies have explored tangible interaction for education. In particular, mathematics - which we observed in theme 1.1 - was explored in [70] who used a touch screen; and spatial intelligence - which we observed in theme 1.2 - was investigated by [26, 67, 75, 83]. While the use of tangibility for mathematics spatial intelligence is not a novelty, beadwork can offer a low cost and affordable alternative to most of the meterial used in the studies (theme 5). Low cost and affordability are generally considered important in education settings (see for instance the UN goal for sustainable development [2]), thus beadwork is a very suitable material for the development of accessible scenarios.

We have seen how beadwork can also have a positive impact on fostering creativity (subtheme 1.4) and artistic expression or cultural heritage (subtheme 1.3). Handicrafts and art in general can have a positive impact on independence and personal empowerment [17, 28, 49]. Our research highlights that beadwork can foster a very unique creative approach in BLV, based on variation and changes in form, patterns and - for low vision students - colors. Color in itself can be particularly relevant, indeed teachers have invested considerable effort and resources in teaching color theories, which has been considered fundamental to aesthetics for a long time [24, 93]. Additionally, recently, different methods to access color have been explored: sounds [44], vibration [43], tactile graphics [14], and tactile symbols and texture [76], beadwork could be arguably fruitfully combine with or be used in alternative to these other approaches.

Additionally, beadwork is also a flexible material that can have a positive impact on different aspects of personal development spanning from STEM to art and creativity (Theme 1). Other flexible tangible materials, that allow for constructing objects by combining units, have been used before in AT for BLVs. Building blocks (e.g. Lego) were particularly relevant in this sense [13, 50, 58]. Indeed, the flexibility and modularity of blocks proved to be useful for chemistry, programming and other topics. Based on our findings, beadwork offers similar potential for covering a variety of different topics. While there is not complete overlapping between what we observed and what Lego is used for (e.g., beadwork was not used for chemistry), the fact that beadwork already touches so many aspects of personal development is non-neglectable. Based on this, we can speculate that beadwork could be used for other topics, e.g. to teach molecular structure in chemistry because beads and strings can resemble chemical molecules. Overall, the level of flexibility of beadwork is arguably comparable to building blocks. Thus it represents a very cheap tool that can complement other tangible devices, offering an alternative that can enlarge the possibilities.

5.2 Beadwork: a Mean to Engage with Society

In our results (especially theme 2), it emerged that learning beadwork can support BLV students in finding job opportunities and obtaining public visibility (subtheme 2.1 and 2.2). This result is aligned with other research that showed how beadwork can provide job opportunities for instance to women living with HIV/AIDS [21, 91, 92]. Compared to the sighted people, employment rates and social connection tend to be lower in BLV people after graduation from school [6, 53]. With beadwork, BLV students can pursue personal development (e.g. learning math) while practicing the beadwork creation skill, which can eventually be useful for creating sellable objects (theme 2). Thus beadwork is particularly valuable for BLV students within the overall scope of life development.

However, the teachers and BLV students have also reported a lack of social visibility. This is not new, as previous research has highlighted the challenges of socializing for BLV individuals [87, 88]. Our participants reported that public exhibitions displaying beadwork have brought some level of visibility; however, this is

[2] https://www.globalgoals.org/goals/4-quality-education/

not enough to completely overcome issues of social isolation. Our participants also highlighted that they would like to have a more inclusive and accessible online platform that can help with learning beadwork and gaining visibility. Platform cooperation proved to be effective in supporting marginalized groups before [18, 82]. Thus, we support that platforms could be an interesting solution to explore.

In the view of our participants, social inclusion and public visibility of the blind community complement each other - a view often confirmed by social science research [94]. In the eyes of BLV students, good inclusiveness means more integration into society, such as study, employment, and communication. Beadwork can help as it can both develop personal skills (discussed above) and become products that can potentially generate revenue. However, we want to stress that this in itself is far from being a complete solution to this problem and dedicated projects that account for the overall social context are necessary.

5.3 Beadwork, Somadesign, and Embodied Cognition

Overall, we have seen how the somatic experience emerging from interacting with beadwork can support personal development (theme 1) as well as engagements with society (theme 2). An active use of somatic processes in design based on beadwork could further amplify the positive effects we observed in our study. Indeed, several studies have highlighted how people can gain better proprioception and overall understanding of their body through soma design (e.g. [31, 32, 85]). Soma design understands aesthetics through body sensation [85], and creative and aesthetic processes through body movements can facilitate self-awareness [31, 32]. Focusing on soma design can be particularly relevant as a way to support cognitive development based on embodied experience. When discussing soma design Hook and colleagues proposed that it can help to turn *"attention inwards [...]"* encouraging *"learning"* facilitating *"somatic awareness"* [33]. In our results, we observed how all the personal developments (from mathematics to creativity) are grounded in the haptic and tangible experience of interacting with beadwork. A somatic process in this context is deeply linked to embodied cognition as the first step develop cognitive processes and mental representations for BLVs [9, 15, 35, 68, 74].

Additionally, it has been pointed out that soma design methods are more effective when they are integrated components of everyday life. For example, Staahl observed how the fact that mats and breathing lamps are common objects used in daily life that contribute to support users to meditate [79]. From this perspective, beadwork, given its popularity and everyday usage in Chinese schools, can be a very suitable material or tool for soma design with BLV students.

Overall, being beadwork a practice deeply intertwined with aesthetic and creative explorations (themes 1), it would be a natural fit for soma design processes - and in many aspects, it can already be considered a soma design activity - deeply intertwined with embodied cognitions and exploration and creativity related to tactile experiences. As such, it would be ideal to be used and integrated into or for designing interactive prototypes for BLV students.

5.4 Limitations and Future Directions

We recognized that our study was prone to certain limitations. For instance, the impact of the BVL students' backgrounds (e.g., educational level, vision level, congenital or not, multiple disabilities or not) on the process of beadwork creation was not analyzed in this study. For instance, some students have developed manual skills before becoming BLV. Such students' beadwork creation learning process differed from those with congenital BLV. In addition, for some students with multiple disabilities, the challenges they faced in beadwork creation courses differed from those of only BLV. We didn't fully analyze the influence of previous vision and other ability levels on beadwork creation for different students and their teachers. Future work could explore how BLV students' backgrounds affect their beadwork creation experience and outcome.

The duration of observation for both classes was 45 minutes, which was a short-term observation. It might provide immediate insights and overlook long-term changes in BLV students' beadwork creation courses. Some phenomena and processes in the courses unfold gradually over time, and their understanding requires observing them over a longer duration. Therefore, a long-term approach will be adopted in future work to lead to a more complete understanding, finding out deeper layers and underlying factors in BLV beadwork creation.

Additionally, our use of focus groups to generate potential solutions may have limited the expression and creativity of BLV students and teachers. In future studies, we plan to use design probe-based participatory workshops, allowing participants to better demonstrate their ideas. For example, the use of tangible support tools can enhance playfulness and foster the creation of more functional and imaginative concepts. Furthermore, integrating computer vision technologies such as object detection [27, 46, 89], semantic segmentation [38, 48, 69], 3D scene/object reconstruction [57, 60], and hand tracking [59] may offer innovative ways to analyze the dynamics of beadwork creation among BLV students. These technologies could provide a high-fidelity visual analytic system that can be integrated into real-time systems for feedback on error correction or material sorting. Testing and trying these technologies will help identify specific educational needs and improve teaching methods, ensuring that future research adopts a more tailored and inclusive approach to education for BLV students.

6 CONCLUSION

In this paper, we presented a study focusing on beadwork creation in the current education of BLV students aimed at understanding what kind of insights for tangible interaction design for BLV students we can learn from beadwork (RQ1) and what are the main issues currently in the BLV beadwork class (RQ2). To this end, we conducted semi-structured interviews, focus groups and observations. As a result, we report the practical beadwork creation class and highlight personal development (encompassing instances ranging from STEM to creativity), social development (primarily centered on career possibilities), practice and issues, and hopes to manifest in beadwork creation education.

Overall, based on our study we suggest that beadwork is a very useful material supporting personal and social development. Its modular characteristics make it a valuable for multiple purposes, furthermore, it is affordable. In our discussion, we highlighted these characteristics and suggested that it can substitute other more expensive materials in HCI prototypes with similar education aims. Additionally, we developed some insights on how beadwork is a valuable material for soma design studies facilitating and initiating embodied cognition as a way for personal development grounded in tangible experience. This can be particularly relevant for BLV participants given that tangibility and embodied experiences are an important part of their interaction with the world. Finally, we analyze the hope of our participants mapping them with state-of-the-art technologies providing design opportunities for future inquiries in HCI.

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