NaCanva: Exploring and Enabling the Nature-Inspired Creativity for Children

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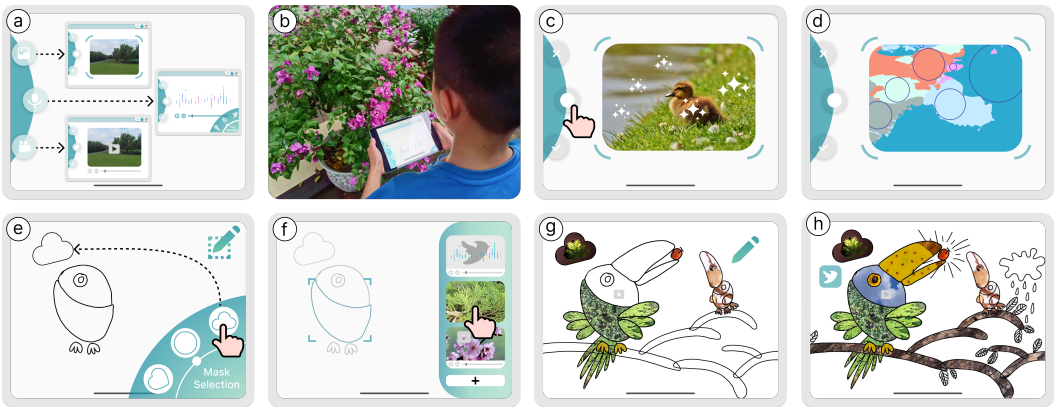

Fig. 1. Workflow of using NaCanva to create a nature collage. (a) Multi-modal material collection. In this step, the user can select a modality out of three and start collection. (b) Children collecting materials outdoors using NaCanva. (c-d) Image segmentation to highlight different objects on the interface. (e) Drawing collage outline. (f) Browsing materials to fill the outline. (g) Filling all areas. (h) Embellishing with free-hand drawing and sound.

Nature has been a bountiful source of materials, replenishment, inspiration, and creativity. Nature collage, as a crafting technique, offers children a fun and educational way to explore nature and express their creativity.

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However, the collection of raw material has been limited to static objects like leaves, ignoring inspiration from nature's sounds and dynamic elements such as babbling creeks. To address this limitation, we have developed a mobile application with the aim of encouraging children's creativity through renewed material collection and careful observation in nature. To explore the possibility of this approach, we conducted a formative study with children (N=20) and a design workshop with experts (N=6). With the results of these studies, we formulate NaCanva, an AI-assisted multi-modal collage creation system for children. Drawing upon the interactive relationship between children and nature, NaCanva facillitates a multi-modal material collection, including images, sound, and videos, which differs our system from traditional collages. We validated this system with a between-subject user study (N=30), and the results indicated that NaCanva enhances children's multidimensional observation and engagement with nature, thereby unleashing their creativity in the creation of nature collages.

CCS Concepts: • **Human-centered computing → Systems and tools for interaction design**.

Additional Key Words and Phrases: Nature-children connection; Creativity support tool; AI-assisted digital canvas

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1 INTRODUCTION

"Painting from nature is not copying the object, it's realising one's sensations." — Paul Cezanne

Nature has a plethora of structures [60], textures [90], species, and events that not only provide for different physical interactions but also rich social and artistic opportunities [35]. Importantly, nature has been seen as a source of creativity, providing inspiration for creative tasks [77, 79, 82] and art creation [17, 38]. It enhances creativity by making individuals more curious, innovative, and flexible in their ways of thinking [69]. The outdoor natural environment is also a significant educational setting for the development of children's creativity [39, 44, 51, 86]. In particular, nature can provide children with plenty of space, variety, and loose parts with endless creation scenarios that contribute to the development of creative thinking skills that will persist throughout life [15, 87].

Nature collages, as one of the nature-inspired art forms, are fun, engaging, and intuitive for children to make [43]. When making nature collage, children arrange and stick naturally found materials, such as leaves and flower petals, onto a piece of paper or canvas [80]. They gather natural resources from the environment before illustrating the design with the collected materials by pasting them directly onto the support or cutting them into desired shapes first. Material gathering, cutting, pasting, and painting are often executed alternately. Such an activity supports children's creativity development by encouraging careful observation of the surroundings and strengthening their connectivity with natural elements [54]. However, traditional nature collages can only be made using tangible objects like leaves and flower petals, whereas other natural elements, such as floating clouds and babbling creeks, are also inspirational. For example, traditional practices lack the use of nature sounds and therefore neglect its integral role in fostering children's creativity [4], which implies the need for multi-modality nature collages.

In the field of human-computer interaction (HCI), researchers have developed a wide range of creativity support tools (CSTs) to engage children in various creative activities, such as drawing [96], storytelling [94], music composition [73], and role playing [92, 93]. They leveraged digital

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technologies (e.g., artificial intelligence, personal robots, mobile technologies) to inspire children's creative thinking [5, 8] or lower the barrier to create [24, 25, 84]. However, there is little work supporting children's creativity in natural environments, despite the well-recognised benefits of nature in nurturing children's creativity [39, 44, 51, 87]. One of the most relevant works is Bio Sketchbook [95, 96], which is an AI-assisted drawing tool designed to enhance children's biodiversity awareness and observational learning. Nevertheless, it emphasizes observing one plant at a time, rather than drawing inspiration from a wide range of natural elements; also, it lacks associated supportive features to help children make nature collages. Thus, we formulated the following research questions:

RQ1 *What are the design considerations of a creativity support tool for children making nature collages?*
RQ2 *How do these design considerations be formulated as the features of the NaCanva application?*
RQ3 *How does the NaCanva application contribute to children's creativity in making nature collages?*

To answer the above questions, we applied a five-stage Design Thinking (DT) process [55], which informed a user-centered design to formulate NaCanva.

Empathize: Formative Study with Children. We first conducted a formative study with 20 children aged 7–11 years who were making traditional collages in nature to answer ***RQ1***. We focused on material collection and collage production from the children's point of view, paying specific attention to their needs and problems in observation and creation. First, we found that interruptions in children's creativity occurred as they lacked attention to details such as textures of natural objects. Second, children also paid extra attention to non-visual information, such as sound. Third, they wondered why the collage had to contain only static contents, which seemed inanimate.

Define and Ideate: Design Workshop with Designers. A design workshop with six experts in children-oriented creativity support tool design and nature education translated the requirements generated by the formative study into three specific system features (***RQ2***): (1) using AI to analyze the captured images to help children pay attention to hidden details in nature, including textures, structures, and materials, through real-time AI-enabled image semantic analysis; (2) encouraging multi-modal observation by integrating sound as a material for gathering; and (3) diversifying children's creation by integrating dynamic videos into collage creation.

Prototype: NaCanva. Building on these findings, we develop a collage program that facilitates AI-assisted observation and multi-modal production. NaCanva supports the two stages of making nature collages: collection and creation. The collection function is designed to be compatible with a variety of materials, from still images to dynamic sound of nature, using AI technology to highlight details in their view and encouraging children's multi-modal observation. With NaCanva, children could use a camera-based input device to capture images, sounds, and videos, all of which are available for use in their painting collages. Images play the main role in the creation, whereas the sound and video complement the diversity of the collage. The creation function allows children to freely assemble the collected materials utilizing their creativity and imagination with just pens and fingers. Children can build from scratch, start from a template, and modify shapes on the canvas as they like. The overall workflow of using NaCanva is shown in Fig. 1.

Test: User Evaluation. Finally, we conducted a between-subject user study with 30 children to evaluate the extent to which NaCanva facilitates nature-inspired creativity (***RQ3***). The results showed that NaCanva enabled children to record and use moving objects in nature to enrich the storytelling in their collages. NaCanva also encouraged children to observe nature elements with both a detailed and holistic lens. Additionally, the multi-modal creative process stimulated children's creative thinking and helped them construct their own worlds in their collages. Children were

also able to translate, transform, transcribe differences in multi-modal materials in their creativity space, extending traditional nature collage practices.

In summary, our primary contributions are as follows:

- We explored design requirements and extended the techniques and creativity space of traditional collages through a formative study with children, a co-design workshop with experts, and the incorporation of more types of materials. We built a diverse and changeable creative environment, thereby allowing children's creativity to flourish.
- We proposed NaCanva, an AI-assisted digital nature collage tool, which enables and encourages children to make multi-modal observations of nature by exposing them to different kinds of information (i.e., image, sound, and video) in nature.
- We conducted a between-subject user study with 30 children to explore how NaCanva contributes to their nature-inspired creativity in making nature collages with quantitative and qualitative methods.

2 RELATED WORK

2.1 Nature Education for Child Development

2.1.1 Child-Nature Connection. Nature has been extensively studied as an important setting in the field of children's development. Numerous studies have demonstrated that active participation of children in natural environments enhances motor skills [34] and cognitive, emotional, and moral development [2, 50, 56]. The embodied cognition theory has also shown that the rich multi-sensory experience of being outdoors encourages children to be more observant and curious about their surroundings, leading to a desire to explore, investigate, and understand their observations [50].

Nature connection is a concept promoted by Schultz's inclusion of nature in self [76], Nisbet et al.'s nature relatedness [63], and Müller et al.'s emotional affinity toward nature [62]. The importance of child-nature connection (CNC) has been extensively studied since its introduction at the end of last century. Over the last few decades, academic interest in CNC has been on how to build an intimate link between children and nature [23, 28] based on two underlying consensuses: (1) direct nature engagement during childhood fosters a deep-seated connection [20, 33, 48]; and (2) early nature experiences encourage pro-environmental decisions and behaviors in adulthood [21, 63, 83]. The consensuses also motivated the Child-Computer Interaction (CCI) community to request contemplation on technology's role in educating children about their relationships with nature and rewarding their ties to the outdoors in CHI 2020 [11]. For example, Cumbo and Iversen [26] stated that future research should investigate whether and how interactive technologies may be built to promote children's nature-based experiences that teach a value for nature and link them to nature. In response to these requests, this article is based on the idea that nature promotes children's development, with the goal of expanding the interaction of children's natural experiences beyond the sphere of creativity.

2.1.2 Nature-Inspired Creativity. Natural surroundings have long been seen to be the wellspring of creativity, and a lack of childhood outdoor exposure has been shown to have a negative impact on the development of children's creativity [57]. In particular, Palanica et al. [66] claimed that the natural environment effectively restores individuals' creativity compared to urban environment. In addition, there are also many studies that seek to explore the reasons why nature enhances creativity. For example, the study by Atchley et al. [12] revealed a deeper link between nature connection and children's creativity, highlighting the importance of Attention Restoration Theory, which suggests that exposure to nature can restore prefrontal cortex-mediated executive processes. Similarly, Rompay and Jol [81] argued that it is the unpredictability and spaciousness of nature that give people room for association and a stage for creativity.

In order to develop creativity in nature, children often need to engage in creative activities. Such activities are named as environmental art [54], including painting and drawing, sculpture and mobiles, weaving and crafts, and handmade art supplies, all to emphasize recycling and utilizing natural materials. Among these activities, making nature collages is both fun and engaging [43]. As early as the 19th century, artists such as Picasso began to add a variety of common materials (newspaper clippings, tickets, folded paper, pieces of glass and wood, thread, sand, etc.) to their cubist artworks [70]. Such techniques and the artworks are described as collages, an art form of arranging and sticking found objects onto a piece of paper or canvas [80]. A collage consisting of primarily naturally found materials, such as leaves and flower petals, is a nature collage. The process of creating a nature collage usually, but not necessarily, starts with collecting raw materials from nature. Some also choose to outline their design before looking for appropriate objects to approximate the artistic effect, or vice versa. The next step is to illustrate the design with the collected materials by pasting directly onto the support or cutting the materials into desired shapes. The creator can also embellish the collage with brushwork. This approach promotes children's creative thinking and thorough observation of their surroundings, which aids in the development of motor abilities fosters and deepens knowledge of natural items [54].

However, the material collection is limited by traditional tools and handwork to tangible objects like leaves and flower petals, which overlooks the irreplaceable inspirations from multi-modality sources, such as nature sound [4]. Moreover, the immature skills of observation may also impede children from drawing inspirations by observing the details of nature elements (e.g., stamens, leaf veins, spots on petals) [47]. Therefore, our work is motivated to leverage digital technologies to support children's nature collage making, especially in the process of material collection and detailed observation, and draws inspiration from the field of creative support tools.

2.2 Digital Tools for Children's Nature and Outdoor Experiences

Encouraging children to go outside and play in nature is deemed the first step of nature education. In recent years, the design of outdoor play interaction has gradually gained attention in the HCI community [97]. Back et al. combined outdoor play with landscape and built playable interactive landscapes near home [14] and at school [13] for children to play in their free time. Hitron et al. designed an editable outdoor play platform with hardware products [41, 42], which gives children greater freedom to customize the rules of the game through visual programming. Such efforts not only increase the fun of children playing in the outdoors, but also nurture their logical skills [64]. which guide children to explore in nature [31].

One separate line of research focuses on diversifying children's nature experiences, which is called environmental HCI [9]. Researchers in this field aimed at leveraging ubiquitous and mobile technologies and corresponding digital tools to create new kinds of experiences that "go beyond the desktop" [72]. For example, Chang et al. [19] compared the WebQuest framework he built for outdoor education to traditional science education, using a controlled-variable approach to leverage mobile technology in nature education. In addition, digital tools are developed to encourage nature exploration by bringing out the fun of outdoor activities [27, 36], providing an expert's perspective on nature's biodiversity and sustainability [75], and highlighting details in natural elements through photo sharing [49]. Overall, Anggarendra and Brereton identified three categories in this discipline: instructional, exploratory, and contributory technologies [9]. In particular, instructional technology allows scientific education activities to occur in natural settings [16, 65, 71]; exploratory technology encourages children to explore the natural world [3, 31, 49, 75], and contributing technology involves children in citizen science activities. Our work belong to the genre of exploratory technology and expands a new category of creative technologies that assist children in creating in natural settings.

2.3 Creativity Support Tools for Children

In the field of CCI, creativity support tools (CSTs) are of special interests because of their relatedness to children's intellectual development. A CST that can properly guide has been shown to be effective in enhancing children's learning results, stimulating interest and curiosity [37], engaging attention, as well as guiding them to develop a growth mindset [67].

A growing body of CSTs aims to lower the barriers of completing particular creative tasks (e.g., compose and mix music) that are complex for children at their age [22]). Among all creativity exercises, image-based art creation (e.g., sketching) is figurative, emotional, and intuitive for children to express their ideas [10]. For instance, children can express their emotions like fears [29] through doodling using simple art tools (e.g., crayons) and in typical art forms (e.g., watercolor). Further, as they get older, they can gradually understand the concepts of "zoom", "canvas", and "brush" in digital arts [89]. This growth in cognitive ability behooves researchers to develop CSTs for children's sketching [89]. These works include digital drawing software [52, 53], drawing games [68], and visual storytelling [94]. Another separate line of CST research focuses on providing inspirations for children in creative activities [6, 8]. For example, introducing non-player characters in collaborative games, providing social robots to enhance figural creativity [5, 7], or using AI partners to generate stimulus [94]. They show the great potential and affordance of interactive technologies in supporting children's creativity.

However, there are only a few works supporting children's creativity in natural environments [96]. In particular, BioSketchbook guides children to photograph natural elements and then translate their photo into a contour sketch. Similarly, I/O Brush [74] and FingerDraw [40] inspire drawing creativity by implementing a camera-based color picker that picks up any "ink" from user's immediate environment. In addition, other CSTs also use textures from nature. For example, Dynamic Brushes is a programming environment that enables the creation of ad-hoc drawing tools that transform stylus inputs to procedural patterns [46]. Sethapakdi et al. present CATS, a digital painting system that synthesizes textures from live video in real-time, making the brush- and texture-gathering workflow more efficient [78]. These nature-inspired creation tools focus on merely visual observation, lack multi-modal inputs and outputs, and do not systematically support detailed observations. Besides, they didn't offer a wider range of nature-inspired textures, patterns, and images that can be easily incorporated into collages. Therefore, our work is to extend the techniques and creativity space of traditional nature collages practices by incorporating multi-modality (i.e., image, video, sound) of material collection and enhancing children's observation abilities with AI-enabled technologies. In addition, as nature facilitates creativity mainly in the first two stages of the creative process–preparation and incubation [69], we expect to support children's creativity in material collection and perception rather than directly helping them to make the artworks.

3 FORMATIVE STUDY WITH CHILDREN

As aforementioned, creating nature collages nurtures children's creativity in the wild. However, there is little work investigating what impedes children's creative thinking when making nature collages in the traditional way. As a result, we conducted a formative study to better understand the requirements and obstacles of children in this creative endeavor that a creativity assistance tool can solve. Specially, we would like to explore the following research questions: ***RQ1****: What are the design considerations of a creativity support tool for children making nature collages?*

3.1 Methods

We recruited twenty children (10 boys and 10 girls, named P1–P20) aged between 7 and 11 years old (Mean=8.95, SD=1.17) by distributing posters in local social groups for parents of elementary school

students. Among them, three children had experience in nature collage creation. We included one parent to accompany each child and ensure they are safe outside. We reminded the parents not to intervene or guide children's activities during the study. What they need to do is just follow and give children a sense of accompany and safety, as well as observe children's behavior. The research was conducted in a nearby artificial park, where youngsters can collect objects.

Before the study, one researcher introduced nature collages to the children through a combination of oral and physical demonstrations, including the types of nature collages, production process, and common production techniques, as not all children have experience in making nature collages.

After an initial familiarization with the process and the park, the children proceeded to create collages formally. The children were given drawing boards, scissors, glue, and other tools to make the collage. Children were allowed to spend 40-min collecting and creating materials. To be mentioned, there is no requirement for the order and detailed time allocation for these two steps. Children can collect all materials and then create, and they also can create while collecting materials. Two research assistants were on site to closely monitor the children's behaviors and take notes. Research assistants were asked not to influence the children.

After the collage making activities, we interviewed children and their parents about the challenges and needs they faced. We also asked about the reason why children collected these materials and why they created such a final nature collage. As parents observed the whole study and are more familiar with their own kid's behaviors, we used a combined child-parent semi-structured interview format with two sets of questions that allowed us to compare and synthesize responses from both sides to get a comprehensive picture of what happened when children created nature collages. We used thematic analysis to organize and summarize the interview notes. Two researchers coded 10% of the data together to establish an agreement before independently coding all the data using NVivo. Then they refined the coded data to ensure the coded result achieved a 90% inter-rater agreement. Finally, four researchers summarized the findings through discussion.

3.2 Survey Findings

We elaborate on three high-level themes with associated behaviors and discourse of participants that reflect the challenges posed by the traditional practices of making nature collages for children's creativity.

3.2.1 Lack of Attention to Details. We observed that children often neglected textural information in exploring nature, but will use textual information in the creation. They preferred to gather beautiful objects with bright colors, because these things are easy to spot and visually attractive. They often focused on the entire object, not the parts, including the texture of natural elements (e.g., stamens, leaf veins, spots on petals). When we asked the children if they had noticed the difference between the head and tail of one leaf in the field, no one mentioned the vein and midrib or the surface smoothness of the leaf. Most of them (15/20) only noticed the color difference, as P4 said *"I know! color is different! Although both sides are green, one side is darker."* However, textures lead to the interesting analogy between objects, as collage is an expression based on different textures and structures [61]. For example, rough and textured bark can be associated with fish scales, while ginkgo leaves with radial veins resemble fish fins. Yet, due to incomplete observation and understanding, we found that although many children (12/20) had ideas to make sensible collages with textual-level information, only a few of them (3/20) were able to configure the objects in their collages that highlight the material texture successfully. In other words, although the child is aware of the value of this information, it is difficult to use them for expression and creation because it is not valued in the process of collection and observation. This finding is consistent with children's developing abilities of observation [47]. For example, without scaffolding, children may

not be able to make deeper observations than noticing the first glance of biological features [32]. However, their skills of observation can also be developed by engaging in more unique and close observations [47].

3.2.2 Lack of Visual-Audio Hybrid Observation and Creation. A nature collage is a visual creation of artistic expression. However, we observed that most children were distracted by other sensory experience in nature, such as sound. For example, more than half of the children were attracted by the chirping of cicadas in the trees during the material gathering process, and one child even tried to find and capture a cicada: *"I caught cicadas with my brother in the countryside and it was so much fun! When I hear the sound, I think of that time. The sound is interesting too."* Some children preferred the sound of leaves and twigs blowing in the wind to the sound of cicadas, with six children describing it as "nice" and "enjoyable". In addition to natural sounds, there are many sounds made by the children. For example, nine children enjoyed picking up tree branches and fumbling with them to make a noise. Besides, sound can also be used as one of the materials for creating collages. Sound as one of the inspirations for children can change the content of their collages: *"Since I heard a cicada chirping, I drew a cicada here"*, as P19 said. However, the traditional tools for material collection cannot support record and utilize nature sound. A prior study has demonstrated that nature sound can boost pupils' creativity and raise their marks within the art classroom setting [4], which further confirms the importance of incorporating sounds in children's nature collage making activities.

3.2.3 Lack of Collecting and Using Moving Materials. We realized that children desire dynamic and changing creations. Seven participants complained about the limitations of traditional collage in terms of the types of materials and forms of presentation. P17 said, *"Every time I make a collage, it's just leaves, petals and seeds. Can't we make something new?"* P15 added, *"Why can't we make a collage with clouds in the sky and water in the pond?"* Besides, we have found that children are often attracted by moving objects (e.g., insects flying through the grass) in nature and show great enthusiasm for them. They also would follow a particular butterfly or dragonfly, even forgetting the collage task. Similarly, some children (P1, P9, P16 and P20) observed the movement of water and touched and felt it with their hands. For instance, P16 said, *"I often watched the water flow and was fascinated. I thought about what was in the water, what I could play with in the water, and what would happen if people lived in the water."* As a result, many children also want their collages to move. Furthermore, some children even envision future collage crafting techniques. Some children (4/20) said they want to author a video form of nature collage. P18 mentioned that *"I especially like to use my mother's mobile phone to turn some photos into dynamic short videos, I wish this software could also!"*. And P2 said that *"I like to edit the videos! For example, draw a small butterfly on the video of photographing flowers."* It can be seen that children not only like the collection of dynamic materials but also the creation of dynamic materials.

4 DESIGN WORKSHOP WITH EXPERTS

To answer our ***RQ2*** *(i.e., How do these design considerations be formulated as the features of the NaCanva application?)*, We conducted a user-centered design workshop with specialists to construct the detailed NaCanva system features based on the survey findings. Three experts were recruited from a local children's product company. Three experts (E1-E3) had extensive experience in designing creativity support tools (CST) for children. Another three experts (E4-E6) were experienced in nature education for children. We first introduced the nature collage collection creation and the findings from our formative study to them. Next, we asked experts to brainstorm the main interactive features that could help children explore nature and trigger their creation while exploring.

4.1 Results: Key System Design Features

We summarized three key features to design a new nature collage format to support children's outdoor play and strengthen their connection to nature, augmenting their creativity. To maintain consistency, we organized these recommended features using the same structure as the findings from the formative study.

4.1.1 Detailed Observation: Children Lead, and AI Helps, but without Detailed Instructions. Given that children often overlook the details they see, experts point out that AI technology can help. Different experts put forward their own ideas on how to use AI to assist observation. E2 pointed out that nature pictures are often composed of different subjects, and children tend to pay attention to the large subject, but ignore the other components. We can help children realize that there are multiple subjects by making AI separate them. However, E3 expressed his concern about involving AI. He thought we should let children take authority over what they want to pay attention to and explore. If AI gives too much guidance, children may become over-reliant on AI and blindly follow the AI's suggestions. In this instance, children's relationships with nature will be more apart rather than closer. Moreover, E1 tried to leverage E2 and E6 concerns by recommending just using AI to point out the existence of subjects but without any detailed exploring guidance (e.g., what subject it is, guiding to go closer). Finally, all experts decided to do semantic segmentation on the image and inform youngsters that the subject is there.

Feature #1: *Helping children pay attention to the hidden details in nature, including textures, structures, and materials, with AI-enabled image semantic analysis in real-time.*

4.1.2 Synesthesia Mechanism: Visual Elements Enhanced by Sound Effects. Sound, as an important part of nature, conveys a lot of information. All experts agreed that the perceptions of sound and visual information do not contradict each other; the combination of the two allows children to experience nature better. Besides, simply omitting the sound from nature lets children miss this opportunity to strengthen their connection to nature. In this case, all experts recommended we add a multi-modality collection feature to our system, allowing children to collect the sound from the visual images. For instance, E4 said, *"Collecting sound is much more difficult than capturing images. For instance, if you hear an amazing frog croak and would like to record it, you need to wait for the next croak and keep focusing. When something is hard won, children are more likely to cherish it and want to use it in their creation."*

Feature #2: *Encouraging multi-modal observation by integrating sound as a material for gathering.*

4.1.3 Dynamic Interaction: Capturing Videos in addition to Images. With the findings from the formative study, E4 proposed that adding more creative forms, especially a dynamic format, to the traditional collage would add variety to the collage, and enhance children's interest and engagement. All experts agreed that the variety of materials that can be collected determines the depth of children's exploration of nature. Moreover, in terms of the form of presentation, it is a generally accepted idea to present visual information in the form of a video on canvas. As E3 suggested, *"In my understanding, the digital canvas limited the expression of spatial dimension with plain screen, but give more possibility on temporal expression. To be specific, in traditional nature collage creation, one place can only be filled with one static object. However, maybe the object could have different forms at different times."* E5 agreed with this point and gave an example, *"Flowers will bloom and fade with time flies. In this case, the same object can trigger different emotions due to the passing of life."*

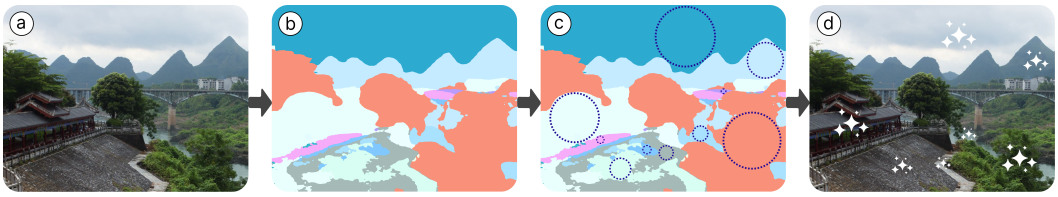

Fig. 2. AI-assisted image recognition: (a) A user-acquired image. (b) AI analyzes and delineates the area of each object. (c) The backend makes the maximum inner tangent circle of each region to analyze the percentage of objects in the image. (d) The frontend highlights each object in the image with a star icon.

Feature #3: *Diversifying their creation by integrating dynamic form (i.e., videos) into collage creation.*

5 NACANVA SYSTEM

Based on the design goals presented in Section 4.1, we designed NaCanva, a collage creation tool using natural elements collected digitally in nature including images, sound, and videos. NaCanva runs on a tablet device with a camera and audio input. In this section, we introduce the NaCanva system.

5.1 System Overview

The NaCanva system consists of two modules: material collection and collage creation. During material collection, NaCanva guides children to observe nature and gradually refines the observation by highlighting details such as the materiality, structure, and textures of natural objects. Within the frame of the camera view, NaCanva scans and identifies different objects and materials. During collage creation, NaCanva facilitates the combination of materials and shapes, and children can switch between the two modes at any time.

To achieve the aforementioned design goals, we designed three main features for NaCanva: 1) AI-assisted image semantic segmentation, which provides detailed observation guidance to children as they collect visual materials; 2) Multi-modal material collection that includes not only visual but also non-visual elements such as sound, allowing children to explore and create with a wider range of sensory inputs; and 3) Dynamic material collection, such as videos, which can be easily integrated into the collages for richer and more engaging creations.

5.2 Image Segmentation-Based Observation Guidance

To expand the amount of content in the natural environment, as well as to guide children to make more detailed observations, we used a set of image analysis models. It can effectively read the outline of each object and analyze and identify all the objects in the frame in real time through AI-assisted semantic segmentation, as shown in Fig. 2b. The proportion of each object is calculated to distinguish a panorama view with one significant object from a display of scattered objects. The system uses “star” to highlight the identified objects, as shown in Fig. 2d. This procedure assists the system in guiding the observer into a detailed examination of objects. Only when the child chooses one object from the identified ones to observe the details in nature does the system recommend that the child capture an image or a video. This feature aligns with the fact that collage is centered around understanding and using materials.

Implementation. To segment images, we used the pre-trained SegFormer, a simple and efficient model for semantic segmentation using transformers [88]. We first identified the semantic objects

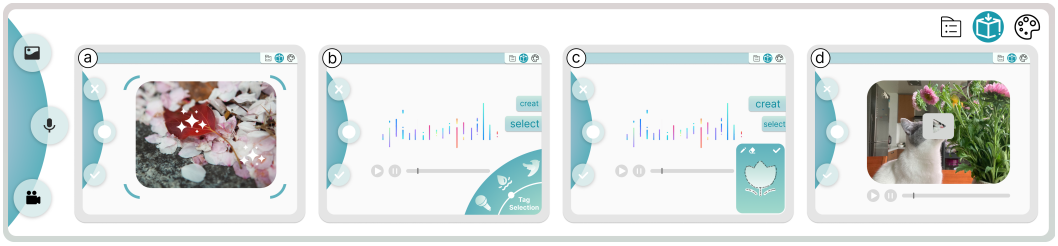

Fig. 3. Functions and interaction modes on the material collection interface: (a) Image collection and analysis. (b) Audio collection and pre-defined tag assignment. (c) Audio collection and custom tag assignment. (d) Video Collection.

in the image using the model. Then, the image center of each semantic object is calculated by finding the maximum inner circle center of the irregular graph, as shown in Fig. 2c. Finally, the coordinates of each center are returned to the front end for highlighting the identified objects on the user interface.

5.3 Material Collection

Material collection is the foundation of collage creation. Based on our design guidelines, we believed that including a variety of materials in the collection process can direct children's attention to details in nature and inspire more diverse creation. Thus, our system supports a multi-modal material collection including three kinds of materials - image, sound, and video.

The user interface has three buttons under the material collection tab - an image icon, a microphone icon, and a video icon. Children need to select one collection mode to start a new collection. The collected materials will be stored in the materials' library. To help navigate material search and selection, children can assign a tag to each material. For sound, we chose to use tags over custom labels because tags are more intuitive and easier for children, as shown in Fig. 3c. For example, when a child records a bird chime, they can click on the icon representing the bird to save it. We provide a variety of icon tags, including "birds", "insects", "plants", etc. If these icons do not meet the needs of children, children can also draw their own tag and save it.

Implementation. To realize the multi-modal collection function, we used MediaRecorder API, a straightforward media recording API, to achieve the audio and the video recording on the web platform. To capture images, we directly used the "call Camera and album" function that comes with the HTML<input> tag. New images will be saved in '.png' format, audios in .mp3 format, and videos in .mp4 format in the local browser cache. These formats are compatible with the Safari browser in iOS.

5.4 Collage Creation

There is no pre-defined sequence for material collection and collage creation. Children can switch between the material collection and collage creation tabs at any time. Digital collages, like conventional collages, are made up of many forms that are either natural to the object or carved by the crafter. In contrast to traditional collages, digital collages can have shapes or masks filled with any visual digital content, ranging from images to videos, as shown in Fig. 4. We implemented the following features to create a mask in our system. First, we provided a range of pre-drawn masks under the 'Mask Selection' tab, such as square, triangle, circle, heart, and pentagon. A 'New Suggestion' button will randomly generate a shape to inspire a new creation. The selection tool can adjust the size, position, and direction of any mask on the canvas. Additionally, a free-drawing pen

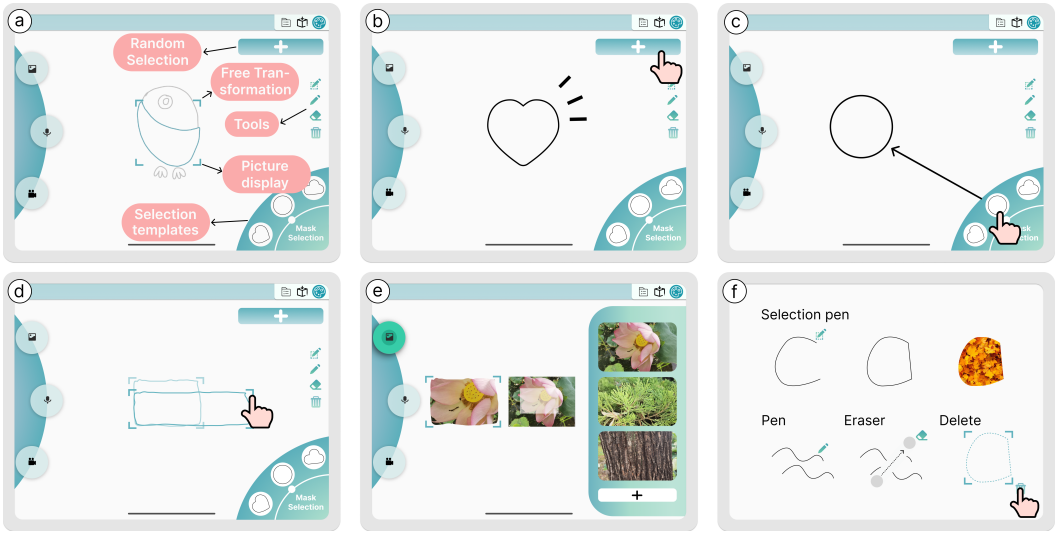

Fig. 4. Functions and interaction modes on the creation interface. (a) Overview of creation interface. (b) The 'New Suggestion' button generates a random outline. (c) 'Mask selection' (self-selecting favorite mask) (d) Basic shape editing. (e) Adding image, sound, or video from the library. (f) Brush tools (f)

tool can be used to create any shape, while an eraser tool can erase unwanted drawings. Children can fill masks with images or videos, and to view the resulting collage with a video, they can click on the video-filled mask in the collage creation tab. The video will play within the mask in a loop by default, and they can also disable looping by clicking on the toggle button.

Any masks placed on the canvas can be filled with the 'Fill' function. The 'Fill' function fills the mask with images and videos from the materials' library. Children can zoom in and zoom out the selected image or video behind a mask. The video is set to play in loops by default, and a toggle button disables looping. Sound, on the other hand, is added as a button and can be played in the background of a collage. In addition to using existing materials, a free-hand brush tool allows children to decorate and embellish the collage as they like.

Implementation. The materials (including masks) will be stored in the same format ('.png', '.mp3', '.mp4') in the paid Object Storage Service (OSS) provided by Alibaba Cloud for access over the internet. The masks are closed paths stored in .svg format and are applied over images and videos on the interface. The materials are self-adjusted to fit the mask as they are selected. Users can adjust the size and placement of the mask.

5.5 Service Deployment and Privacy Protection

NaCanva is a frontend interactive web application implemented by React, a JavaScript library for building frontend interfaces, and Flask, a backend micro-framework written in Python. To enable access to users for NaCanva, we deployed the frontend on 'github.io' and the backend on Python's built-in HTTP server. The web-based nature of NaCanva allows it to run on a web browser on different mobile devices, such as iPad. The devices should be equipped with a touch screen, a microphone, and a camera.

Regarding the data collected by the NaCanva app, we prioritize the privacy and safety of our users, especially children. The ownership of the created collages belongs to the users who create them, and we do not claim any ownership over them. We collect only necessary data for app functionality

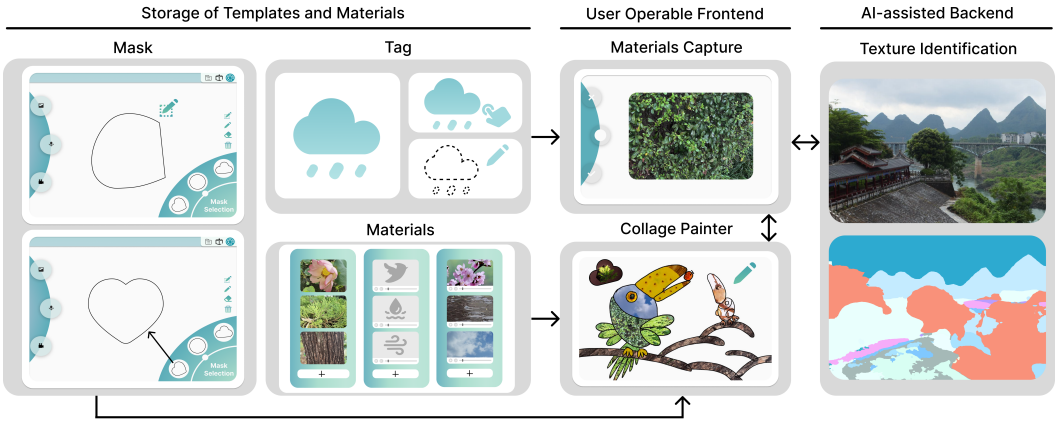

Fig. 5. NaCanva Implementation Structure. Templates and materials are stored on a cloud service, which can be accessed from the user operable frontend. Image segmentation for collected materials is powered by the AI in the backend.

and user experience and do not share material data with third parties. Collages are stored locally and can be uploaded to a secure, third-party cloud storage service for access across devices. Our data practices comply with all applicable regulations, including including the Children's Online Privacy Protection Act (COPPA), and are explained in detail in our privacy policy.

6 USER STUDY

As aforementioned, our ***RQ3*** is "How does the NaCanva application contribute to children's creativity in making nature collages?" The evaluation of NaCanva posits the following sub-questions:

- To what extent could NaCanva enhance children's connection to nature? And how do our main features (i.e., multi-modal materials collection and AI-assisted details observation) contribute to that?
- Does NaCanva support children's creativity by augmenting children-nature connection?

6.1 Participants

For this study, we recruited 30 participants (16 girls, 14 boys) aged 7-11 years old (mean = 9.13, std = 0.98) by posting an announcement on the authors' personal social media accounts and distributing flyers at local libraries, elementary schools, and community centers. These participants were equally and randomly assigned to groups that had two different guidance modes for controlling the variables. Twelve of the children had experienced nature collage creation, and they were equally divided into two groups. P1-15 were assigned to the experimental group, which used our NaCanva system. They were all familiar with how to use iPads and had interest and experience in playing in a natural environment, as self-reported by them and confirmed by their parents. P16-30 were assigned to the control group, which was tasked with creating a nature collage using traditional physical materials, such as paper, glue, and scissors. All participants were given a toy worth $15 as compensation. Our user study protocol was approved by our institution. The parents signed the informed consent for their children. Similarly to the formative study, parents will be included in our study as observers and protectors.

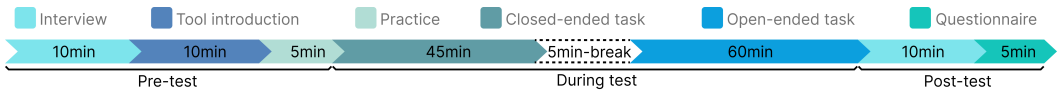

Fig. 6. Procedure of the user study and time allocated for each section.

6.2 Apparatus and Site

All participants used an iPad equipped with an Apple Pencil for sketching. All participants used the stable versions of the system interface running on Google Chrome browser. The experimental site was an urban park with rich vegetation that simulates a natural environment.

6.3 Procedure and Tasks

A research assistant introduced to each participant how to use the system, including how to collect the materials, how to use the mask, how to fill in the material, and so on. Then, we allowed our participants to practice for 5 minutes to make sure that they understood NaCanva's functions. Besides, we informed the parents that they can accompany their children for security but should not guide or affect the collection and creation process. Finally, we gave children and parents time to explore the surrounding area.

Each participant performed two editing tasks using our NaCanva. Specifically, we continued with the block of the closed-ended task, after which the participant would take a short break before performing a open-ended task.

- **Closed-ended task (45 mins).** In this task, we presented traditional nature collages (i.e., a tank) for children's reference. Children were asked to choose one example and reproduce the elements and contents of their choice, with freedom in the choice of materials.
- **Open-ended task (60 mins).** In this task, we provided some keywords (e.g., an interesting tree) or abstract description to illustrate the keywords if children asked. Then the children were asked to collect materials and create a collage.

After the experiment was completed, participants would fill out two post-questionnaires. Finally, they participated in a short semi-structured interview about user experience. The whole user study procedure is shown in Fig. 6. We also let participants' parents chat about their comments about children's behavior and interview answers from their prescriptive.

6.4 Metrics

6.4.1 Post-Study Surveys. We conducted two post-study surveys to ask children about their feelings of this experience in order to assess nature-children connectivity and NaCanva's creativity support index using 5-point Likert Scales (i.e., 1-strongly disagree, and 5-strongly agree). To ease children to answer the questions, we voiced the questions to the children and explained the meaning of each question.

For connectivity with nature, three perspectives were included in the evaluation: 1) Being IN nature (i.e., feeling comfortable in natural spaces, being curious about nature); 2) Being FOR nature (i.e., reading natural spaces, acting in natural spaces, knowing about nature, feeling attached to nature spaces, and recalling memories with nature); 3) Being WITH nature (i.e., taking care of nature, caring about nature and being one with nature).

The second questionnaire is derived from Creativity Support Index (CSI) [18], a standardized survey metric for creativity support. Considering that collaboration was not considered when we design the NaCanva, five dimensions were chosen from the framework: 1) enjoyment, 2) exploration, 3) expressiveness, 4) immersion, and 5) results worth effort.

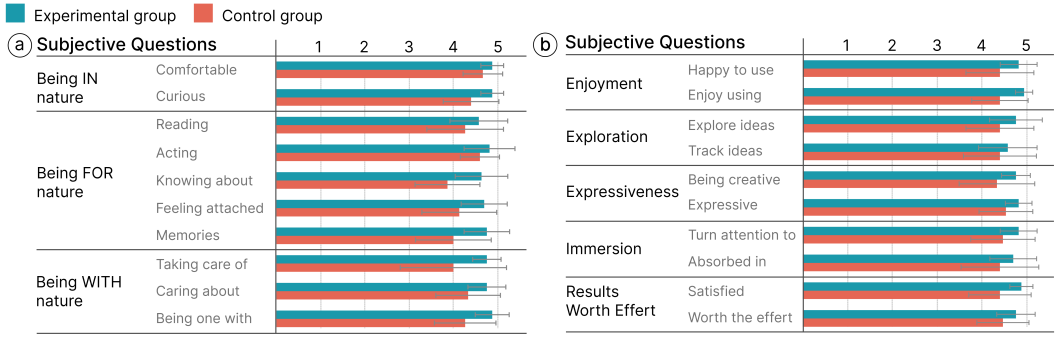

Fig. 7. Bar charts of user self-rating data distribution of the connectivity between children and nature (left) and children's creativity (right).

6.4.2 Think-Aloud and Semi-Structured Interviews. Since echoing our research questions is difficult for youngsters their age, our qualitative study used the think-aloud approach and semi-structured interviews to gather more information on the questions. Throughout the study, while children were playing outdoors and making collages, we constantly asked for their thoughts about the tasks, the observations, and their feelings in real time, which were then exported in the form of dialogues by the experiment assistant. It is worth mentioning that most of the questions were about children's thoughts and motivations after an action has taken place, and we made sure that our questions did not interfere with children's next action, no matter material collection or creation. For example, we encouraged children to speak through the process when they saw an element that they would like to photograph and when they pick a material for their collages. The experimenter guided children to explain reasons for the choices they made. This way, we could dive into children's cognitive activities as they interact with NaCanva.

After all tasks were completed, we concluded the study with semi-structured interviews. The interview questions revolved around two themes. 1) What did they notice that they used to neglect? 2) Did they learn something about nature? We recorded the interviews using audio recording, which were transcribed for later analysis.

7 RESULTS

7.1 Quantitative Results

As described in the last section, two kinds of aspects were evaluated for both the control group (using the traditional nature collage format) and the experimental group (using our system for the nature collage), as shown in Fig. 7.

For children's connection to nature, the questions were divided into three broad gradients, 1) "being in nature", 2) "being for nature", and "being with nature". For the "being in nature" section, children in the experimental group were more likely to be interested in and curious about nature (mean = 4.86, std = 0.26). Children felt very comfortable in the natural environment from both groups. In the "being for nature" section, exploring nature (mean = 4.56, std = 0.65), learning about nature (mean = 4.63, std = 0.59), and playing in nature (mean = 4.83, std = 0.57) were clearly easier for children in the experimental group who were guided by NaCanva. In addition, they reported that they were able to retain more memories about nature with the help of our device (mean = 4.76, std = 0.51). Notably, in this section, we found that the experimental group showed significantly higher scores than the control group in two metrics: knowing about nature (student t-test, p = 0.020

< 0.05) and recalling memories with nature (student t-test, p = 0.036 < 0.05). For knowing about nature, we associated the higher rating for NaCanva to the fact that NaCanva encourages children to pay attention to smaller things, according to our qualitative data. We also associated the higher rating in recalling memories with nature to the system feature of NaCanva that enables collecting dynamic information. In "being with nature" section, the difference between the two groups of children was negligible. Both groups of children had a strong sense of caring for living things in nature and caring for nature (mean = 4.76, std = 0.32). Moreover, most of the children considered themselves as part of nature (mean = 4.86, std = 0.38). Furthermore, children resonated with "being one with nature" significantly more using NaCanva than doing traditional collage (student t-test, p = 0.035 < 0.05).

To evaluate creativity support, the majority of children found our system interesting and indicated that they enjoyed the process of using it and were happy to use and play with it several times (mean = 4.93, std = 0.19). It is worth mentioning that, for the question *I would be happy to use this system or tool on a regular basis,* NaCanva was rated significantly higher than traditional natural collage (student t-test, p = 0.032 < 0.05), suggesting that our system truly enhance children's enjoyment. Children also generated more novel ideas when using our system for collage making than traditional collages (mean = 4.76, std = 0.59). At the same time, children were more likely to express their ideas due to the simplicity of the drawing method (mean = 4.83, std = 0.30). As for the degree of children's engagement, the experimental group showed similar data to the control group, both showing a strong sense of immersion (mean = 4.83, std = 0.41). However, children's sense of collection and accomplishment when performing traditional nature collages was higher than that of children using our design (mean = 4.76, std = 0.43; student t-test, p = 0.041 < 0.05). This notable difference can be attributed to the physical nature of traditional collages [1], which preserves personal traces in a tangible form that is meaningful to users and therefore heighten children's feelings of accomplishment and collection. In contrast, NaCanva's digital screen falls short in providing haptic and textural feedback when displaying the final masterpiece, resulting in a diminished sense of fulfillment.

7.2 Qualitative Results

Towards the end of the study, participants came back with a variety of paintings, which are shown in Fig. 8. In this section, we report the qualitative results from the perspective of art creation and creativity. Note that the language used by the participants in the experiment was Chinese, which was later translated into English by the researcher.

7.2.1 Merry-Go-Round: Recording Moving Objects Make Children Chase Their Stories. Visual is the simplest and the most direct stimulation, way beyond textual and audio expression. Moving objects, in natural landscapes, appear to be an attraction yet also a distraction in children's attention span. For example, if some children are photographing flowers and a butterfly glides by, they will switch from photography to video recording mode to capture the flying butterfly. However, moving objects also symbolize liveliness and movement, which create a narrative in children's observations of nature. A girl (P3) told us, *"The butterfly is dancing. Isn't it tired?"* (Fig. 8b6). They started chasing butterflies and birds and sharing their emotion and storytelling, which are the inherent patterns behind their observation habits.

Similarly, lifeless objects also move with wind and light, and children would project life on these objects. The video capturing function provided by our NaCanva system enable children to record these interesting moments and enhance children engagement with nature. P1 noticed that the reflection from the dew on the grass moved when wind blew and said, *"The sparkling things are moving. Are they fighting?"* Then he held up his iPad and started recording. P10 also mentioned

Fig. 8. Children's collages made on NaCanva: (a) Children's closed-ended collage works with a theme of 'a tank'. (b) Children's open-ended collage works with a theme of 'an interesting tree'.

that she liked to photograph the reflection of trees and flowers on water because the water was not completely still and the shadows moved as the water rippled. And thus she liked our system, and she pointed out that *"Water alone is nothing to look at, but this view, I could stare at this all afternoon! Now I can create with it and take it home to share this beautiful light with my brother."* To some extent, our NaCanva system allows the child to record things other than the still objects themselves, such as the interaction between things and things, and things and environments (e.g., light). In addition to paying attention to the shifting shadows of things that are otherwise still, children also paid attention to the shadows of moving things. For example, they often noticed each other's shadows on the ground and started chasing each other (P5, P6, P14). For instance, P14 keeps chasing other children. The more his partner ran away and refused to let him film, the more he wanted to film. They laughed, bickered, and communicated with each other about their observations and how these observations inspired them.

The video capturing function gives children a lot of fun, and makes them willing to do nature collage. More importantly, it gives them a new perspective to think about what they could use for creation, and thus re-think what they could feel, observe and interact while collecting materials in turn. Specially, compared with traditional nature collage, our NaCanva system expands children's attention from still object to the relationship among nature (e.g., the relationship between object-object, human-object, object-environment, human-environment). In this case, they will have more feelings and experience when observing and more inspiration and materials for creation. In summary, observing and recording these moving objects help children better construct a knowledge system and gives children a dynamic mindset about the liveliness in nature, a narration of positivity, and a channel to release and exchange their imagination.

7.2.2 Magnifying Glass: AI-assisted Image Analysis Encourages Close Inspection. The purpose of implementing AI in NaCanva is to guide children towards detailed observations and triggers their curiosity. The current implementation is focused on analyzing the number and position of elements on images. This implementation, to our surprise, already encourages children to explore nature

and observe more objects. Image segmentation can direct a person's attention to a specific aspect of the picture, such as the number of stars. While counting the stars, they may come across new objects and exclaim, "Wow, there is something here!" For instance, a boy (P6) took a picture that he thought was a close-up and contained only a few elements, but it turns out to contain many labelled stars (i.e., recognized segmented parts) in the image. Perplexed, he wonders, "Why are there so many stars?" He then examines the objects represented by the stars (as shown in Fig. 8a1) and proceeds to explore the image collection from different viewpoints, making new observations along the way. To some extent, this indicates that children tend to see the world from a holistic perspective at the beginning, rather than focusing on the various parts that make up the scene. When the AI reminded the children of the composition of the scene, the children were surprised at first, and then stimulated to explore, so that they began to explore independently. In addition, this feature added to the fun of the whole collection process, with many children showing the lab assistant the photos they had taken with the smallest number of stars.

We also unexpectedly found that the computing time of AI gave children more time to observe and stay, which inadvertently promoted children's observation. For example, one girl (P5), while waiting for the results of the analysis to come back, noticed the snail shell on the tree trunk she photographed: *"There's a shell! It looks like..... It looks like a snail's shell!"* (Fig. 8b5). A waiting boy (P8) also spots the maple fruit: *"What is this? There are two little wings."* (Fig. 8b2). P11 Parents said to us, *"My child used to be very impatient and impatient. We tried many ways to let him learn to observe, but he couldn't calm down. But the little star of the system gives him expectation, so he is willing to wait, and while waiting, he may feel a little bored, he will look at his surroundings and feel nature. This makes me very happy as a parent."*

7.2.3 Building Blocks: Construct Their Own World. Outlining the collage and coloring it are two interwoven yet distinct steps. The outline is the configuration of the picture and the content contained in the picture. Drawing on the analogies of Merry-Go-Round and Kaleidoscope, it is the frame of the story that children want to narrate. The coloring step, i.e. filling the outline with captured materials, on the other hand, is the logic of that story. Unlike many CST systems, our NaCanva does not give children too much guidance and teaching on the creation level, such as how to use materials to form graphs and so on. We discovered that not designing is also a type of design. Our design invites youngsters to think of themselves as silently auxiliary. The diversity of their creations as shown in Fig. 8 suggest effective creativity support by our system.

Depending on the age and cognitive maturity, as well as the outline, the logic of children's filling process include color, materiality, shape, and common sense, which combined describe their ideology. For example, a girl (P3) resonated with colorful abstraction most, *"I feel good about these colors, yellow, pink, white ....."* (Fig. 8b6), and a boy (P11) filled the clouds he drew with white, *"Clouds are white! Clouds are just white!"* (Fig. 8b7). The difference in their coloring logic suggests that they treated this activity as a free and spontaneous entertainment to please and reflect on themselves and their own liking. In addition, some children reasoned their choice of images and videos from the material and texture. For example, a boy (P4) drew a tank camouflaging in a rainforest and colored it with leaves (Fig. 8a3). Another girl (P3) drew a bird's nest and colored it with a picture of hay, *"I've seen bird's nests, they are made of this kind of grass. Don't you think they are similar?"* (Fig. 8b6). This reasoning based on materiality and common sense diverges subjective observations to objective observations developed as they explore the world.

7.2.4 Kaleidoscope: Translate, Transform, Transcribe Differences in Creativity Space. Materiality is an integral part of nature and yet is difficult to transcribe. Children, while making visual observation, liked to feel and touch things with unusual and interesting texture. For example, a boy (P11) was attracted by the moss covering a stone and touched it. After touching it, he expressed his

feeling and thought, *"It's furry, like my dog!"* (Fig. 8b7). Another child (P9) found an army of ants crawling on the stone while touching the stone, *"Look, look, there are ants over here! What are they doing?"* (Fig. 8a2). The haptic feedback reminded them of something familiar and lead to further observation and imagination. The translation of textures, from moss to fur, and of attention, from stone to ants, guides children to have a more intimate interaction with nature. This intertranslation between senses is expressed in their collage works as well. For example, a boy (P13) wanted to draw a boat because the noise from a nearby construction site reminded him the time he rode a boat with his parent, *"It (the boat) was as loud as this. I was riding with mom and dad"* (Fig. 8a4). Although traditional collages can also allow children to contact nature, such contact occurs naturally because children need to physically collect such materials. However, because this is a necessary procedure, children neglect to appreciate it. In our experiment, children in the control group had less spontaneous and unnecessary contact with natural objects.

Our design succeeded in getting children to pay attention to things in nature that have different resolutions. This result is not only brought via video shooting function as we mentioned in subsection 7.2.1, but also triggered by our sound recording function. Whereas visual information is explicit, auditory information is somewhat mysterious. For example, children may hear cicadas, but they may not see them. The child hears the sound of a frog, but does not necessarily know where it is. We found that *"Less is more"* can also be applied in nature exploring. When children know they can pick up sounds, they become more sensitive to them. Compared to the controlled group, the children in the experimental group more frequently sought sound source objects after hearing some specific sound. What's more, regret is also beautiful. Many voices are fleeting and never repeated. After hearing a bird's cry, P9 discovered that he not only couldn't find the bird but also couldn't hear the bird's call, and he abruptly exclaimed to us: *"Do I do something birds don't like? Why don't they play with me? let's go to buy food for the bird."* Compared with the traditional collage group, the group using our system will have more deviating behaviors from the purpose of creation. Perhaps, in part, our system inspires more children's awareness and thinking, which is also a very important part of creativity cultivation.

8 DISCUSSION

8.1 The Relationship between Observation, Creation, and Imagination

Throughout the nature collage process, observation, imagination, and creativity are intertwined and mutually reinforcing, generating an organic cognitive unit.

Creation incentivizes observation. The process of observation is motivated by creation. Children photograph beautiful views so that they can include the elements in their collage later. For example, a boy (P8) found a leaf and started looking for its origin, *"Found it, it's from this tree. It was ..... blown by the wind ..... or a little bird"*. A girl (P3) also thought of rainbows when she saw the sunset. This triggered their imagination and ability to associate their observation with unseen objects from their memories. As such, the incentive of creating nature collage eventually turns an observation into a narrative of the interwoven natural phenomena.

Observation inspires creation. Profound observation diversifies creation. We observed that a girl (P12) drew a picture of what she saw in front of her eyes and embellished the picture with her own imagination, *" You just wait and see (what I will draw)!"*. Another boy (P8) closely examined a tree and constructed a tree house with materials he collected from the tree. Neither of them reproduced the scene, but instead used their creativity to construct a new thing based on their observations. The richness and whimsy are beyond our scope as adults. We concluded that observation and creation promote each other, and imagination is present throughout. Outdoor activities are a curiosity-driven exploration for children, where children are surrounded by information, construct

knowledge, and express their feelings in nature. Hence, an activity that combines observation and creativity just like nature collage is an immersive experience, augmenting children's engagement. Besides, sometimes, it can even help children release themselves from stress, by focusing on enjoying nature-inspired creation rather than thinking about other things (e.g., homework).

8.2 The Relationship between Children and AI

Currently, the younger generations are growing up interacting with AI as AI natives rather than just digital natives [30]. Many children's toys, education products use AI to power the interactive experience and functional features. However, the interaction between AI and children has yet to be completely investigated. But the children-AI relationship is really important and will indeed impact children development [85]. Although with much attention, researchers concerns are primarily cyber privacy and safety. Some research questions, such as to what extent should AI be involved, when to involve, involved by which kind of form still needs further exploration, especially for applying AI for children nature education.

Besides, for the form of AI, we wonder what would be a natural and constructive way to give children feedback. This kind of feedback should be effective in guiding children's independent thinking and exploration without imposing AI's ideas on them. In this case, we hope to design an AI-assisted system that sharpens children's sensitivity to their surroundings without blurring or misdirecting their attention. For example, a conversational agent could prompt questions to further promote reflection and imagination on the process of both material collection and creation.

It should be noted that when considering children-AI relationships, parents are also a participating party that must be considered. This is because most AI-enabled products are used by children under parents' guidance. We value the ways that CSTs could help parents interpret AI-processed content and give guidance. Parents often care about whether the content is "sensible" and the expression "beautiful". During the study, we found that parents often took this opportunity of making nature collages as an educational moment that emphasized embodied interaction with nature. For our AI-enabled image analysis, some parents think it is misleading to children, especially when they see that the picture is not being analyzed accurately enough. In the eyes of the parents, the parents care more about the correctness of the AI than the fun. In this way, it is necessary to further explore how to leverage AI into children-oriented parent-relieved systems.

8.3 Limitation and Future Work

Our system can guide children to see many details, such as texture, material, and structure. Collages can consist of 2.5D to 3D materials, which also create special visual effects and further emphasize the materiality and physicality of natural objects. But these details are often omitted on a 2D canvas, as NaCanva provides. With mature technology in reconstructing 3D objects using tablet's camera, it is possible to create a 3D space to add dimensions and interactivity to children's creation experience. While NaCanva currently only supports the creation of 2D collages, it has the potential to be transformed into a platform that empowers children to quickly produce personalized functional objects for actuation [58, 59], sensing [45] and control [91], as rapid fabrication techniques like 3D printing is being democratized. Allowing children to bring their imaginative ideas from collages into interactive objects in real world can further stimulate their creativity and motivation. During the user study, we found that parents are often worried about children's outdoor activities. Besides, such activities are valuable for parents to educate and bond with their children. NaCanva is yet designed to minimize adult's intervention in the creative process of nature collage. In the future, we hope to implement a constructive and healthy system that encourage parents to be involved. Certain procedures, such as mask creation, were found to be unintuitive, which is a limitation. Furthermore, our user study revealed that sound was not frequently used in the creation, potentially due to

children's lack of patience in listening to multiple audio options. To improve the user experience, we plan to explore more intuitive design options, such as providing more visual cues during creation. Additionally, we intend to investigate the use of machine learning techniques to personalize collages creation guidance and integrate advanced audio features to enhance the creative experience for users.

9 CONCLUSION

We created NaCanva, an AI-assisted system that collects photos, sounds, and videos from nature as raw materials for collage painting for children, motivated by engaging children in creative thinking and developing avenues of exploration in nature. NaCanva uses image segmentation to magnify and redirect children's attention to details, leading to further observations as children play in natural landscapes. In addition to offering a new tool for fun children activity, we emphasized the enhancement of creativity and imagination of children, validated by an extended user study. We conclude that NaCanva helps children make fresh and vivid discovery compared to traditional nature collaging along the development of their realization of knowledge and beauty in nature.

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