Exploring On-Skin Prototyping Toolkits for Wearable Creation: A Workshop Study with Middle School Students

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Figure 1: This paper investigates using an on-skin toolkit, SkinKit [22], in a hands-on workshop designed for middle school students. (a) The SkinKit device consists of PCB modules and skin-conformable wire modules. (b) Students worked in pairs. (c) Students experienced prototyping different wearable functionalities and designed the look and placement on the body.

ABSTRACT

Emerging wearable construction toolkits offer new avenues for hands-on learning through an accessible and creative making process. This paper uses an on-skin wearable prototyping toolkit in hands-on workshops with a total of 45 middle-school students aged between 11 and 15. Besides investigating the effectiveness of utilizing the on-skin toolkit to foster creativity, we iteratively designed and optimized the workshop format, which consists of a hands-on tutorial, a group-making process, and a presentation of project prototypes. Our findings suggest positive engagement and interest in the making process from the middle-school students who participated in the on-skin wearable workshop.

CCS CONCEPTS

• **Human-centered computing** → *Ubiquitous and mobile computing systems and tools.*

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1 INTRODUCTION

Hands-on learning activity represents a cohesive, interdisciplinary approach to equipping students with critical thinking and problem-solving skills [6, 11]. Previous wearable construction toolkits such as Lilypad [4] and MakerWear [19], have demonstrated the effectiveness of utilizing toolkits in workshop settings for children [5]. Beyond traditional wearable form factors, emerging on-skin interfaces [16, 22] can provide new opportunities for prototyping bodily interactions with soft, flexible on-skin circuitry. In this work, we leverage a recent on-skin interface prototyping toolkit, SkinKit [22], which consists of skin-adaptable base materials and reusable flexible printed circuit boards (FPCBs), for wearable creation through workshops with middle-school children. The modular toolkit utilizes a plug-and-play construction [3, 19] approach to support accessible, easy-to-learn, and customizable on-skin device prototyping.

The workshop targets middle school students, as they can tackle complex projects and apply critical thinking more effectively than younger children [11, 12], and makes them ideal candidates for the multidisciplinary skills required by SkinKit. The outcomes gathered from these sessions, the first on-skin toolkit workshop for children, shed light on how SkinKit may contribute to a hands-on learning experience. By designing and building prototypes, students developed application ideas and practiced low-fidelity prototyping. We present the students' final projects to demonstrate the learnability and feasibility of the on-skin wearable toolkit. We also examine their reactions to prototyping circuitry that can be applied directly to the skin surface. Through two pilot studies and a formal study involving 45 middle-school students, this paper contributes preliminary insights into how middle-school students can learn and create on-skin wearable prototypes in a workshop setting.

2 RELATED WORK

2.1 Learning through Demonstration

Based on the Kirkpatrick model [20], hands-on learning emerged as a component of representative research methodology that merges practical and interactive learning experiences. The role of non-formal educational settings in enhancing teaching practices highlights the importance of diverse educational environments in providing inclusive and effective learning opportunities [8], which are instrumental in expanding STEM outreach within K12 education [2, 10, 17, 28]. Supporting this trend of hands-on learning, this paper introduced an on-skin toolkit in the workshop studies that deploys a straightforward crafting process to provide younger learners with a creative and accessible learning experience.

2.2 Toolkit Research in HCI

The approach of toolkit development has reduced technical barriers and facilitated experimentation, empowering developers and researchers to create wearable applications that monitor health [9], enhance communication [15], and provide multi-device interactions [25]. In addition, toolkits can support hands-on learning through an accessible prototyping process [4, 14, 18, 19]. Conventional wearable toolkits consist of E-textiles incorporating conductive materials directly into the fabric, allowing clothing or other textile products to interact with electronic devices [1, 7, 26, 27]. Another form factor, smart tattoos, can be applied directly to the skin and can integrate technology more intimately with the user's body [13, 23, 24, 29]. Based on the e-textile and smart tattoo research, recent on-skin toolkits incorporate wearable technology in thin, flexible circuits that can deploy on the body's surface [21, 22]. Our research utilized an on-skin prototyping toolkit, SkinKit [22], to explore whether the wearable toolkit workshop could provide an interactive and engaging learning experience for middle school students.

3 WORKSHOP DESIGN WITH SKINKIT

3.1 Introducing SkinKit

We used an on-skin toolkit, SkinKit [22], in our workshops. SkinKit consists of two components: wire module and PCB module, as shown in Figure 1a. The substrate of the wire modules is made of multi-layered silicone, which is skin-conformable. The PCB modules have different functions that can be placed between tessellated wire modules. The modular nature of SkinKit enables one to prototype on-skin devices intuitively by manipulating the tangible plug-and-play circuit modules. This approach simplifies the circuit construction, making them more accessible to students.

3.2 Pilot Study

To explore the designs of SkinKit workshops for middle school students, we executed two pilot studies to refine the workshop materials and format based on an IRB-approved protocol.

3.2.1 Pilot Study 1. 11 middle school students participated in the first pilot study. The students were recruited via participation in the New York State 4-H Youth Development Conference held at Cornell University in 2022. We focused on assessing students' abilities to understand and follow the instructions to work with the toolkit.
Outcomes. We discovered that students were engaged to personalize, decorate, and wear the devices they made. Learning from the pre-study and post-study survey results, we analyze the effectiveness of each part of the workshop and modify the workshop process accordingly. The list of improvements includes making a more inviting introduction to wearable technology, adding an open-ended task of team projects, and changing the making process into groups to encourage collaborative efforts.

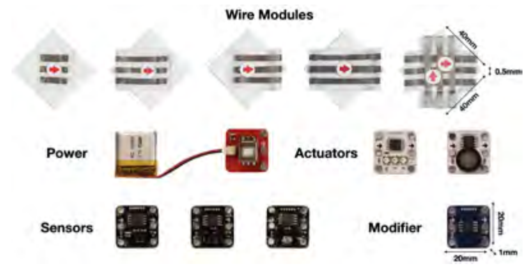

Figure 2: The workshop materials of wire and PCB modules.

3.2.2 Pilot Study 2. Based on the modifications above, we shifted the focus in the second pilot study towards evaluating teamwork and project presentation as the workshop outcomes. Twelve middle school students worked in pairs throughout the workshop. They were given 20 minutes to work on a project idea that they had to present in the group demonstrations. The students were recruited via participation in the New York State 4-H Youth Development Conference held at Cornell University in 2023.
Outcomes. We observed that the new group work format helped reduce frustration or difficulties in the making process and stimulated a positive atmosphere in exchanging ideas. The emphasis on collaborative work and final presentation successfully improves the learning experience, highlighting the benefits of peer support.

4 SKINKIT FORMAL WORKSHOP AND EVALUATION

The formal workshop aims to investigate how well the middle school students learned the on-skin wearable prototyping concepts and to observe what they could create for the final projects.

4.1 Method

4.1.1 Participants. We recruited twenty-two middle school students. Thirteen of them (aged 11 to 14, 5 male, 6 female, 2 prefer not to say) consented to data usage for research. participants were recruited via participation in Ithaca Sciencenter's summer camp. This study followed an IRB protocol approved by Cornell IRB.

4.1.2 Apparatus. We provided each group with a prototyping instruction and a SkinKit set that contains PCB Modules and Wire Modules (Figure 2). The PCB modules include a Power module, two actuator modules (LED and buzzer), three sensor modules (IMU, Light, and proximity), and a signal modifier module that makes an input signal blink. Each group had ten skin cloth substrates to customize the device layouts. Scissors and medical-grade adhesive were provided for device attachment to the body.

4.1.3 Procedure. The workshop's total length is around 75 minutes. It starts with a pre-study survey that records students' prior experiences with wearables. This was followed by a 10-minute introduction to SkinKit, during which we engaged students in learning

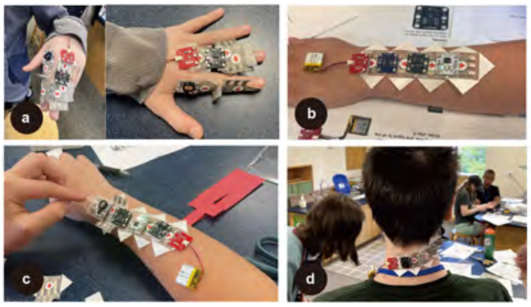

Figure 3: A subset of projects: (a) Finger-switch Buzzer, (b) Interactive LED, (c) Posture Monitoring, (d) Social Distance.

about the circuit structure and module functions. Then, we demonstrated how to wear the device on different body parts. The next 10 minutes were dedicated to a step-by-step tutorial on making a minimal example of the SkinKit device. The students had around 25 minutes to prototype the final project and work in groups with the researchers' assistance. After the making phase, there was a 10-minute group presentation session where students showcased their work to describe the functionality and design concepts. Finally, a 10-minute post-workshop survey was conducted to collect the participants' feedback.

4.1.4 Data Analysis. The post-study survey includes Likert-scale questions about the effectiveness of each workshop step. Qualitative data were also collected from transcriptions of the researcher's conversations with students during the workshops and open-ended questions in the surveys.

4.2 Findings

A subset of final projects presented in Figure 3 provide insights into how middle school students can learn and create with SkinKit. Grouped by the device functionalities, we provide insights from our observations of the making process.

Finger-switch Buzzer. Among the group projects, we were surprised by one of the groups' creativity; they successfully comprehended the toolkit construction and designed a novel interaction beyond our expectations. As shown in Figure 3a, though we only suggested the students assemble and control the circuit with the power, they devised a finger movement control that completes the circuit connection and turns on the buzzer by closing the index and middle fingers. We observed the great potential of hands-on experimentation to encourage students to think outside the box and implement and validate their ideas.

Posture Monitoring. Five groups designed functionality for posture monitoring with different body locations and application scenarios. For example, Figure 3b demonstrated a device that measures the tilting angle of the forearm. According to the students' idea, this technology could help climbers determine a secure angle for stepping. On the other hand, builders could employ this device to measure angles during construction.

Shared Feedback Device. Figure 3c shows a device that helps determine the proximity of objects relative to the wearer's arm with visual and audio feedback. When an object comes within a pre-defined distance from the sensor, the LED driver lights up, providing a visual alert to the surrounding people, and the buzzer can notify the wearer as an eyes-free feedback.

Social Distance Warning. One group of students designed the interaction with considerations of social aspects. As shown in Figure 3d, they designed a social distance signaling that integrates a proximity sensor placed at the nape of the neck. Once the sensor detects a person walks closer than the predetermined range, it activates a buzzing sound to notify the wearer.

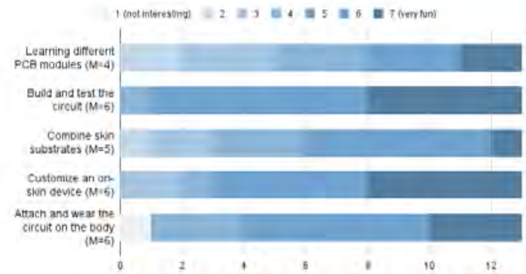

Figure 4: The survey results from the workshop indicate how participants felt about each segment of the workshop.

4.2.1 Students' Feedback. As shown in Figure 4, the students rated each activity on a scale from 1 (not interesting) to 7 (very fun). We observed that participants were interested in practical, demonstrative parts of the workshop. Conversely, "Learning different PCB modules" received the lowest median score of 4 showing lower interest in slideshows and instruction reading.

We also found that students describe the learning outcome in various aspects. For example, P13 was less confident in crafting, but they reported increased interest in wearable designs.

> "Yes, I'm willing to learn more about the aesthetic designs of wearable devices in the future."

On the other hand, P9 found the process of building and contextualizing the practical applications to be exciting:

> "What I learned today can be helpful in our daily life. For example, if someone has a disability in their hands and cannot write usually, the posture monitor on-skin device can help."

The study shows encouraging results that support the on-skin workshop as an effective approach of hands-on learning.

5 CONCLUSION

This paper presents the design and evaluation of on-skin wearable workshops for middle school students through creative and hands-on learning experiences. We envision that future workshops with innovative wearable technologies can promote STEM education and have a broad impact on young learners.

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