NIKITA SONI | RESEARCH STATEMENT

With an unprecedented adoption of natural user interfaces in real-world educational settings such as museums, it has become important to design natural user interactions that **do not hinder learning** and enable learners to engage in meaningful learning experiences themselves. As a human-computer interaction (HCI) researcher, I focus on understanding, designing, and evaluating touch and **gestural interactions** for STEM informal learning technology, that can help non-expert learners visiting museums (e.g., children and families) learn from science data visualizations. My research integrates HCI, interaction design, computer-supported collaborative learning, and learning sciences. My research approach is iterative, often beginning with formative studies and concluding with field deployments of touch-interactive learning interfaces in museums where hundreds of children and adults learn from the interfaces developed as a part of my research. So far, my major research accomplishments include (a) understanding how learners of all ages **interact** and **collaboratively** explore **science data visualizations** around **large touch-surfaces** of different form factors (e.g., multi-touch tabletop and spherical displays) [CSCW21, CHI'EA19, PerDis19, CHI20, ISS20], and (b) designing effective touch-interactions to support learning, particularly from interactive science data visualizations [RISE20, CSCL19a, CSCL19b, IJCSCL20]. My primary research can be summarized as understanding users' gestural interaction preferences and collaboration patterns, to help **design gestures that afford learning more directly**.

I am confident that my training and experience have prepared me for independent research in this area. My Ph.D. education in the Human-Centered Computing program at the University of Florida stressed user-centered design. Although my research methods largely stem from the disciplines of HCI and computer science, my work also heavily draws upon theoretical tools from developmental psychology, social cognitive theory, and learning sciences. I honed my ability to apply these theoretical tools to design interactions for touch-enabled learning interfaces by undertaking coursework in "Advanced Development Psychology", "HCI and the Learner" and "Neuro-technologies in Education". Next, I discuss user-centered design approaches that I have employed to design learning interfaces for children and families across touchscreens of different form factors such as flatscreen tabletops and multi-touch spherical displays.

Understanding Touch-Interactions with Science Data Visualizations to Support Collaborative Learning: Informal learning settings like science museums are increasingly using large touchscreens to enable visitors to explore abstract and complex data visualizations. However, designing accessible interfaces that help learners of all ages explore unfamiliar science data sets, is still difficult. Most prior work in designing touch-interactions for data visualizations has considered that learning is happening during *any* interaction, without considering how *specific* touch-interaction methods can be linked to learning more directly [CSCL19b]. As a part of my Ph.D. research[1], I focused on understanding the specific nature of touchscreen gestures with interactive science data visualizations that help facilitate collaborative learning around multi-touch tabletops [RISE20, CSCL19b, IJCSCL20]. For instance, does the dragging gesture or any other touch-interaction method affect the way groups explore a complex science dataset around an interactive surface? We investigated this question based on a lab study with 11 family groups interacting with our tabletop prototype (Figure 1), which was designed using a combination of user-centered design methods such as a museum observational study and in-lab pilots [CSCL19b, IJCSCL20]. Our analysis revealed that (a) using **draggable and re-sizable interactive lenses** (Figure 1, red and blue lenses) helped learners focus on a subset of the data at a time and offered paths to deeper understanding across time and space dimensions of the science dataset [CSCL19b], and (b) allowing learners to simultaneously manipulate interface elements through **cooperative gestures** encouraged group participation and learning [CSCL19b]. These findings helped us establish the value of exploring the **link between gesture and learning** and laid the groundwork for my future research agenda into studying the interaction design space for different educational data visualization types and learning domains beyond the museum learning context.

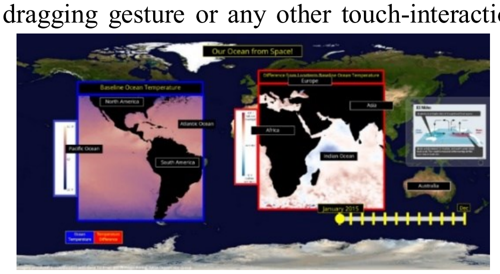

Figure 1: Multi-touch tabletop prototype developed using a user-centered design process.

[1] Conducted as a part of the NSF-funded Touch Interaction for Data Engagement with Sciences on Spheres (TIDESS) project: https://uftidess.wordpress.com/.

Designing Gestures for Collaborative Learning around Multi-Touch Spherical Displays: Beyond flatscreen displays, novel learning technologies like multi-touch spherical displays are also increasingly being used in museums [CHI20]. My Ph.D. dissertation research explores the interaction design space for multi-touch spherical displays to support collaborative learning from interactive science data visualizations [ISS20]. So far, along with the TIDESS[1] team, I have conducted three studies to demonstrate my contributions in this space. (1) The first study was an **in-the-wild exploratory study** in which 27 children and adults in six small groups naturally interacted and collaborated around a multi-touch spherical display prototype (Figure 2), developed using a version of our tabletop prototype (Figure 1) [CHI'EA20]. One of our main findings from this study was that users did not always find interacting with the spherical form factor to be very intuitive [CHI'EA20], let alone interacting with science data visualizations on these displays to develop a deeper understanding. (2) Therefore, as a follow up [PerDis20, CHI20], we conducted a **lab-based gesture elicitation study**[2] with 26 children and adults, to understand gestures they find intuitive when interacting with a spherical display and understand the impact of the display form factor (e.g., spherical vs flatscreen displays) on users' interaction preferences. Our analysis of children's and adults' touch gesture patterns (e.g., number of fingers) [PerDis20] and gestural interaction mental models [CHI20] helped us conclude that the display form factor **strongly influenced** users' mental models of interaction with the sphere. Our findings also showed that children's developmental abilities influenced their touch-gesture patterns on the sphere, hence pointing towards the need to consider children's developmental needs when designing interactions for novel learning interfaces. With this study, we advanced the current understanding of gesture design and surface recognition technology for spherical displays. We are currently in the process of designing a user-defined gesture set for multi-touch spherical displays that can be used in future educational applications for this form-factor. (3) Designing interactions for collaborative learning also requires supporting multiple simultaneous users and addressing interaction design challenges related to **group collaboration** around spherical displays. To investigate this, we studied group collaboration patterns around multi-touch spherical displays by conducting an *in situ* **five-day-long museum deployment study** [CSCW21]. This analysis helped us draw upon learners' natural collaboration behaviors to recommend guidelines for designing **interactive lenses** for spherical touchscreens that not only allow learners to collaboratively explore the underlying science data visualizations but also to manipulate the data and facilitate learning. This analysis will be the first to study interaction design for multi-touch spherical displays to afford collaborative learning from science data visualizations in a museum context.

Figure 2: Children interacting with a multi-touch spherical display prototype.

FUTURE RESEARCH PLANS

Natural user interfaces such as touchscreen technologies of different form factors, Augmented Reality (AR), and Virtual Reality (VR) technologies have the potential to help enhance learning experiences. However, at the moment, interactions for these interfaces are not always designed with users' gesture preferences and developmental abilities in mind. And **critically, little is known about the impact of different interaction design choices on the learning afforded by these interfaces**. Building on my experience of applying knowledge from HCI and computer science, I plan to continue pursuing research to improve natural user interactions for novel interactive learning technologies. For future research, I will focus my efforts on advancing the two problems I have described: continuing to investigate lower-level features of interaction design (e.g., usability) based on learners' developmental abilities and gesture preferences and simultaneously tying interaction design choices to higher-level cognition and learning for educational data visualizations. (1) The first problem I will investigate deals with ***exploring effective interaction design for data visualization related STEM learning interfaces for children in classrooms***. Although multiple research efforts have established the best design practices for the *visual* design of data visualizations for children [IDC09], little research has investigated effective *interaction* design for data visualizations for this age group. I will seek funding from NSF-IIS to support a project that contributes an empirically validated understanding of touch interaction design for data

[2] During a gesture elicitation study, the participants are asked to propose gestures for touchscreen actions such as to make an object **bigger** or to **stop the sphere rotation** while thinking aloud about their gesture creation process.

visualizations for children in **STEM classrooms** and evaluate how these interaction design choices tie to higher-level cognition (e.g., hypothesis generation) among children. In the long-term, I am interested in helping establish best practices for interaction design in educational data visualizations for children, as well as extending beyond touchscreens to design novel interaction techniques for AR and VR science learning technologies. (2) For the second problem, I will ***explore interaction design for creative art-based technology in STEAM (STEM with Arts) Learning:*** My Ph.D. research focused on STEM learning applications, but STEAM is another important effort where education technology can be helpful. Employing art-based touchscreen interfaces for learning can help increase engagement among children while allowing them to visually learn STEM subjects. Visual literacy is an essential tool in learning science concepts such as diagrams of the human-eye drawn by children in primary school [IJEE17]. Most current digital painting creativity support tools (CSTs) are primarily targeted at professionals and can be sometimes overwhelming for novice users (including children). In fact, findings from one of my side projects that dealt with exploring the research-practice gap in children's mobile technologies indicated that commercial apps designed for children do not always adhere to research-based interface design recommendations that consider children's developmental abilities [IDC19]. Through my Ph.D. research, I have had experience with running multiple types of lab and field studies to design interactions for novel science learning technologies. Building upon my experiences, in the future, I will explore how children's expectations and abilities impact the design and development of novel interactions for drawing and painting technologies for science learning. NSF-IIS is a natural fit for this program, but I will also seek industry funding from organizations that develop creative technologies and applications such as Microsoft and Adobe Creative Technologies. For this project, I would seek out partnerships with researchers in the visual arts and learning scientists to inform the design of art-based learning applications for children. To achieve success in research and funding, collaboration is crucial. HCI is a multi-disciplinary field; as a part of my Ph.D. research, I frequently collaborated with researchers both within sub-domains of computer science (e.g., social computing) as well as outside of computer science (e.g., learning scientists). Both of these collaborations have resulted in multiple peer-reviewed publications in HCI conferences such as CHI and IDC. I will continue these collaborations and expect to develop new ones as I pursue grants to fund my research. My goal for future work is to continue to design, develop, and evaluate novel learning technologies for children.

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