

# Formative Evaluation of MindfulNest: A Tangible User Interface for Emotion Regulation

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## **Abstract**

The development of a child's emotional regulation skills is a crucial part of early childhood learning. Additionally, the introduction of well designed, interactive technology at a young age is also important as it creates positive attitudes in children about their ability to positively use and create technology. To bring both these areas into one tool we designed and developed MindfulNest through a series of co-design exercises with teachers and students. MindfulNest was first designed with teachers through a series of workshops focusing on design principles of brainstorming and prototyping. From this we developed an early version of MindfulNest that we pilot tested in two classrooms over the course of eight weeks each. We observed and talked with students and teachers as they used MindfulNest in their classrooms. From these tests, we found design improvements and general design takeaways for designing technology for young students.

## **Introduction**

Decades of rigorous research illustrate that the early years of development fundamentally shape a child's brain architecture, influencing the progression of skill development and social-emotional competency. In a world faced with rapidly evolving educational, technological, cultural, and biological landscapes, the capacity to self-regulate emotion supports one's capacity to navigate resulting challenges. The ability to recognize, process, and regulate their emotional responses effectively helps children to manage interpersonal interactions and respond constructively to hurdles. Technology provides a unique opportunity to support the development of these skills when designed carefully with principles of active, hands-on, engaging, and empowering interactions in mind. This paper explores the importance of social and emotional skill development and proper technological development and how these principles were applied through co-design workshops with teachers and students to produce MindfulNest, a technology tool for supporting emotion regulation.

## **Background: Social and Emotional Development**

### **The Social-Emotional Shift**

A true decade of decadence, the 1980s brought excess to new heights with its big hair, even bigger shoulder pads, and giant employment surges in fields like manufacturing and mining. Spurred by a boost to oil and gas markets, mining employment alone grew by 45,000 jobs in 1987 – an expansion that the Monthly Labor Review then called a promising sign for the industry (Ulmer & Howe, 1987). The success of these labor-intensive industries rested as heavily on worker's physical capabilities as it did on their interpersonal and critical thinking skills.

Yet the 1980s also ushered in a wave of rapid technological advancement and societal change. Between 1984 and 1986, Apple Mac computers hit the shelves, laser printers became standard workplace equipment, and the first dot-com appeared on the scene along with an innovation that would irrevocably alter the way the world would live and work: the worldwide web. The web expanded technology in ways that increased automation, spawned internet-based business, and placed unprecedented impact on the workplace and the world, marking massive shifts in labor markets.

Fast-forward through the decades and society faces new challenges in the form of climate change, health care demands, and financial shifts brought on by longer life spans. Humanity also faces novel quandaries such as a virulent pandemic, the regulation – or not -- of social media and the growth of digital currencies like Bitcoin. These technological, cultural, and biological evolutions demand new approaches, imaginative solutions, inventive processes, and vibrant vision. But for our children to survive and thrive in this competitive and turbulent global village, they must also possess an ability to collaborate with others across the world.

According to a report by Wall Street Journal, “companies across the U.S. find it is becoming increasingly difficult to find applicants who can communicate clearly, take initiative, problem-solve and get along with co-workers” (Davidson, 2016). The publication surveyed nearly 900 executives and 92% said it’s equally important or more important for employees to demonstrate these “soft skills” than technical skills. Yet 89% of those surveyed cited difficulty finding people with those attributes, “a problem spanning age groups and experience levels” (Davidson, 2016).

So, if the work of the modern era and the future of humanity requires an ability to play and work well with others, how do we prepare our children to adapt successfully? A growing number of researchers and educators believe that, in part, the answer lies in supporting the development of *emotional regulation* of early learners.

## Defining Self-Regulation

Emotion regulation in early childhood is a key aspect relating to children’s future achievement and school readiness as well as facilitating positive interactions in the present with their parents, teachers, and peers (Urasche et al. 2012, Nix et al. 2013, National Scientific Council 2004).

Google the term “self-regulation” and the search engine spotlights a therapy-based definition:

Self-regulation is the ability to monitor and manage your energy states, emotions, thoughts, and behaviors in ways that are acceptable and produce positive results such as well-being, loving relationships, and learning (“What is Self-Regulation”, n.d.).

A scan of resources related to the study of self-regulation returns multiple delineations of the term. The American Psychological Association (APA) (2020) presents a clinical description, referring to “the control of one’s behavior through the use of self-monitoring (keeping a record of

behavior), self-evaluation (assessing the information obtained during self-monitoring), and self-reinforcement (rewarding oneself for appropriate behavior or for attaining a goal).

At the root of the APA definition is the Social Cognitive Theory of Self-Regulation presented by Bandura (1991), who emphasized the psychological subfunctions that individuals experience, both responsively and reflexively, to internal and external influence.

If human behavior were regulatory solely by external outcomes, people would behave like weathervanes, constantly shifting directing to conform to whatever momentary social influence...In actuality, people possess self-reflective and self-reactive capabilities that enable them to exercise some control over their thoughts, feelings, motivation, and actions...people adopt certain standards of behavior that serve as guides and motivators...Human functioning is, therefore, regulated by an interplay of self-generated and external sources of influence... self-regulation operates through a set of psychological subfunctions that must be mobilized and developed for self-directed change. (Bandura, p. 249)

This perspective offers a logical segue into the significance of using emotional regulation strategies to support the progression of self-directed change during the formative years, as our aptitude for self-regulation as an adult takes root in early childhood.

## Emotional Development in Early Childhood

An ever-expanding body of scientific research asserts that emotional development begins in a child's earliest years. As a report from Harvard University Center for the Developing Child (2009) points out, "in the first few years of life, more than 1 million new neural connections are formed every second...These are the connections that build brain architecture – the foundation upon which all later learning, behavior, and health depend". These neural connections support a child's capacity to feel and express a range of emotions and develop ways to cope with their feelings.

In its commonly-used framework, the Collaborative for Academic, Social, and Emotional Learning (CASEL, as cited by O'Conner et al., 2017) identifies five core competencies that encourage social and emotional development in young children when prioritized across early learning settings:

- *Self-awareness*. Knowing what one feels, accurately assessing one's interests and strengths, and maintaining a well-grounded sense of self-confidence.
- *Self-management*. Regulating one's emotions to handle stress, control impulses, and motivate oneself to persevere in overcoming obstacles, setting and monitoring progress toward the achievement of personal and academic goals, and expressing emotions appropriately.
- *Social awareness*. Being able to take the perspective of and empathize with others, recognizing and appreciating individual and group similarities and differences.

- *Relationship skills*. Establishing and maintaining healthy and rewarding relationships on the basis of cooperation and resistance to inappropriate social pressure; preventing, managing, and constructively resolving interpersonal conflict; and seeking help when needed.
- *Responsible decision-making*. Making decisions based on a consideration of all relevant factors, including applicable ethical standards, safety concerns, and social norms; the likely consequences of taking alternative courses of action; and respect for others. (CASEL, 2012 as cited by O’Conner et. Al, 2017)

Yet, helping children to develop in these areas requires consistent – and persistent – integration of support strategies into daily routines and ongoing learning activities.

## Creating Strong SEL Environments

Children who experience environments rich in social-emotional supports experience more positive outcomes that support lifelong learning and overall well-being. These children show tendencies toward greater happiness, more motivation to learn, higher participation in class activities, and demonstrate more positive academic performance than their peers (Hyson, 2004; Kostelnik et al., 2015, as cited by Ho & Funk, 2018). High-quality early learning environments may adopt a number of strategies to provide children with opportunities to learn and develop emotional regulation skills and integrate social-emotional supports into the fabric of learning spaces, daily schedule, and interpersonal interactions.

Providing competent social-emotional supports starts with a basic understanding of developmentally-appropriate practice (DAP). Using this construct as a foundation, providers of quality early learning environments understand that young children demonstrate a wide range of capabilities, interests, and skills. They also use research-based practices that respond appropriately to how children learn best – through play-based discovery and exploration. DAP also requires educators and caregivers to manage their expectations of children’s behavior. To do so effectively, NAEYC recommends the use of three core considerations to foster optimal development and learning for each child: commonality in children’s development and learning, individuality reflecting each child’s unique characteristics and experiences, and the context in which development and learning occur.

Beyond the foundations of DAP, the U.S. Department of Education Institute of Education Sciences (as cited by O’Conner et. al, 2017) identifies three critical strategies for the development of social-emotional skills in early childhood educational settings: social and emotional competence of the educators, classroom climate, and instructional strategies.

### *Social and Emotional Competence*

Educators with social and emotional competence “hold prosocial values and make responsible decisions based, in part, on how their decisions may affect others” (O’Conner et al., 2017).

Classroom educators with a strong self-awareness and a high level of emotional intelligence may more effectively implement instructional and interventional strategies to respond empathetically and appropriately to the needs and behaviors of young children. “Moreover, teachers who succeed in managing their feelings may respond more effectively to challenging situations with students” (Zinsser et al., as cited by O’Conner et al., 2017).

### *Classroom climate*

Effective early learning spaces encourage individual investigation and playful exploration. The arrangement of the environment significantly impacts children’s level of engagement, use of tools and supplies, and the capacity of educators to effectively facilitate learning experiences. An environment that encourages children’s interests while providing emotional support positively impacts their learning outcomes, and leaves them feeling free to experience the excitement of learning new things.

An effective classroom climate creates a safe space for high-quality interactions between children and between the children and adults. It also lends itself to “teachable moments” by increasing opportunities for small group and individual social-emotional activities and interactions. Example practices include providing adequate space, setting up interest areas, and careful material selection (O’Conner et al., 2017).

### *Instructional strategies*

Studies suggest that early childhood educators may foster social and emotional growth through emotion socialization (Denham, Basset, & Wyatt, 2007; Zinsser et al., in press, as cited by O’Conner et al., 2017). The Institute of Education Sciences (2017) describes emotion socialization in three components: modeling emotions and social exchanges, reacting to student emotions and interactions with others, and teaching about emotions and relationships.

Examples of instructional strategies for social and emotional learning include:

- Participating in conversations about feelings.
- Allowing children time to tell their own stories that incorporate personal experiences, hopes and dreams, and practices and traditions
- Talking deliberately about the context and meaning of emotions.
- Using real events to help students attend to others’ emotions (“How do you think Jake feels with his dad away?”).
- Teaching the difference between feelings and acting on those feelings (for example, it’s okay to be angry but not to hit).
- Teaching children the labels, causes, and consequences of emotions.
- Labeling feelings for children, asking how they feel, and asking them to identify the feelings of others.

(Denham et al., 2012; Figueroa-Sánchez, 2008; Hromek & Roffey, 2009; Kemple & Ellis, 2009; Macklem, 2008b; McCabe & Altamura, 2011; Schonert-Reichl; 2011; Thompson & Twibell, 2009; Whitted, 2011; Zinsser et al., in press, as cited by O’Conner et al., 2017)

## Background: Technology and Design Principles

In order to explore the application of technology to social-emotional development we launched the MindfulNest project.

### Participatory Design

The development of the MindfulNest system utilized a participatory design process (also known as co-design), which can facilitate the collaboration between participants of two distinct roles: “designers” and “users.” The designers strive to learn the real needs of the users, while the users strive to articulate their desired aims and learn the appropriate technological means to obtain them (Simon & Robertson, 2012). Some of the benefits of this process are that it addresses an area in which no participant normally knows everything and lets both roles have a say in what they are making.

Typically, participatory design offers two distinct types of tools for making: participatory prototyping and generative tools (Simon & Robertson, 2012). Prototyping uses mock-ups and other low fidelity models and presupposes that you have already identified the object of the design. Generative tools provide ambiguity to non-designers in order to encourage expression of unspoken and latent needs, aspirations, and dreams. We leveraged both of these through our design process with teachers.

### Technology Design for Young Children

Recommendations from the National Association for the Education of Young Children (NAEYC) further informed our design objectives. NAEYC splits screen time into two categories: non-interactive and interactive (NAEYC 2012). Interactive screen time is when children are engaged in an activity using screens which facilitates active and creative use and encourages social engagement with other children and adults. Effective uses of technology and media are active, hands-on, engaging, and empowering (NAEYC 2012). Tools should also give the child control, provide adaptive scaffolds to ease the accomplishment of tasks, and be used as one of many options to support children’s learning.

The field of Embodied Child Computer Interaction (CCI) focuses on “the design, evaluation, and implementation of interactive computer systems for children” (Hourcade, 2015). The focus on interactive systems fits well with the above guidelines. In order to encourage interaction, tangible user interfaces (TUIs) have been used in interactions with children. Numerous TUIs have been used to support spatial learning in children and have been shown in multiple developmental studies to directly relate to school readiness and STEAM success (Baykal et al, 2018).

Developmentally appropriate practices drive our team's technology integration and development decisions. Therefore, we aim to make an interactive app with tangible devices that shifts the focus away from the screen and onto the child themselves. In doing so, we are prioritizing preschool learning standards such as 16.1 PK.A, which states that students should be able to "distinguish between emotions and identify socially accepted ways to express them" (Office of Child Development and Early Learning, 2014).

## **Teacher Design Workshops**

In order to discover how best to combine technology and social-emotional development, we recruited teachers for participatory design sessions beginning with brainstorming and ending with a fully designed prototype. We recruited pre-kindergarten and kindergarten teachers (N = 6) from early childhood education centers and schools within Pittsburgh, PA and the surrounding area. Teachers represented a mix of school types (urban, rural, suburban), years of teaching experience, teaching philosophies, student populations (ages 3 to 6, demographics, income), classroom sizes, and program types (evening family programs, mixed-age classes, single-age classes). We chose to initially recruit teachers as co-designers, instead of children, due to the young target ages of the students and the educational intent of the tool. Each participatory design session supported a single step in our generative design process: brainstorming, paper prototyping, and digital prototyping (Sanders and Stappers, 2013; Saffer 2007).

### *Brainstorming*

During the brainstorming session, we explored the problem space and considered potential ideas and project directions without restriction on final project technologies. Teachers completed some structured brainstorming activities shown in Figure 1. Through these participants shared their social and emotional learning goals for students and identified the areas where students most struggled. Self awareness, self regulation, and appropriate ways to express emotions were priorities. Teachers also wanted students to be able to recognize their emotions before they became problematic, and be able to cope with these emotions in a socially acceptable way. Other goals included teaching students a growth mindset, kindness, and social skills.

5x5 Brainstorming Grid	Alone	Dramatic Play	Together	Parallel Play	With an Adult
Building Empathy	Thinking about & feeling	Saying are you ok and have the appropriate	working together to solve a problem	meeting w/ a peer about a behavior	discussing feelings w/ an adult
Reciprocal Communication	Talking to one's self	communicating w/ family	problem solving w/ a peer	repeating what others are saying	Talking through a problem w/ an adult
Identifying Emotions	Identifying emotions	acting out roles of children in different scenarios	modeling emotions as a group	playing with another using emotions	playing emotion game
Managing Emotions & Behavior	Sticker chart of class jobs	acting out app	characters to model appropriate and inappropriate	repeating emotions and identifying emotion behaviors	sticker chart - playing how to feel/ how to feel/ how to feel
Managing Interpersonal Conflict	deep breathing, calming down strategies	acting out situations of conflict w/ a peer	problem situations	keeping to self	counting to ten, yoga

Figure 1. An example of a brainstorming grid designed to elicit ideas about activities to support important social-emotional skills.

Teachers also shared examples of the technologies they had used with students previously and the pros and cons of these technologies. As reflected in the literature, hands-on, active engagement and physical interaction were highly valued by participating teachers (Chordia et al, 2019). Teachers also wanted to limit screen time and ensure any intervention would not take too much time. The session ended with structured activities to brainstorm ideas for technologies to help teachers meet their social and emotional learning goals.

This brainstorming workshop and the related literature informed the following design goals for MindfulNest:

1. Support student's self awareness, self regulation, and appropriate emotional expressions.
2. Be actively engaging through the use of hands-on, physical interaction.
3. Provide teachers one option for support of students' social and emotional development.

### *Paper Prototypes*

Based on these goals, we created six paper prototypes (Figure 2), each consisting of a TUI and tablet screens. In order to select designs to develop further, the second session focused on potential in-class use cases, teacher reflections on usability for their students, and determining the most important concepts for the tools to support. Overall teachers wanted a tool that students could use for a short amount of time to help them calm down and return to the classroom, thus limiting screen time. From any designed tangible device, teachers wanted physical interaction that could not be achieved with a tablet. From any designed app, teachers wanted some sort of login to help them track student emotions. Teachers also liked ending the interaction with a final check-in about how the student felt leaving the tool and going back to the class.

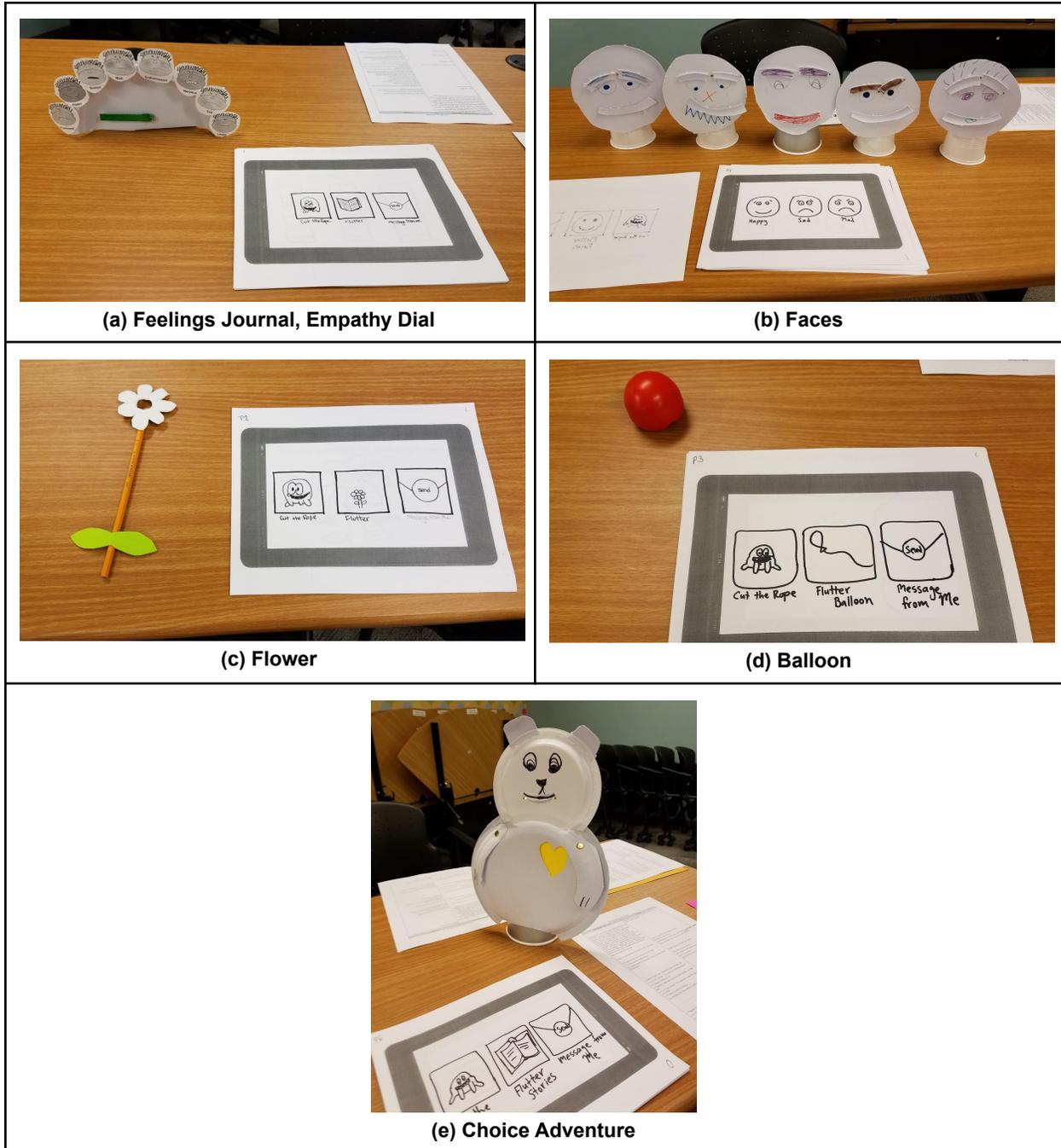


Figure 2. Images of five stations representing the six paper prototypes from the teacher design workshops. Each station utilizes a TUI and tablet screen. (a) Emotion dial station with the “Feelings Journal” prototype, where students use the dial to indicate their current emotion and record how they are feeling, and the “Empathy Dial” prototype, where students use the dial to identify emotions of characters in narrative presented on the tablet screen. (b) Faces station with the “Faces” prototype, which teaches students to recognize and identify different emotions and expressions. (c) Flower station with the “Flower” prototype, which guides students through controlled breathing. (d) Squeeze station with the “Balloon” prototype, which displays a balloon floating into the sky that is controlled by the squeezing of a soft red ball. (e) Bear station with the “Choice Adventure” prototype, a choose your own adventure style game where students listen to the teacher reading a story on the tablet; the heart on the bear lights up different colors depending on the choices made by the class.

The session ended with teachers ranking the six prototypes. The top three prototypes were the “Feelings Journal” prototype (Figure 2a), the “Flower” prototype (Figure 2c), and the “Balloon” prototype (Figure 2d).

### Digital Prototypes

Based on teacher ranking and feedback from the paper prototyping session, we created two digital prototypes (Figures 3 and 4). Teachers individually tested the prototypes with researchers to provide feedback on designs. One prototype focused on recognizing emotions in others, empathy, and exploring how social actions can impact the emotions of others through narrative storytelling.

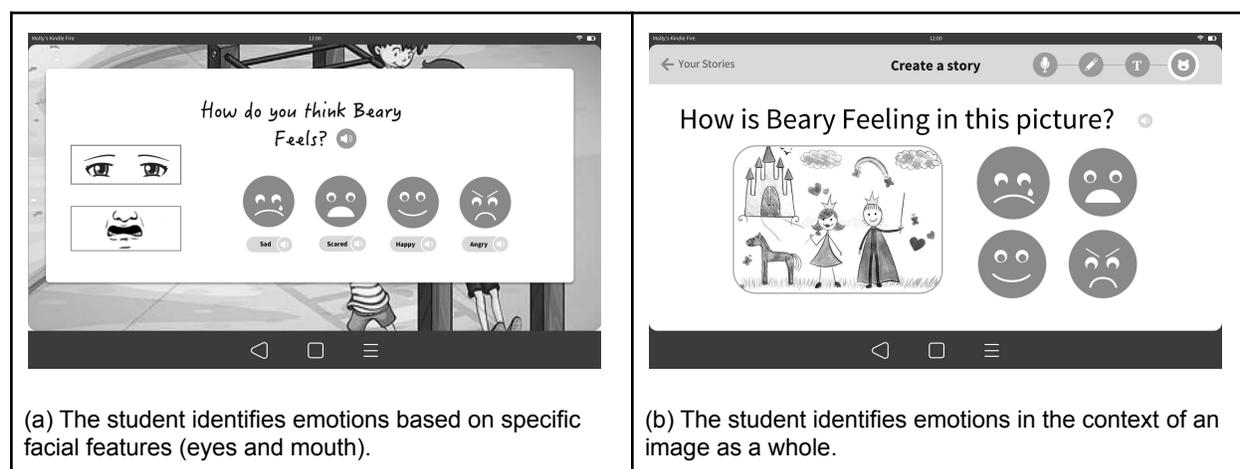


Figure 3. Screenshots from one of the two digital prototypes that were created for the teacher design workshops. This prototype focused on students recognizing emotions through a character named Beary, inspired from one of the paper prototype designs.

The second prototype focused on students recognizing their own emotions and developing emotional regulation skills. It led students through a process beginning with children identifying their emotion, choosing a coping skill activity, and finally checking in with their body. Designs for activities included guided breathing with a tangible flower (Figure 5a), guided stress relief with a tangible squeezable object (Figure 5b), calming through moving to music with a tangible wand to sense motion (Figure 5c), and encouraging the student to ask for a hug or talk to their teacher.

The second prototype (Figure 4) was a clear favorite for the teachers and served as the foundation for the MindfulNest prototype. The other activities in MindfulNest were inspired by the final discussion with the teachers and the background research done previously.

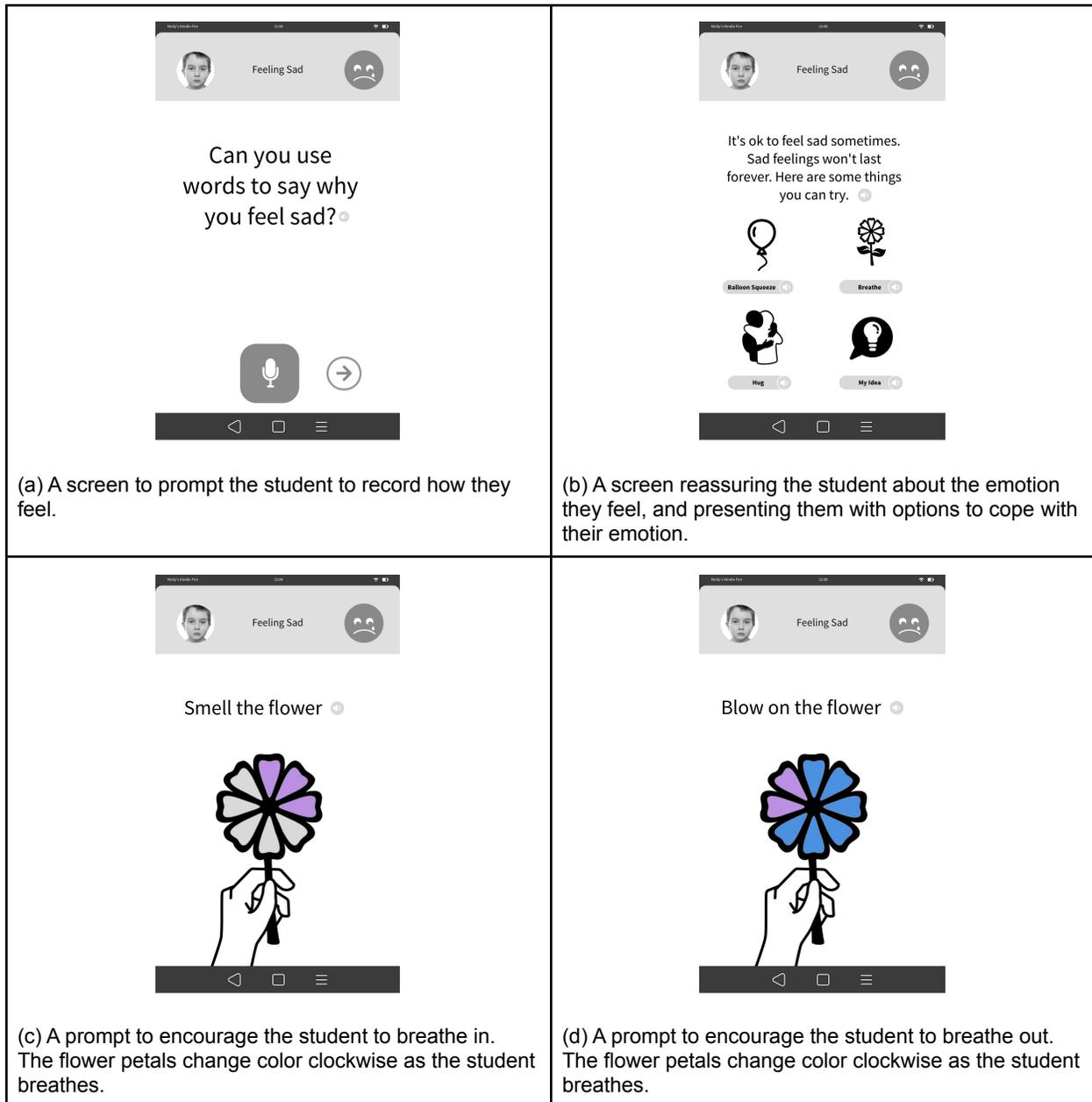


Figure 4. Screenshots from one of the two digital prototypes that were created for the teacher design workshops. This prototype focused on students recognizing their own emotions and developing emotional regulation skills by choosing from a list of suggested coping skills.

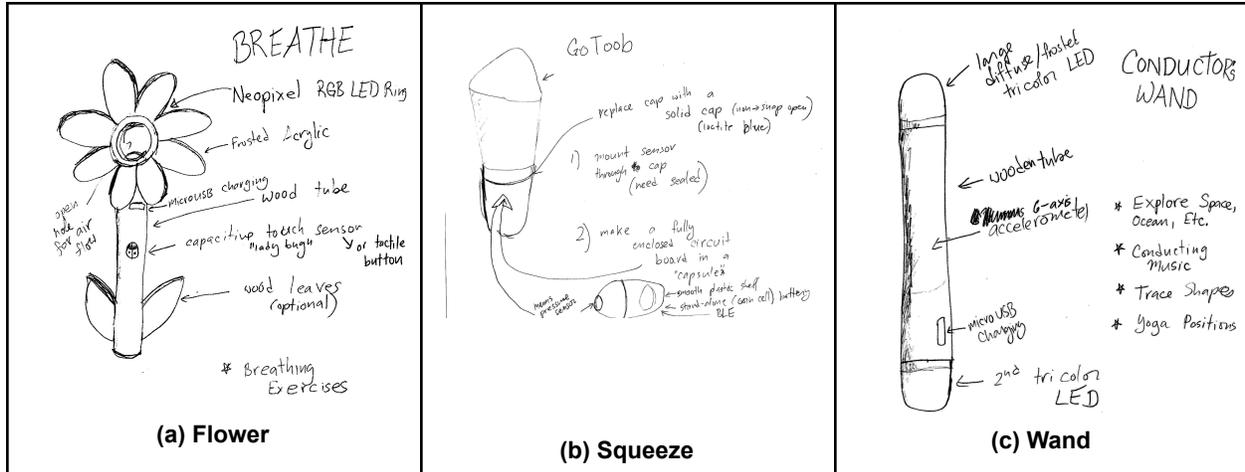


Figure 5. Initial sketches for three of the tangible user interfaces.

## The MindfulNest System

From the initial participatory design workshops with teachers, we developed a prototype of MindfulNest involving a guiding app and different TUIs. It centers on four TUIs: the wand, wristband, flower, and squeezer (Figure 6) connected via bluetooth to a tablet. The wand and the wristband, both accelerometer based, were designed from teacher discussions highlighting gross motor movements as regulation skills. The wand detects arm and wrist movement then reacts using an RGB LED and sound on the tablet. The wristband is designed for use during exercise and stretching activities to track student movements. The flower was designed from teacher discussions involving guided breathing activities. The flower has a microphone for breath detection, RGB LEDs for feedback, and a small button, identified by a plastic ladybug. The squeezer was designed from teacher discussions centering on channeling frustration and anger through safe and positive outlets. It was made with a silicone shampoo bottle stuffed with beads and an air pressure sensor to detect change of pressure inside the bottle when squeezed.



Figure 6. The initial prototype of MindfulNest prototype with the flower, squeezer, wand, wristband, and tablet showing the logo.

The MindfulNest app follows the flow shown in Figure 7. Students were provided with a selection of activities (pictured in Figure 8, described in Table 1) based on the emotion they chose. After they selected and completed an activity, students were guided through a series of regulation check-ins, including measuring their heartbeat, selecting their post-activity emotion, and recording how they feel. Students then selected whether they were ready to rejoin their friends or needed more time to calm down.

Table 1. Descriptions of available activities and the TUI used. Screens without video or animation are considered static, otherwise they are dynamic.

Activity	TUI	Screen	Intended Activity Design	Activity Implemented for Pilots	Time of Implementation
Flower Breathing	Flower	Dynamic	The student is guided to push the button on the flower to start the activity. They are then asked to smell the flower then blow on it three times.		Pilot 1 - Week 1
Wand	Wand	Dynamic	The student is guided to wave the wand slowly to make the music play.	A version of the planned activity; data was very noisy.	Pilot 2 - Week 8
Squeeze	Squeezer	Dynamic/Static	The student squeezes the squeezer to make the balloon float higher in the air.	A static screen showing a hand holding the squeezer, prompting the student to squeeze the squeezer until they felt in control.	Pilot 1 - Week 8
Stretching	Wristband	Dynamic	The student is guided with audio, video, and feedback from a wristband through different stretches. There are four stretching sequences to choose from.	The wristband had a casing for technology but was in an analog state with no microcontroller or bluetooth.	Pilot 1 - Week 7
Jumping Jacks	Wristband	Dynamic	The student is guided with audio and video through doing jumping jacks.	The wristband was added for the potential of feedback.	Wrist band included Pilot 2 - Week 2 Activity available Pilot 1 - Week 1
Cuddle a Toy	--	Static	The student is encouraged to cuddle a toy until they feel better. They would select a toy they liked from the classroom thus it is not considered a TUI or manipulative for the purpose of this study.		Pilot 1 - Week 1
Invite a Friend	--	Static	The student is encouraged to invite a friend to play with them.		Pilot 1 - Week 1
Dance	--	Static	The student is asked to make up a dance to show how they feel as background dance music plays.		Pilot 1 - Week 1
Talk with Your Teacher	--	Static	The student is encouraged to talk to their teacher about how they feel.		Pilot 2 - Week 1

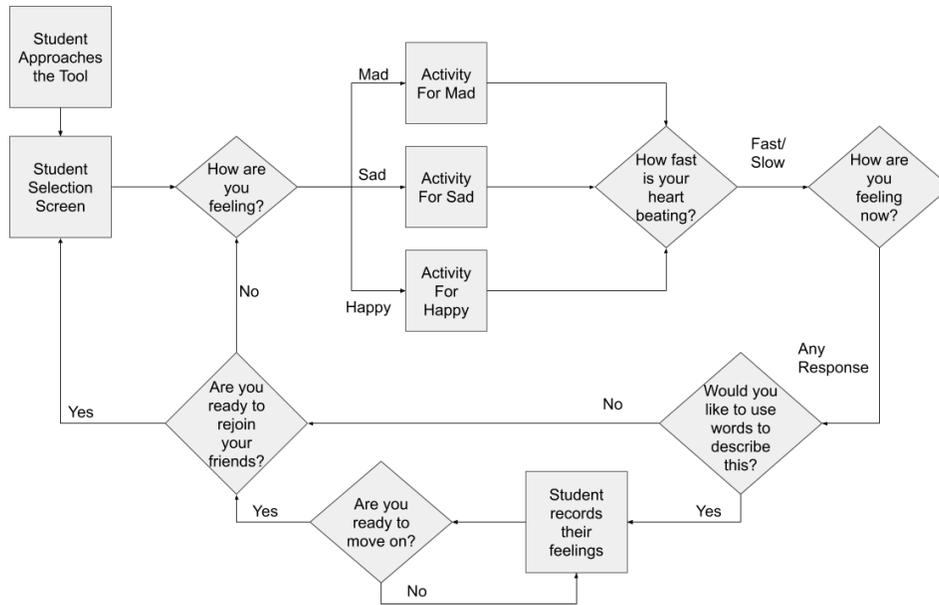


Figure 7. A flow chart of a student's interaction with the MindfulNest app.

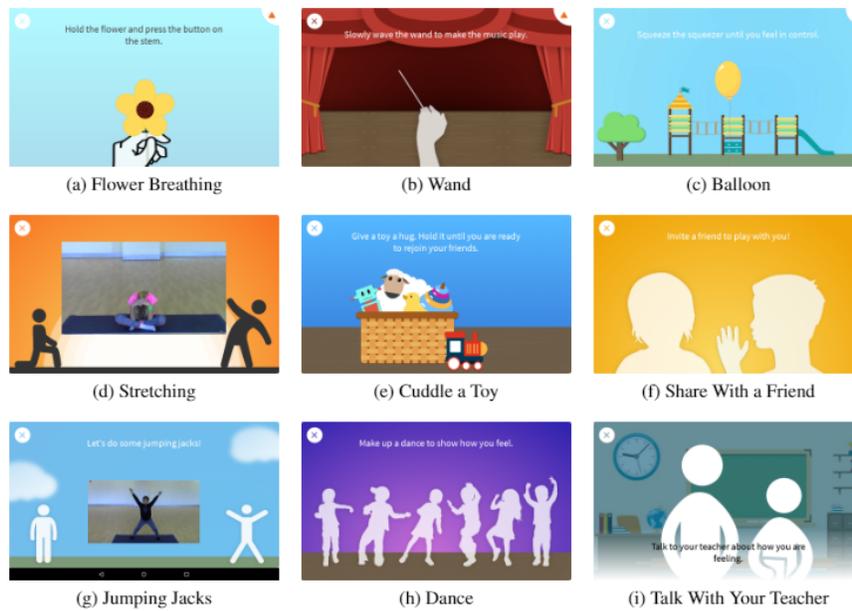


Figure 8. Screenshots of available activities. Guidance is given through audio prompts which match the text on the screen.

## Pilot Testing of the Design

### Methods

We conducted two eight-week long pilots to perform evaluative research (Sanders and Stappers, 2013) in two different classrooms, beginning in January and April. The classrooms were located in urban neighborhoods in Pittsburgh, PA and served primarily low and moderate income families. The first location was a pre-Kindergarten classroom (ages 4 and 5) with nine students (2 boys, 7 girls), one teacher, and one aide. The teacher had participated in the teacher design workshops. The second location was a preschool classroom (ages 3 to 5) with 11 students (4 boys, 7 girls), one teacher, and one aide. All students and two of the teachers were black. Two teachers were white. Teachers and aides attended 3 hours of professional development before introducing MindfulNest into their classrooms.

At least two researchers observed the classroom weekly for two and a half hours. Each classroom had two MindfulNest sets. Notes were taken as semi-structured field notes. One week after the conclusion of each pilot, the researchers conducted an interview with the teacher. Observation notes and feedback from teacher interviews were reviewed, and specific and general takeaways were found that informed a final prototype of MindfulNest. The goal of these short tests was to include children in the design process and intuit their preferences through observation of their interactions with the prototype and through direct conversations with researchers. Furthermore, software development to implement more activities was ongoing during the pilots, and equipment was updated weekly to add more activities as well as address any observed technical issues. Table 1 describes the activities as they became available during the pilots.

### Observations

We observed each classroom to see if the children using the devices could complete coping activities as intended and were calmed by the process. This initial testing informed design changes to the TUIs and app flow (Table 2). For instance, during the first test, the teacher informed us that students were making up stories about being sad so that they could use the flower, which was only available under the emotion “sad”. In response, we made the flower activity available across all emotions. The TUIs also received updates given the observations of and conversations with students (Table 2).

In response to conversation with a child experiencing daily tantrums, the squeezer was implemented as an activity encouraging students to “squeeze the squeezer until you feel in control,” even though it did not yet have the planned sensing capabilities. Even in this analog state, we found the tool to be useful, especially in calming students down during moments of anger. Similarly, the wristband was implemented without any sensing abilities. Students enjoyed

the stretching activities so much without the band's sensing capabilities that we chose to remove it from future testing. The wand was briefly brought into the classroom to gather sample data. The data was noisy and proved difficult to work with, leading us to alter the board and sensor used for the final prototype (Table 2).

Table 2. Changes that were made to the MindfulNest system based on observations during the pilots.

Change Made	Timing of Change	Reason for Change	General Take-aways
Flow: Available for all emotions	During Initial pilot	Students were making up stories about being sad.	Students do not always associate certain activities with certain emotions.
Flower: Single press over holding button	During initial pilots	Students had trouble holding their hand in the same place for 18 seconds.	Younger students lack fine motor skills and attention to do certain tasks.
Flower: Larger button	After initial pilots	Students couldn't push the smaller button.	
Flower: Hardware updates	After initial pilots	Breath collection was inaccurate.	Students have trouble exactly directing their breathing to one location.
Wristband: Removed	After initial pilots	Teachers all agreed it wasn't serving any purpose.	Students can be motivated to do an activity even without feedback on how well they're doing the activity.
Wand: Hardware	After initial pilots	Student data was too noisy.	Young students have more sporadic movement requiring better sensing and algorithms to determine speed and direction.

## Discussion

We found students lacked certain fine motor skills and attention to do certain tasks such as press smaller buttons and hold them down. Additionally, they had trouble exactly directing their breath, needing a bigger target to guarantee they hit it. We also found that children were often self motivated enough to complete certain activities, mainly those involving large motions, without feedback. For smaller motions however, we learned students were not easily able to control these perfectly, showing the need for better sensing and algorithms for determining their motions. These findings were incorporated into the final prototype of MindfulNest.

## Conclusion

Collaboration among researchers, teachers, and students through a participatory design process and set of initial pilots resulted in the design of the MindfulNest system. The initial teacher design workshop informed our decision to support the development of emotion regulation strategies in the classroom while also providing an opportunity for students to participate in using technology in early education. Student observations during our pilot testing

indicated that students were able to engage with the MindfulNest system and its TUIs and informed our changes to the system to improve its efficacy. For example we changed hardware because interaction designs should avoid fine motor skills which some younger children may struggle with, such as small hardware buttons or less robust motion sensors. These changes are related to general take-aways that would be beneficial for others to consider when designing TUIs for early education classrooms.

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