MindfulNest: Strengthening Emotion Regulation with Tangible User Interfaces

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ABSTRACT

Child care programs provide an environment for children to develop their social and emotional skills. To provide additional support for teachers in nurturing this development, we created MindfulNest, a technology tool designed to support 3 to 5 year olds' development of emotion regulation strategies. We evaluated MindfulNest through a year-long test. We found that students of all ages did not associate particular emotion regulation skills with specific emotions. Younger students struggled to understand complex interactions and occasionally struggled to use the interface, however they were still able to use MindfulNest to regulate their emotions when guided by their teacher. Older students did not struggle to use MindfulNest or understand complex interactions and were able to successfully regulate their emotions by themselves and with teacher guidance.

CCS CONCEPTS

• **Human-centered computing** → **Interactive systems and tools**; **Usability testing**; **User studies**; *Interaction design*; • **Applied computing** → **Education**; *Interactive learning environments.*

KEYWORDS

Education, Learning, Children, Tangible, Embodied Interaction, Emotion Regulation

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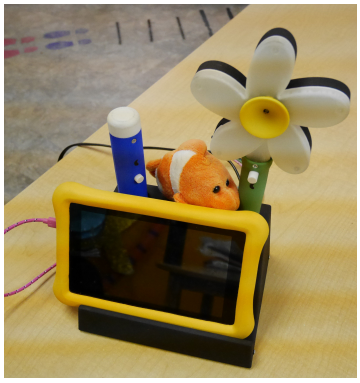

Figure 1: MindfulNest which includes a tablet, Wand, Squeezer (Fish), and Flower.

1 INTRODUCTION

Children's social and emotional development is a very important area to consider in order for young children to better navigate their social and academic worlds. "The foundations of social competence that are developed in the first five years [of life] are linked to emotional well-being and affect a child's later ability to functionally adapt in school and to form successful relationships throughout life" [17]. Therefore, early childhood programs must "aim to help students develop socially and emotionally" [17] in addition to fostering academic preparedness. Although children are rapidly developing since birth to cope with and manage a variety of feelings, emotional development often receives less focus than other highly visible skills such as motor control, cognition, and communication [17].

Teachers and classrooms often lack ample resources or strategies for addressing social and emotional development in the classroom. With a high student to adult ratio, it can be difficult to provide all children with the individual attention they need, especially in times of distress. The potential in using technology to provide teachers with needed support for emotion regulation in the classroom remains unexplored [21]. To explore this application, we designed and developed MindfulNest.

MindfulNest is a tool to help 3 to 5-year-olds develop emotion regulation strategies and was designed directly with teachers through participatory design workshops and pilot tests with students [26]. MindfulNest consists of a set of tangible user interfaces (TUIs) paired with a tablet app (Figure 1). The app guides children through various activities to support coping skill acquisitions. In some activities, the TUIs respond to the child's actions, providing visual,

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tactile, or auditory feedback. For example, the flower responds to a child's breath by lighting up and then slowly dimming to guide their breathing rate.

To explore the potential for MindfulNest, we conducted a qualitative classroom study over the course of one school year, testing in two classrooms from the same center. Through this test, we aimed to answer two questions:

(1) What aspects of MindfulNest enable intentional interactions for students ages 3 to 5?
(2) To what extent are 3 to 5 year olds able to employ emotion regulation strategies through the use of tangible interfaces supported by an app?

This paper describes our evaluation of the MindfulNest system including the teachers' implementations of and students' interaction with the tool. From our evaluation we found general design recommendations for TUIs and apps with this age group that are also described.

2 BACKGROUND AND RELATED WORK

2.1 Emotion Regulation and Child Development

Weissberg [29] theorizes the five keys to successful social and emotional development are self-awareness, self-management, social awareness, relationship skills, and responsible decision making. The Collaborative for Academic, Social, and Emotional Learning (CASEL) has also adapted this set of interrelated cognitive, affective, and behavioral competencies [20]. MindfulNest focuses on the skills of self-awareness and self-management by encouraging students to identify their emotions and build coping skills to create a socially appropriate outlet for managing their emotions.

A review by the U.S. Department of Education Institute of Education Sciences [20] asserts three critical strategies linked to the development of social and emotional skills in the early childhood space: classroom climate, instructional strategies, and social and emotional competence of the educators. Each factor represents a proactive, rather than reactive, approach to fostering children's emotional growth and eliciting positive behavioral responses. MindfulNest reinforces this approach for building social and emotional skills, using techniques to guide children to talk through their emotions; help children label their own emotions and contextualize the emotions of others; encourage children to understand the causes and consequences of their emotions; and teaching students how to act constructively on their feelings [26].

Self-management takes multiple forms. There have been efforts in the past to measure the effects of various coping models [6] [8]. Ayers et al. reviewed existing literature on child coping and interviews with 57 children to develop a four-factor model of children's coping strategies: active, distraction, avoidance, and support-seeking strategies [6]. As active strategies are much more context specific (i.e. require active cognitive and behavioral efforts to define and understand the situation), MindfulNest focuses on distraction strategies and support-seeking strategies (e.g. Emotional Support). The specific strategies and skills supported by each MindfulNest activity are described in Table 1. MindfulNest may also indirectly serve as an avoidance strategy when use of the system implies leaving the stressful situation.

2.2 Technology Design for Young Children

The effectiveness of any education medium depends on the quality of the content and the ways in which it supplements instruction [9] [15] [11]. Guernsey's "3Cs" are a framework for selecting and using appropriate tools [5]. The "3Cs" ask educators to consider the Content (How does it support engagement or exploration?), the Context (How seamlessly does it integrate into a child's natural form of play?), and the Child (How can we consider the individual needs, abilities, and interests of the child?). Additionally, the National Association for the Education of Young Children (NAEYC) defines effective uses of technology and media as active, hands-on, engaging, and empowering [14]. These principles guided the development of MindfulNest, giving it the potential to be an effective classroom technology.

MindfulNest also builds on foundational work in the field of embodied child-computer interaction (CCI). One key theory in CCI is that abstract thought can be enabled through movement and that young children learn primarily through their physical, sensory, and perceptual interactions with the world [1]. For example, Sylla et al. shows that an interactive learning tool can be used during preschool play to encourage students to engage with storytelling [27]. Nonnis and Bryan-Kinns [18] designed a sonic textile based TUI to engage students aged 4 to 10 in social play. In a further study they showed that a similar design showed promise for improving socialization between children with autism [19].

2.3 Biofeedback Devices and TUIs for Emotional Support

Many studies have shown that calming techniques when augmented with biofeedback can have positive effects on calming students and lowering their anxiety [7] [23][24][25][2][3][16]. Bossenbroek et al. show that biofeedback used in a virtual reality game can lower anxiety for older students (ages 12-17) [7]. The work done by Morales et al [16] helps children with autism at younger ages (age 6-12) practice box breathing with a biofeedback device. C. Fage et al. [13] showed that an app that guides students with autism through emotion identification and co-regulation strategies improved their ability to self-regulate in the classroom.

Prior work with TUIs to guide children's breathing has shown that active calming techniques are more effective than passive ones [25]. Sonne initially designed the "ChillFish" to calm children with ADHD and later tested it as a means of calming children while they had blood drawn [23][24][25]. They found that when children breathed into the ChillFish to control an onscreen game, they were less fearful than when passively watching a video.

A wearable neurofeedback system, Mind-Full, has also been shown to help children improve their self-regulation skills [2]. Using Mind-Full, Antle et al. were able to show that a 16-week intervention was able to reduce anxiety in young children [3]. Mind-Full also showed promise in being able to help students at home as well as in the classroom [4]. Wallbaum et al [28] explored the use of a TUI storytelling kit that was geared entirely towards use in the home

Table 1: Emotion regulation skills and the MindfulNest activities designed to support practice with each skill.

Emotion Regulation Skill	Reason for Inclusion	Transition to MindfulNest and Embodied Child Computer Interaction
Deep breathing	Deep breathing can be used as a calming technique in many situations, however young children often struggle with this skill without guidance.	The tangible Flower paired with the Flower Breathing activity to give students a point of focus and self-guidance.
Controlled gross motor movement	Slow and intentional movements support students as they calm themselves because it guides their attention to one singular point of focus.	A tangible wand paired with the activity to engage students and encourage slow, calming movement. A stretching activity guiding student movement.
Channeling Frustration	This skill gives students who calm themselves through emotional aggression [12] a socially acceptable channel with which they can cope through physical action.	A tangible device for squeezing paired with an activity providing visual feedback for actions.
Channeling Extra Energy	This skill gives students a socially acceptable outlet to channel their extra energy.	An activity guiding students through jumping jacks. An activity encouraging students to dance.
Distracting Actions Through Physical Comfort [6]	Students can make themselves feel better through distracting themselves from their emotions with physical comfort such as hugging a soft toy.	An activity that encourages the student to give a classroom toy a hug.
Checking Your Heart Rate	This check gives students a way to identify their emotional state based on how their body feels.	A post coping skill activity encouraging students to feel their own heart rate.
Emotional Support [12][6]	The student talks about how they are feeling with a peer or an adult in order to work through their emotions.	An activity to guide students to talk with their teacher. An activity that encourages students to share their emotions with friends or record how they feel.

to benefit parents of children ages 5 to 9 in understanding their child's emotions.

MindfulNest aims to build upon these past technology interventions by providing a range of support for multiple emotions and engaging students through the use of physical and visual feedback. Following the recommendation that technology be deployed in all areas of the school, MindfulNest will be deployed in classrooms, not as an intervention, but as a tool available at all times to students [22].

3 SYSTEM DESCRIPTION

The MindfulNest tool consists of three TUIs, a tablet app, and a stand with integrated charging (Figure 1). Each TUI contains LEDs, sensors related to their utility, and an internal battery. The interfaces communicate wirelessly over Bluetooth to the MindfulNest app. The app's main landing screen is the student selection screen which displays all students with their name and picture. Students are guided through a sequence of prompts (Figure 2) and activities, shown in Figure 3 and described in Table 2. These activities were included to support different emotion regulation skills (Table 1) [26].

3.1 Hardware

The flower is composed of a central ring of tri-color LEDs along with a sound sensor. The phrasing and timing of the activity prompts are designed to guide the student through several cycles of slow and calm breathing. As the student blows on the flower, the sensor detects their breath and the LEDs' color changes. This interaction encourages students to continue their breathing and provides visual feedback for their actions.

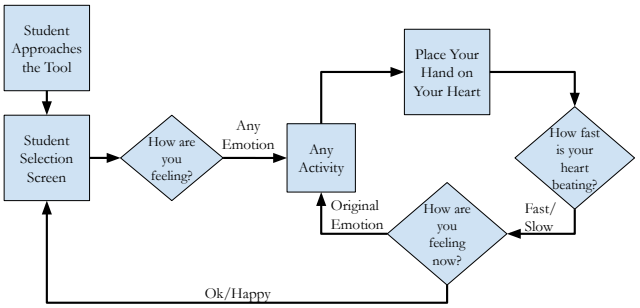


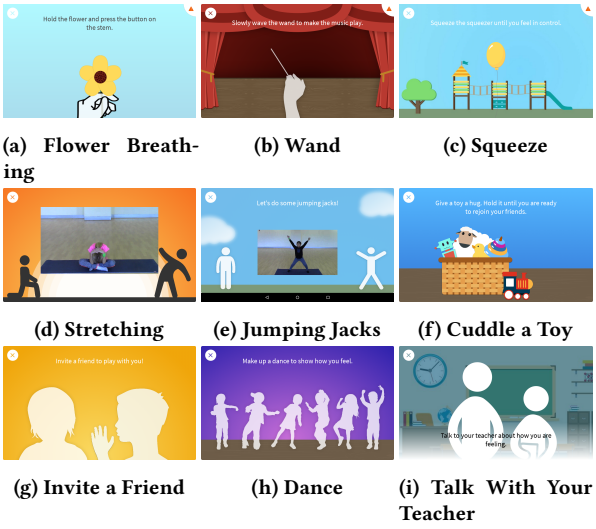
Figure 2: Student flow through the MindfulNest app.

The wand uses an IMU to detect the speed that the student moves the wand. An on-screen animation models the desired back and forth movement of the wand. To encourage slow and thoughtful movement, the app plays music in response to the movement of the wand. When the wand is waved slowly, the music plays at full volume. If the wand is waved too quickly the volume drops very low. In addition an LED at the end of the wand changes color whenever the wand moves too quickly (red), too slowly (white), or just right (green). If the student continues moving the wand at the right speed, they can also press the button on the wand to change colors.

The squeezer is paired with an on-screen animation of a balloon that moves upward when the squeezer detects that it is being pressed. This interaction provides students with both physical and visual feedback. The squeezing itself provides students with a safe and productive manner for releasing physical aggression or anger,

Table 2: Descriptions of available activities and the TUIs used. Screens without video or animation are considered static, otherwise they are dynamic.

Activity Name	Activity TUI	Activity Screen	Percentage of Use by Students	Activity Description
Flower Breathing	Flower	Dynamic	15.5%	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.
Wand	Wand	Dynamic	14.1%	The student is guided to wave the wand slowly to make the music play.
Squeeze	Squeezer	Dynamic	19.7%	The student squeezes the squeezer to make the balloon float higher in the air.
Stretching	–	Dynamic	17.1%	The student is guided with audio and video through different stretches. There are four stretching sequences to choose from.
Jumping Jacks	–	Dynamic	4.8%	The student is guided with audio and video through doing jumping jacks.
Cuddle a Toy	–	Static	4.7%	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 for the purpose of this study.
Invite a Friend	–	Static	1.2%	The student is encouraged to invite a friend to play with them.
Dance	–	Static	19.9%	The student is asked to make up a dance to show how they feel as background dance music plays.
Talk With Your Teacher	–	Static	3.0%	The student is encouraged to talk to their teacher about how they feel.



(a) Flower Breathing (b) Wand (c) Squeeze

(d) Stretching (e) Jumping Jacks (f) Cuddle a Toy

(g) Invite a Friend (h) Dance (i) Talk With Your Teacher

Figure 3: Screenshots of the available activities.

and the visuals provide incentive to focus on the activity. Part way through the study, the squeezer was updated to use a button inside of a stuffed animal rather than the initial bead-filled silicone bottle which relied on sensing the changing air pressure within the device (Table 3).

4 METHODS

The MindfulNest system was tested over one school year in two preschool classrooms simultaneously and at the same center. The center was in an urban neighborhood in the Pittsburgh area and served primarily low and moderate-income families. Each class had one teacher and one aide. There were a total of 29 students (14 girls, 15 boys). Teachers and aides attended 3 hours of professional development before using MindfulNest. Following professional development, they used MindfulNest in their classrooms from October through the end of the school year in March (22 weeks). [1]

In week 10 of the study, we conducted an interview with one of the teachers. The second teacher was not available for an interview but had shared her observations and feedback with the first teacher to pass on to us. The interview asked about classroom integration, the ability of MindfulNest to promote emotion regulation, student engagement and capability with MindfulNest, and future improvements.

Each classroom had two MindfulNest sets. The app recorded basic usage statistics (timestamps and the emotions and activities selected). At least one of three researchers observed each classroom once a week for two and a half hours. Observation times were coordinated with the classroom teacher to correspond with times when students were in the classroom and likely to be able to use MindfulNest. Researchers recorded observations as semi-structured field notes on the following topics:

(1) How do teachers introduce, use, and interact with MindfulNest in their classroom?
(2) How do students interact with MindfulNest?
  (a) Is it independent or teacher led?
  (b) Are students displaying understanding of MindfulNest activities?
(3) How does MindfulNest impact students' emotions?
(4) Are there any hardware or app interaction issues or bugs impacting ability to use MindfulNest?

At the end of the study, each observer independently organized the children into groups based on similarities in the children's

[1] The school year was cut short due to the COVID-19 Pandemic.

Table 3: Changes that were made to the MindfulNest system based on observations and teacher feedback during the study

Time of Change	Change Made	Reason for Change	General Take-aways
Week 6	Squeezer: Hardware	Air pressure sensing was unreliable and students found it frustrating to use.	Students are impatient when hardware does not work perfectly, simpler more reliable implementations are better.
Week 13	Activities available for all emotions	Students choose emotions based on the activity they desired .	Students do not prefer activities based on the emotion they feel, but by their favorite activity.
	Changed final prompt	Students were confused about the meaning of this question and often selected the wrong option.	Phrasing must be carefully selected for young students to understand. The choices given to students should be limited to necessary options.
	Removed recording option	Students were not using it to talk about their emotions.	Students were unable to complete an open-ended prompt without becoming distracted.
Week 16	Student icons: Increased size	Students did not recognize their pictures.	Students needed larger icons in order to identify themselves.
	Added a click delay	Younger students would rapidly click on the screen without pausing to think or observe results between clicks.	When young students do not know how to interact with the screen, they explore by clicking until they get a reaction, but they cannot react fast enough to new information to avoid accidental inputs.
	Heartbeat: Added video	Students were not following just the audio prompt.	Visual cues improve student response across all ages.

interactions with MindfulNest. The final groups, determined by majority agreement, aligned with student age: Group 1 (age 3, N=6), Group 2 (age 3, turning 4 before the end of school year, N=7), Group 3 (age 4, N=10), Group 4 (age 4, turning 5, or age 5, N=6).

Researchers performed a thematic and content analysis on the qualitative data collected through observations. All notes were divided into student use and teacher use of MindfulNest. Student use notes were labelled with the student's group number and the week of the study. Researchers then performed content analysis to categorize notes into the following categories, derived from the research questions: emotion regulation with MindfulNest, one category for each activity (listed in Table 2), and general use (e.g. app navigation). For the two categories of notes that were not specific to an activity, we analyzed the notes through thematic analysis to further classify the notes based on emergent themes. Thematic analysis was chosen for these categories as we did not note the counts of student uses, just the trends observed during student uses. For categories specific to activities, researchers applied another round of content analysis to determine student use trends.

5 EVALUATION

5.1 System Updates

From the feedback of both teachers in week 10, the trends observed by researchers to this point in the study, and trends seen in earlier studies [26], changes were made to MindfulNest (see Table 3). We began by making changes we believed would improve interaction for students of all ages, and then made changes specifically aimed at improving interaction for younger students. The observed results of the changes are covered in the sections below.

5.2 Teacher Use

The teachers often guided students to use the tool when they noticed students struggling with emotions. The teacher would list different things they could do to feel better, including going to MindfulNest. In these cases, students would not always choose MindfulNest, sometimes opting for other options, such as receiving or giving a hug. When the students did go to the tool, they were able to use it to calm themselves down or feel better. We also noted cases where the teacher did not suggest MindfulNest. Often when children were throwing tantrums, the teacher would not allow for use, as the child might see the use of the tablet as a reward for their behavior. Teachers would also talk about emotions in their morning circle time with the whole class, with varying levels of MindfulNest integration.

5.3 Tangible Interface Use

When students in Group 1 explored the flower breathing activity, only 2/6 observations saw intended use. One student blew on the flower rapidly to watch it light up and did not follow the pace of the breathing prompt. Students in Groups 2-4 followed the activity and prompts about half of the time (15/22 observed times). Some of the older students demonstrated an understanding of the flower as a tool and made associations between the prompts "smell the flower" and "blow on the flower" and taking deep breaths. As the students got older, we observed a transition of the skill away from MindfulNest itself. In fact, during the second week of the study, one four year old was able to do flower breathing without the MindfulNest device when prompted by the teacher.

The youngest students often did not use the wand as intended (0/8 observations saw intended use). Students would pretend the wand was a microphone, get confused by the LED's changing colors, and use the wand from the wrong MindfulNest set. One Group 1 student even did the activity without the wand itself, simply swaying from side to side. Group 2 students used the wand as intended in 5/7 observations. Some altered their gestures to make the music play louder or softer. However, one student who was moving the wand quickly got so frustrated that the music was quiet that he returned the wand to the stand only to pick it back up a few seconds later as the music got louder with the slowed movement. Similar interactions occurred with those students in Group 3 (5/7

Table 4: Observed child responses to screen-based activities by age group. Reported numbers are out of the number of observations for that group and activity. For observations not reported in the table students did not attempt the activity before exiting the interaction. **Use by this age group was not observed.

Activity Title	Group 1	Group 2	Group 3	Group 4
Stretching	Completed steps (3/8). Did a different physical activity (1/8). Just watched the videos (3/8).	Completed steps (4/7). Did a different physical activity (1/7). Just watched the videos (1/7).	Completed steps (5/6). Just watched the videos (1/6).	Completed steps (2/2).
Jumping Jacks	**	Completed jumping jacks (1/4). Did a different physical activity (1/4). Just watched the video (1/4).	Completed jumping jacks (3/3).	Completed jumping jacks (1/1).
Cuddle a Toy	Hugged the MindfulNest squeezer (2/2)	**	Hugged the MindfulNest squeezer (2/5) or a toy (3/5)	Hugged the MindfulNest squeezer (1/2) or themselves (1/2)
Invite a Friend	**	**	Identified a friend, but did not play with them (2/2)	**
Dance	Danced (12/12)	Danced (5/5)	Danced (10/11). Listened (1/11)	Danced (3/4). Listened (1/4)
Talk With Teacher	**	Only chose this when with their teacher (2/2)	Talked with an adult (2/2)	Only talked to the screen if they talked at all (1/3)

observations saw intended use). Students in Group 4 waved the wand in time with the music (4/4 observations). We found that these students began testing the wand's behaviors as early as week three.

We noticed a similar pattern in interaction with the squeezer activity. Students in Group 1 were most likely to use the squeezer incorrectly (3/6 noted uses) vs Groups 2, 3, and 4 (0/5, 4/13, and 1/12 incorrect uses respectively). Incorrect uses included failing to recognize when using the squeezer from the wrong set and setting up races between the two sets. Students in Groups 2 and 4 realized they needed to switch the squeezer if they or another student grabbed the incorrect one (3 noted uses). Students in Groups 2 and 3 sometimes used the squeezer in response to an emotion, especially when they were mad, for example saying, "She needs to use squeeze because she's mad."

5.4 Use of Screen-Based App Activities

MindfulNest includes six activities that do not use a TUI (Table 2). The app also includes a post-coping skill activity that guides students to put their hand on their heart and report on how fast their heart is beating. Student interactions with the screen-based activities are summarized in Table 4.

For the heartbeat measuring activity, students from all age groups at first generally skipped putting their hand on their heart (10/16 noted instances). After we added a video of a child placing her hand on her heart (Table 3), we observed students of all ages mimic the video (8/10 noted instances).

5.5 General Use of MindfulNest

Students of all age groups were able to navigate the app with at least some success. In the earlier weeks, Group 1 students were mostly observed clicking on the screen randomly without intent. One Group 1 student would hold the wand and then click wildly on the screen until something reacted. He would select any activity, and immediately close out when he realized it was not the wand activity. As early as week 13, aligning with the changes in 3, we observed students from Group 1 no longer tapping the screen and exiting activities until they found a specific one. This was later confirmed by reviewing how often students selected emotions in the app. For example, happy was chosen only 31.0% of the time in the first 13 weeks but increased to 45.6% for the remaining 9 weeks.

Students in Group 2 were able to select options on screen with intention while being guided through the choices by their teacher. A majority of the observations of Group 2 students when navigating the app were purposeful navigation. Group 3 students were similar to Group 2 students in this regard. However, this group did explore the app navigation more, e.g. discovering the way to return to the picture selection. There were no noted instances of students in Group 4 clicking randomly. When the app required scrolling, Group 1 students rarely scrolled while Group 3 and 4 students would scroll through the activities.

Students had varying levels of success selecting their image from among their classmates to identify the emotions as their own. Students in Group 1 generally struggled with this skill. All but one student could do it only with teacher guidance. Some of the Group 1 students used the image selection as a game, picking their friend's image. By week 16, after increasing the size of the students' images and altering the order so that the youngest students appeared first, some Group 1 students were able to select their own image. Other students continued using the image selection as a game, disjointed from their emotions.

Students of Group 2 followed the same general trend as those of Group 1. However, by week 20 they were noted to be using the app under their own image. Students in Groups 3 and 4 could recognize when they were not working under their own image and change to their own picture. However, they still used the selection screen as a game on occasion, telling each other to pick a different student's image. We observed one student in Group 4 who noticed a student from Group 1 had not selected his picture. The older student made

the younger return to the picture selection screen and select his image properly before continuing to use MindfulNest.

5.6 MindfulNest as an Emotion Regulation Tool

We observed students in Groups 2, 3, and 4 expressing emotions they were feeling as they used the app (weeks 5-10). For example, a student in Group 2 was playing happily with the app alongside a friend. After a while he stated "I miss my mommy" and cried a few tears. Earlier in the morning he had made a similar statement, and he recalled and expressed this while using the app.

(a) With the help of a teacher, a girl from Group 1 uses the app to stop crying after being dropped off at the classroom by her family (week 3).

(b) A Group 3 student was sad that she could not find a friend to read with her. Without teacher involvement, she went to MindfulNest; indicated that she was sad; and did the cuddle (pictured), squeeze, stretching, and wand activities until she felt better (week 17).

Figure 4: Students using MindfulNest during the year-long evaluation study.

In the early weeks (weeks 3-8) we observed Groups 1, 2, and 3 using the app with a teacher to calm down. The teacher would bring the student to the app and sit with the student and help them through the steps of using the app. In these instances, we observed that students who were crying stopped crying as soon as they engaged with the app (Figure 4a). After some time, they became calm and ready to return to regular class activities.

Across all age groups, there were times when we observed that the teacher suggested the app in response to student emotion, but the student did not want to use it at that time (weeks 5-21). On two occasions an adult separately suggested the app to a Group 1 and Group 3 student, but after using the app on their own for a while, the student was still upset and needed a different intervention (weeks 5,7). In other instances when the teacher prompted a student to try the app, the student was able to use the app independently to calm themself (Group 3, weeks 8,16). In week 17 and later, Group 3 and 4 students were observed to go to the app without prompting and use it to deal with an emotion (Figure 4b).

Finally, the teacher reported that some of the Group 1 and 3 students (week 4) could use "flower breathing" when prompted to calm down in situations when the app was not available, for example outside or in the gym. We also observed an interaction between a Group 4 student and teacher in which the student was upset. The teacher instructed him to "take a deep breath," however he held his breath instead. After a few repeated attempts to get him to breathe, she said, "Smell the flower," and he understood. She counted with him so he could repeat the breath five times and then he was calm (week 11).

6 DISCUSSION

6.1 Designing for Multiple Ages

6.1.1 TUI Interaction. The MindfulNest TUIs use a variety of input and output modalities varying in type and complexity. Older students were able to intentionally use tangible devices of all kinds, while younger students were not able to intentionally use the more complex devices. The direct interaction design used by the flower was easy for students of all ages to understand. Students of all ages understood the squeezer's slightly less direct interaction when using the correct squeezer, however only older students understood when it wasn't working because they had the wrong squeezer. The wand was the most complex TUI. Younger students were unable to grasp the connections between the input (speed) and the outputs (music volume and LED color), while older students were not only able to grasp this connection, but readily explored it early on in the test.

The youngest students could not troubleshoot TUI use across the two sets, while older students could. Based on the preschool practice of assigning preliterate children a unique symbol to label their belongings and work, the parts were labeled with matching symbols to indicate a set. One student in Group 3 initially assumed the groups were distinguished by color; however, once a researcher pointed out the symbols on the sets, the student understood and followed them as the distinguishing factor. This leads us to conclude that a symbol can be used by older students to tell the two sets apart, but needs to be more prominent to be recognized as a distinguishing factor.

6.1.2 App Instruction. Students received instruction for MindfulNest through audio and/or video prompts from the app and the teacher modeling use to the whole class and to students one-on-one. We found that audio instruction alone was insufficient for the younger students. When students were simply instructed to place their hand on their heart via audio prompt, very few did so without further prompting from an adult. Once the video was added, the students would mimic the video and place their hand on their heart. Even with follow-along videos, younger students more often watched the videos without following the steps whereas older students usually followed instructions.

In addition to video instruction, we observed that teacher instruction had a heavy influence on how children used the app. In particular, the most effective teacher modeling was in the physical interactions shared between student and teacher in real-time. Students would often copy how the teacher had modeled the use of MindfulNest, rather than following the app instructions. For example, students almost always followed what the teacher modeled for the *Cuddle a Toy* activity, over the app's audio instructions (Table 4). Because of the importance of teacher modeling, preschool technologies should include carefully designed, specific guidance for teachers.

6.1.3 App Navigation. We found that younger students struggled more than older students when navigating the app. Modifications such as a click delay and larger student images helped guide them in their use of the app. The click delay helped to guide younger students to think between clicks and wait for the app to respond before clicking again. The younger students also had trouble recognizing their own picture in the app in the beginning of the study. Once the image was made larger, they realized its importance and were able to correctly identify when they were in the wrong student profile.

Not all choices fit on a single screen, and so students had to scroll down to see them. Younger students had trouble recognizing when they should scroll, but scrolling was easy for the older students. To aid the younger students, the choices they were required to make (personal picture selection) were placed at the top of the screen. Similarly the most popular activities were placed at the top of the screen to facilitate use by the younger students, but allow all choices to remain available by scrolling.

In general, students in the older two groups (Groups 3 and 4) were able to better navigate the app, the tablet, and the sets of tools leading to more instances of intentional use. They also used this knowledge to help guide the younger students. Data on students' use of tablets outside the classroom was not collected, which could affect student comfort level with general app navigation. However, we observed these trends across all 29 students throughout the year, regardless of their backgrounds with technology.

6.1.4 General Design Considerations. Based on our observations, there are several general takeaways for consideration when designing technology for ages 3 to 5. Students younger than 4 benefited from simple, direct tangible interactions with visually obvious connections between student action and tool response. Since interactions from younger age groups can be drastically different from even slightly older age groups, accommodations should be provided for younger students without sacrificing features for older students when designing tools for preschool classrooms where multiple ages are paired together. Additionally, hardware should be paired with visually obvious symbols to distinguish connection.

Instruction and selections throughout the app should be short, simple, and included only where necessary. Although visual and auditory cues can help guide interaction, face-to-face teacher modeling was most effective at guiding interaction and should be prioritized.

6.2 Support of Emotion Regulation Strategies

We found that an app with TUIs has the potential to support 3 to 5 year olds as they learn and practice emotion regulation strategies. This extends previous findings [7] [23] [24] [25] [2] [3] [16] that older students (age 6-17) can calm down through the use of biofeedback and tangible devices.

We observed some general trends for students of all age groups. Contrary to findings from da Câmara et al. [10] and our initial thought that students would associate activities with specific emotions, we noticed students always preferred favorite activities regardless of emotion. Removing the connection between activity and emotion may encourage students to focus on accurately identifying their emotions. Students did not make connections between the selection of their image and the "self" aspect of their emotions, often selecting other student's images as a game. Going forward, careful design choices must be made regarding this feature in order to balance student ability and teacher needs [26].

There were many instances where teachers guided students through the use of MindfulNest, students employed an emotion regulation strategy, and they calmed down. Students of all ages could use the tangible devices to support the strategies for calming down when guided by the app and teacher together. After students had become familiar with the activities, they could even employ the same emotion regulation strategies outside of the classroom without the tangible device and app. MindfulNest provided students with a reference for and practice of emotional regulation strategies.

Younger students showed less success calming down when guided only by the app without their teacher. They would often use MindfulNest when they were happy, playing with the activities and using the tangible devices to see them light up. However, they would not use MindfulNest on their own when they were upset. Of the younger students, only Group 2 students (age 3, turning 4) were observed talking about emotions when using the app.

The older students using MindfulNest began the school year independently using it as they were happy, and exploring the interactions of the different activities and devices. As the year went on, they would go to MindfulNest without their teacher prompting them when they were upset or crying, follow the app's instructions, choose an activity, and leave the tool more calm than when they came. They tied their emotions to the use of the tool, expressing in words what they were feeling as they used MindfulNest.

7 CONCLUSION

This paper makes two primary contributions. The first is the presentation of qualitative evidence of the use of technology in support of emotion regulation strategies for children ages 3-5. Older students were able to use MindfulNest to cope with their emotions completely independently. However, the younger students (age 3) needed teacher guidance, as well as app guidance, in order to use MindfulNest.

Students in Groups 3 and 4 not only made connections between their emotions and use of the app, but also explored the TUIs and appt. Overall, we found that all students made strong connections to the activities and did not associate individual activities with particular emotions. Teachers were able to use MindfulNest in their classrooms to help individual students regulate their emotions, but we saw a need for additional whole-group instructional materials, as teacher guidance heavily influenced student use for all ages.

This paper's second contribution is that of general design considerations for technology intended for students ages 3-5. Group 1 (age 3) struggled the most to use MindfulNest on their own. The more complex TUIs, like the wand, and the more advanced app navigation did not help enable the younger students to use MindfulNest. However, there were ways to mitigate this without sacrificing quality interactions for older students. Group 2 students (age 3 turning 4) did not always use the tool as intended, but started having more meaningful interactions later in the school year. Students in Group 3 and 4 (ages 4 and 5) were able to have intentional interactions with the MindfulNest app and understood the interactions with the TUIs.

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