Engagement with a Multimodal Tool for Developing Young Children's Emotion Regulation Skills

SAMANTHA SPEER, Carnegie Mellon University, USA
MARION HANEY, Carnegie Mellon University, USA
MICHAEL TASOTA, Carnegie Mellon University, USA
EMILY HAMNER, Carnegie Mellon University, USA

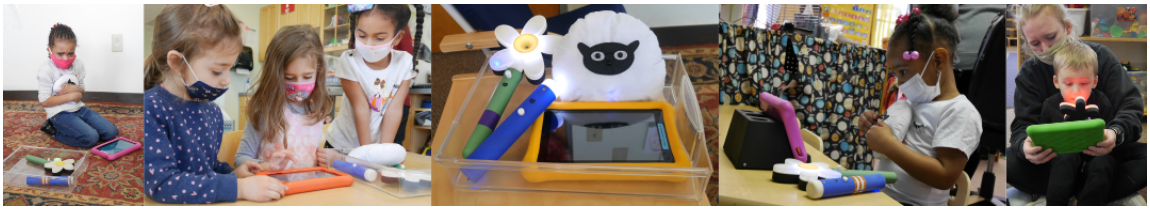

Fig. 1. The MindfulNest tool (center) and images of student use throughout a 16-week study.

The first five years of a child's life are crucial for emotional development, impacting children's ability to learn both cognitively and socially. Children's emotion regulation skills benefit from positive engagement in learning tasks. We studied how student engagement during an emotion regulation learning task changed with differing levels of interaction. We designed two versions of MindfulNest (a tool for emotion regulation skill development), one that leverages more modes of interaction through tangible user interfaces and one with only tablet-based interactions. We tested these versions in a 16-week crossover study in two preschool classrooms and found that students (ages 3-5) were more engaged with the tangible version. Students spent longer per session with the tangible version of the app, and the least-used activity employed only visual and auditory interaction. Additionally, all four teachers reported the tangible version of MindfulNest was more engaging than the tablet-only version without distracting students.

CCS Concepts: • **Hardware** → *Emerging interfaces*; • **Applied computing** → **Education**; **Computer-assisted instruction**; • **Human-centered computing** → **Interaction devices**; **Empirical studies in interaction design**; *Field studies*.

Additional Key Words and Phrases: Education, Children, Tangible, Embodied Interaction, Emotion Regulation

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1 INTRODUCTION

Emotion skills developed in the first five years of life are essential for children's interactions with parents, teachers, and peers and future achievement [13, 14, 21]. Despite this, emotion regulation (ER) is often under-supported in classrooms, which focus on highly visible skills such as motor control, cognition, and communication [13].

ER skills, learning, and school readiness can be supported in classrooms through positive engagement with teachers, peers, and classroom activities [24, 25]. Multimodality increases engagement in language learning tasks [11, 27], and

Authors' addresses: Samantha Speer, Carnegie Mellon University, 5000 Forbes Ave, Pittsburgh, PA, 15213, USA, snspeer@andrew.cmu.edu; Marion Haney, Carnegie Mellon University, 5000 Forbes Ave, Pittsburgh, PA, 15213, USA, marionhaney@gmail.com; Michael Tasota, Carnegie Mellon University, 5000 Forbes Ave, Pittsburgh, PA, 15213, USA, tasota@andrew.cmu.edu; Emily Hamner, Carnegie Mellon University, 5000 Forbes Ave, Pittsburgh, PA, 15213, USA, etf@andrew.cmu.edu.

tangible user interfaces (TUIs) have been shown to be able to support children, ages 6 and above, in employing ER skills [1, 2, 5, 7, 12, 16–18, 20]. However, past research shows mixed results with the engagement of children ages 3 to 5, finding that often children's engagement was focused on playing with the TUIs, rather than using the TUIs as a tool for learning [20]. Complicating a system with multiple modes of engagement also adds potential points of failure and complicates classroom setup [20]. Further research is needed into young children's engagement with TUIs during ER learning tasks and the trade-offs between multimodality and distraction.

We aim to study if multimodal interaction (tablet with TUIs) is more engaging for students as compared to purely tablet-based interactions (touch and audiovisuals), while also keeping the focus on the activity itself (i.e. focused on ER, not used as a toy). We designed two versions of MindfulNest (Figure 1 center), a tool for children's ER using multimodal activities [20]: one with only tablet-based interactions and one that leverages more modes of interaction through TUIs.

We tested these versions in a 16-week crossover study in two preschool classrooms, finding students (n=32, ages 3-5) were more engaged with the TUI version. Students spent ≈1 minute longer per session with the TUI version, and the least interactive activity had the lowest usage. All four teachers reported that the TUI version of MindfulNest was more engaging than the tablet-only version. This paper presents the results from this study, showing that more multimodal interaction during an ER learning task was more engaging for students, while teachers reported it was not distracting or used as a toy. We also present initial anecdotal results of teacher-reported gains in ER, however, due to an increase in one participating teacher's ability to evaluate emotional regulation we could not corroborate the interview findings with survey data.

2 RELATED WORK

2.1 Emotion Regulation and Child Development

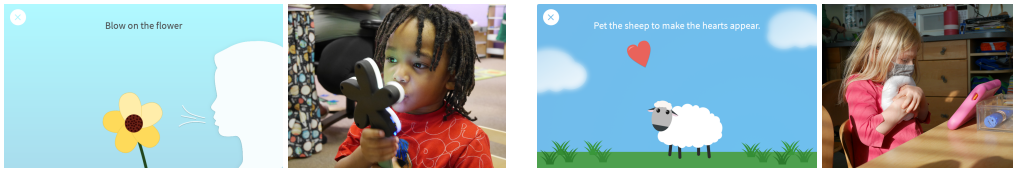
Children with strong social and emotional skills: are usually in a positive mood; have close relationships with caregivers and peers; recognize, label, and manage their own emotions; and understand others' emotions and show empathy [10]. There are five keys to the successful development of emotion regulation skills (herein referred to as emotional development): self-awareness, self-management, social awareness, relationship skills, and responsible decision-making [15, 23]. MindfulNest focuses on the skills of self-awareness and self-management by encouraging students to identify their emotions and build coping skills to manage emotions [20].

There are 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 [15]. Each factor represents a proactive, rather than reactive, approach to fostering children's emotional growth and eliciting positive behavioral responses. Engagement in a positive classroom climate and instructional strategies is an important part of a child's emotional development [6].

2.2 Multimodal Tools for Emotion Regulation and Engagement

Psychology research has shown that emotion processing is tied to the somatosensory-motor elements of an emotional experience [26]. Emotions can be analyzed through the lens of embodied cognition, the idea that thoughts are shaped by bodily states. It follows that when learning ER, the whole body should be engaged to regulate the bodily process affecting one's emotions [26].

Accordingly, biofeedback devices and TUIs can have positive effects on calming students [1, 2, 5, 7, 12, 16–18]. Biofeedback devices have helped students age 12-17 lower anxiety [5] and have helped children age 5-8 self-regulate anxiety and attention in the classroom and at home [1–3]. Studies with autistic children as young as 6 years old, show



(a) Flower Breathing Activity (b) Cuddle Activity

(c) Conducting Activity

Fig. 2. MindfulNest screens for the tablet-only activities (left) and TUI use (right).

that biofeedback and apps can help students practice coping skills and self-regulate [9, 12]. TUIs have been used to help parents understand 5-9 year old children's emotions [18, 22] and have even been shown to be more effective than passive techniques for calming 6-11 year olds [16–18].

Multimodality also has an effect on student engagement. Kaminski studied children 8-10 years old as they interacted with multimodal texts, finding that multiple modes are necessary for different kinds of engagement [11]. Yelland also studied multimodal engagement of 4-8 year olds with literacy tasks, and found a multimodal approach beneficial to student learning [27].

Prior research with the MindfulNest tool presents an exploratory design study to suggest design features that enable young students (age 3-5) to use the system and keep them engaged with the tasks [20]. This study found that students became distracted by some activities involving TUIs as well as some app-based interactions. Though the study explores and lists design features for a system involving TUIs, it does not compare the modalities of interaction to see which is more effective for keeping students on task and engaged. In this paper, we aim to implement the same MindfulNest activities with different interaction modalities to directly compare the engagement of the two.

There is little prior work studying the impact of TUIs and multimodality on ER with children age 3-5. We aim to expand prior research on TUIs and ER to include younger children ages 3 to 5, and to further study the effect of multimodality on engagement, specifically during ER learning tasks. To do so, we compare engagement with TUI to tablet-based interactions with children ages 3-5 as they do emotion regulation tasks.

3 THE MINDFULNEST TOOL

MindfulNest (Figure 1 center) was developed to support children ages 3-5 with learning ER skills through participatory design sessions and classroom studies[19, 20]. The design process resulted in a tool consisting of three TUIs and a paired tablet app.

Each TUI contains LEDs and sensors related to its utility. The app guides students through a sequence of prompts and activities (Figure 2) designed to support coping skills for ER.

We developed a tablet-only version of the MindfulNest tool without the TUIs to compare engagement between TUIs and tablet-only interactions. The operation of the activities in both versions is described below and summarized in Table 1.

Table 1. Interaction modalities for the two versions of MindfulNest. Note that all activities are introduced by auditory directions.

Activity (ER Skill)	TUI Version	Tablet-Only Version
Flower Breathing (Deep Breathing)	Seeing flower petals change on screen Listening to auditory cues **Blowing on the flower → Seeing flower LEDs light up**	Seeing flower petals change on screen Listening to auditory cues **Blowing**
Cuddle (Physical Comfort)	**Hugging the sheep** → Seeing hearts appear on screen	**Swiping to 'pet'** → Seeing hearts appear on screen
Conducting (Controlled Movement)	**Watching the wand on screen move** **Waving the wand** → Listening to music play, **seeing wand LED change**	- **Moving the wand on screen** → Listening to music play

3.1 Flower Breathing Activity

The breathing activity (Figure 2a) consists of prompts and visuals to guide students through three rounds of slow, deep breaths to calm down [4, 20]. The tablet-only activity animates a flower on the screen with guides to smell and blow on the flower.

The tangible version of this activity includes the use of the flower TUI. The flower consists of a ring of LEDs with a sound sensor at the center. As the prompts guide the student to breathe out, the sensor detects their breath and lights up the LEDs.

3.2 Cuddle Activity

The cuddle activity (Figure 2b) consists of prompts and visuals to guide students in using physical comfort for ER [4, 20]. In the tablet-only version, a sheep is displayed on screen and students are encouraged to 'pet the sheep to make the hearts appear'. The app then detects their swipe over the sheep and makes hearts appear accordingly.

The TUI version of this activity uses the sheep TUI, which is a plush sheep containing a button. When the button in the sheep is compressed, the hearts appear on the screen, encouraging the students to continue hugging the sheep.

3.3 Conducting Activity

The conducting activity (Figure 2c) consists of students conducting calming music with controlled gross-motor movement for ER [4, 20]. Students control the music through the movement of a wand; in-tempo motion makes the music play, and out-of-tempo motion stops the music. In the tablet-only version of MindfulNest, students move the wand on screen using their finger.

In the TUI version, students wave the wand TUI. They follow the speed of the wand on the screen to ensure the correct tempo. If they match tempo, an LED in the wand lights up green. Pacing too slowly turns the LED white and too fast turns the LED red.

4 METHODS

To evaluate the engagement with the versions of MindfulNest, we recruited two classrooms to participate in a crossover study with two consecutive trials of eight weeks each. Classroom A first received the TUI version of MindfulNest and then the tablet-only version. Classroom B received the inverse. Teachers participated in 2.5 hours of professional development before trial 1, covering the use and integration of MindfulNest in their classroom. Before trial 2 teachers were given 5 more minutes of professional development to learn the new version of MindfulNest.

During trial 1, teachers introduced the first MindfulNest version through six structured lessons over three weeks (two per week). During the first week of trial 2, teachers introduced the new version of MindfulNest, ensuring the children knew the differences in use. During the first four weeks of each trial, teachers were required to guide each student through using MindfulNest to ensure students could properly use that version. During the last four weeks of each trial, teachers were asked to encourage students to use MindfulNest independently. During all 16 weeks, teachers were required to use MindfulNest during their morning arrival routines for daily student practice. In all trials, MindfulNest was available daily to students in the classroom for use as needed.

4.1 Participants

A total of four teachers and 32 students participated in our study. Classroom A had one teacher, two aids, and 20 students (11 girls, 9 boys). Classroom B had one teacher, a rotating aid (non-participating), and 12 students (8 girls, 4 boys). Students from classroom A were 4 (n=12) and 5 (n=8) years old and from a mix of low to high socioeconomic backgrounds. Students from classroom B were 3 (n=6), 4 (n=5), and 5 (n=1) years old and were from primarily low socioeconomic status families. The study was approved by the authors' home institution's IRB and teachers and parents gave written consent before participating.

4.2 Data Collection

We conducted classroom observations during weeks 4, 8, 12, and 16 of the study, recording student use of MindfulNest including when the students began using the tool, when they calmed down (if applicable), and when they left. We observed 465 MindfulNest sessions (232 tablet-only, 233 TUI). In addition, the app saved usage statistics for all student sessions including selected activities. We attempted to measure calm-down time for students however, measurement methods were limited and case numbers were too low to gather statistical significance (see 7.1).

In order to evaluate the effectiveness of the MindfulNest tool, we asked participating teachers to complete the PreBERS assessment tool [8] for each child as a pre/post-test for each intervention. However, the teacher from classroom B, reported that she learned more about ER through the use of MindfulNest and did not feel she accurately completed the pre-surveys. Due to this, the survey data was excluded from analysis (see 7.1).

Finally, we conducted 30-minute interviews with each of the teachers and aids to assess their perceptions of student response, perceptions of emotional development, and version preferences.

5 RESULTS

5.1 Engagement Statistics

We measured the length of all sessions for each child during classroom observations. Time spent per session was skewed right, where most sessions were ≈1-2 minutes long and 15% of sessions were between 3 minutes and 48 minutes long. Additionally, we noted during observations that individual children used MindfulNest for differing amounts of time on average, where some children generally preferred longer sessions.

To control for the skew of session length and individual child preferences, we calculated the average time spent by each child with each version. We then calculated the difference between these average times (TUI - tablet-only) for each child, finding the distribution was roughly normal (Figure 3). We ran a t-test with an α level of 0.05 on this data finding that children spent statistically significantly longer with the TUI version than they did with the tablet-only version by an average of 65 seconds (t = 2.41, df = 28, p-value = 0.01). Eleven observed sessions were over 10 minutes long; 9 were the TUI version and 2 were the tablet-only version. The longest session observed was 47.2 minutes with the

TUI version. With this outlier removed, our results retain significance (t = 2.14, df = 28, p-value = 0.02), with children spending 53 seconds longer with the TUI version. We performed the Mann-Whitney U test to see if students had a larger difference in average time spent in Classroom B. The test fails to reject this hypothesis with W = 91.5, p = 0.5906, showing there is insufficient evidence to conclude that classroom distributions result from different populations.

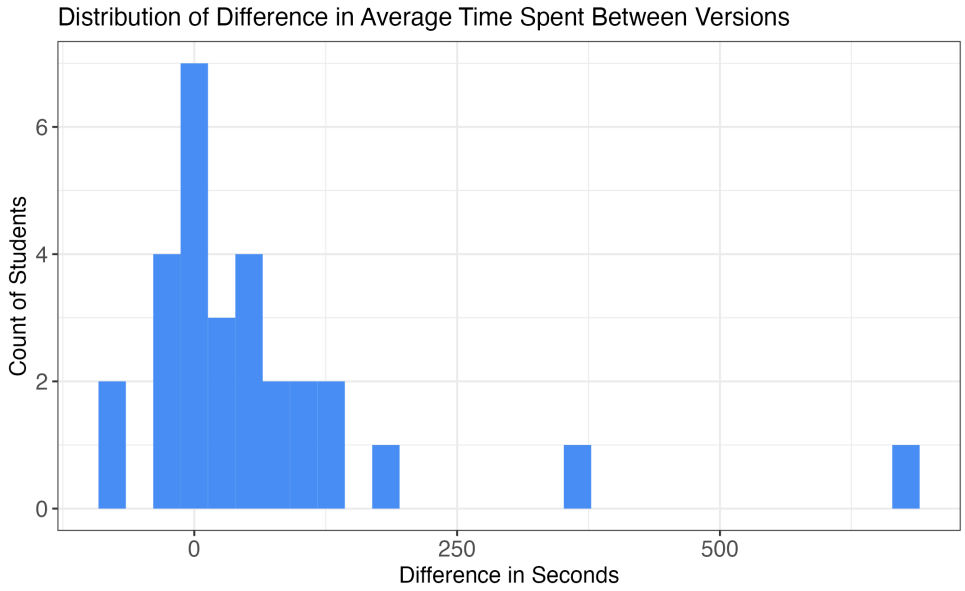


Fig. 3. Distribution of students' average time spent with TUIs minus the average time spent with tablet-only.

We also observed a difference in activity usage between MindfulNest versions (Figure 4). Using usage data recorded by the tablets, we completed a χ^2 test of independence with an α level of 0.05 on the counts for each of the three activities in the two versions. The activity breakdown differed significantly between versions (χ^2 = 45.444, df = 2, p-value = 1.355e-10). The flower breathing and cuddle activities became more popular in the TUI version, each increasing their relative usage by approximately 8%. The conducting activity was the most popular in both versions, but its popularity difference shrank in the TUI version. These results suggest that including a TUI made the flower breathing and cuddle activities relatively more engaging to children over tablet-only interactions.

5.2 Teacher Interviews

We interviewed all teachers at the end of both trials, asking:

(1) Did students respond differently to the two versions?
(2) Which version of MindfulNest did you like better and why?
(3) How well did MindfulNest help to promote students' emotional development?

Student Response. All four teachers reported that the students were more engaged with the TUI version of MindfulNest. The three classroom A teachers reported this directly. T1 reported the TUIs "are more exciting and we had a wider range of children that were engaged with [the TUIs]". T2 reported that the students were initially intrigued when the TUIs were removed from MindfulNest, but "once the [TUIs] were gone less students used it". T3 agreed with this

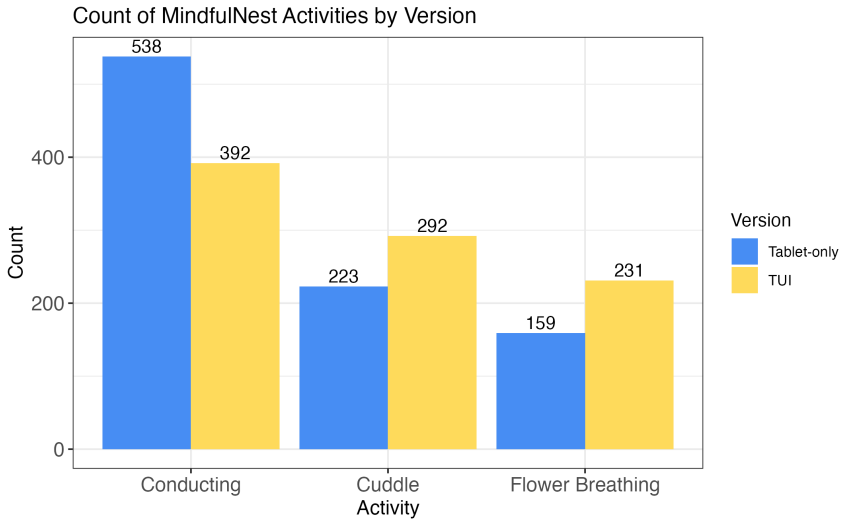


Fig. 4. The difference in activity counts per version.

assessment and this is supported by our statistical results (Sec 5.1). The teacher in classroom B reported that students were engaged with MindfulNest, noting the TUI version was particularly engaging.

Preferred Version. Three of the four teachers reported that they prefer the TUI version of MindfulNest. T4 reported: "I like the physical components, it put things into perspective for them." T2 reported that the TUI version "got their whole body engaged" with T3 nodding in agreement. T1 reported that she preferred the tablet-based version as she encountered technical issues with the TUIs and had trouble charging them.

Teacher-Reported Emotional Development. All four teachers stated that MindfulNest helped promote students' emotional development, and was not distracting or used as a toy. T4 reported that "The days we didn't do it, you could notice they were still doing things like flower breathing and hugging the sheep" showing the positive impact that MindfulNest (specifically the TUI activities) had on students' emotional development. T2 reported instances where students even applied the concepts from MindfulNest to her. She told a story of a time she felt frustrated and the students identified her emotion and suggested she use flower breathing to calm down. Though these initial results are anecdotal, they show that MindfulNest specifically benefits student ER by bringing awareness to emotions and coping skills that can be applied when needed.

6 DISCUSSION

Our evidence supports that students were more engaged with the TUI version of MindfulNest than with the tablet-only version. While the total number of MindfulNest sessions was roughly the same for each version, students on average spent ≈1 minute longer during sessions with the TUI version. This increased engagement is significant for classrooms as positive engagement with classroom activities can generally support ER skills and learning [24, 25]. Additionally, teachers reported the increase in engagement helped reach more students which provides the opportunity for increased benefit.

Additionally, the relative activity usage of the flower and cuddle activities increased with the inclusion of TUIs. The flower breathing activity in the tablet-only version was chosen the least of all the activities and was the least interactive

having only visual and auditory interaction. We conclude from the lack of popularity of the tablet-only flower activity that the students were not as engaged with this less multimodal interaction.

We corroborated these findings with teacher interviews. Teachers reported that students were more engaged with the TUI version of MindfulNest, and did not find the multimodality distracting. Teachers generally attributed engagement to the physical components and the embodiment provided by the TUIs. Additionally, three of four teachers stated they preferred this version. The one teacher who preferred the tablet-based version noted her preference was due to technical issues and still reported that the TUI version was more engaging and helped students' emotional development.

By using a crossover study design, we were able to test for the existence of a "novelty effect" with the introduction of TUIs. A concern with including the TUIs was that students would play with them instead of using the TUIs along with the associated tablet activities. However, our findings suggest that the TUIs enhanced the MindfulNest tool and made it more engaging without distracting from the students' development of ER skills. Observations and teacher interviews reported that children were engaged with MindfulNest and did not play with the TUIs as toys. Furthermore, teachers reported students' emotional development was positively impacted through the use of MindfulNest.

7 CONCLUSION

We present the findings of a 16-week crossover study between two classrooms using two versions of MindfulNest: a TUI version and a tablet-only version. Across 32 participants (ages 3-5) we found statistically significant evidence that children were more engaged with the TUI version. They spent on average about one minute longer using this version than the tablet-based version. Students also chose the flower breathing and cuddle activities more in the TUI version, showing their engagement with the TUIs over the tablet-based version. Additionally, all four teachers reported that students were more engaged with the TUI version of MindfulNest, and three teachers preferred this version.

This paper presents an in-situ study with teachers and students from underserved populations. As such, we encountered limitations in measuring ER gains and the effectiveness of calming down (discussed in 7.1). However, our results do demonstrate that student engagement with MindfulNest was higher with TUIs than tablet-only interactions showing that students spent longer practicing ER skills when they had TUIs. Additionally, we show initial suggestions from teacher reports that MindfulNest with TUIs helps students' emotional development without being distracting.

7.1 Limitations and Future Work

We attempted to evaluate the effectiveness of using MindfulNest to learn ER through surveys and observation of the time taken to calm down using the MindfulNest tool. We asked participating teachers to complete the PreBERS assessment tool [8] for each child as a pre/post-test before and after each trial. However, T4, the sole teacher from classroom B (the classroom with primarily low socioeconomic status families), reported that she learned more about ER through the use of MindfulNest and did not feel she accurately completed the pre-surveys rendering the data non-viable.

Additionally, we defined the time when students calmed down as the moment when they ceased to show physical signs of emotion. However, during our observations, it was not possible to accurately gauge these physical signs as students were wearing masks, or not showing their emotions strongly. Due to the in-situ nature of the study, only a handful of the hundreds of uses were instances where students showed strong enough indicators of emotion (crying, etc) to identify a calm down moment. This small sample size was insufficient to gather statistical significance to conclude whether the tangibles helped students calm down faster.

Future work will include more reliable methods for measuring the ER of students including, more defined protocols for observing emotion and methods of ensuring that teachers have the resources to accurately and consistently measure students' ER through a validated survey.

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