Audio-guided mindfulness training in schools and its effect on academic attainment: Contributing to theory and practice

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ABSTRACT

We report the results of a randomized trial (N = 337) examining the effectiveness of a daily audio-guided MBI in raising academic achievement in 16 volunteer classrooms across two socio-demographically diverse United States primary schools. The study's findings were that, over the intervention period, improvements in Math scores, Social Studies scores and Grade Point Averages (GPA) were generally higher for students in intervention classrooms. However, confidence intervals were wide and there was pre-existing variability between schools and grades. Through a careful discussion of the study's results, the paper contributes to theory by generating a comprehensive agenda for follow-up research. The study also contributes to practice by reporting on the effectiveness of technology-enabled mindfulness training because participating teachers seemed able to implement the inter- vention with almost no further training or need for hiring external mindfulness experts.

1. Introduction

Mindfulness can be defined as a process of openly attending, with awareness, to one's present moment experience (Brown, Ryan, & Creswell, 2007). An exponentially increasing body of evidence accumulated since the 1990s suggests a solid link between mindfulness interventions and increased wellbeing and cognitive performance (Creswell, 2017).

In the face of this growing enthusiasm for mindfulness, scholars advise against taking too uncritical a stance towards the extensively reported salubrious effect of mindfulness training (Baltzell, 2016; van Dam et al., 2018), and call for more nuanced and balanced reporting of the research evidence in this field (Coronado-Montoya et al., 2016). Nonetheless, the potential of mindfulness and its capacity to increase attention and awareness (Brown et al., 2007) is especially relevant for education today, because it might help counteract the increasing tendency among students to get distracted by a proliferation of social media activity, shown to adversely affect academic achievement (Hollis & Was, 2016).

While mindfulness training may serve as a potential catalyst for higher student achievement, the evidence-base examining the potential link between Mindfulness-Based Interventions (MBIs) in schools and academic attainment is still patchy. The evidence from prior meta-

analyses of MBIs in schools (Zenner, Herrnleben-Kurz, & Walach, 2014; Klingbeil et al., 2017) and with general youth populations (Zoogman, Goldberg, Hoyt, & Miller, 2015) points to broad potential benefits but more research is needed in this emerging field. In particular, Klingbeil et al.'s (2017, p. 5) comprehensive meta-analysis of 6121 children and youth participating in school and clinical MBIs found generally small, positive effects on young people's overall outcomes, as well as specifically on academic achievement, however the authors reported on varying research quality across the 76 papers included in the analysis. By the same token, the findings from recent systematic reviews on mindfulness training with children and adolescents in general (Black, 2015) and in school settings (Felver, Doerner, Jones, Kaye, & Merrell, 2015; Maynard, Solis, Miller, & Brendel, 2017, p. 5) report on considerable potential benefits in domains such as executive functioning as well as physical and mental health. However, Maynard et al.'s (2017, p. 5) systematic literature review suggests that not enough evidence exists to determine undisputable statistical effect on academic grades.

1.1. MBIs and academic attainment in schools

Programs designed to regulate emotional arousal and enhance cognitive functioning are collectively called Social Emotional Learning (SEL) programs and are increasingly considered foundational for

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cognitive and intellectual development in schools because SEL promotes pre-frontal cortex development associated with executive functions (McClelland, Morrison, & Holmes, 2000; Payton et al., 2008; Pelco & Reed-Victor, 2007). A meta-analysis reviewing 213 school-based SEL interventions found that SEL was effective in increasing social and emotional skills, attitudes, and behaviors, and generated an 11% improvement in academic performance (Durlak, Weissberg, Dymnicki, Taylor, & Schellinger, 2011). SEL is a key predictor in school children's *readiness to learn,* in other words their ability to regulate emotions and behaviors and inhibit impulsivity (Diamond & Lee, 2011). Readiness to learn appears to be a critical ingredient in children's ability to translate classroom instruction and academic content into embodied learning (Blair, 2002; Scott-Little, Kagan, & Frelow, 2006). In a recent study of attainment of academically at-risk primary school students (Cerda, Im, & Hughes, 2015), suggest that readiness to learn can enhance academic achievement, because executive control functions in children's brains e.g. to modulate impulsive tendencies, or to shift and focus attention at will may interact with their capacity to self-regulate their behavior and their social competence skills.

Mindfulness-based SEL programs (MBSEL), used to focus and sustain attention and self-awareness, can be considered a sub-type of SEL programs (Bakosh, Snow, Tobias, Houlihan, & Barbosa-Leiker, 2015; Klingbeil et al., 2017). These programs can positively impact readiness to learn, by reducing limbic arousal and enhancing pre-frontal cortex activity, therefore improving academic aptitude and achievement (Black, Milam, & Sussman, 2009; Diamond & Lee, 2011; Meikeljohn et al., 2012). Mindfulness practices have also been shown to improve executive functions including self-regulation skills, attention, cognitive flexibility, and working memory, which all have been linked to academic outcomes in specific clinical student populations (Semple, Lee, Rosa, & Miller, 2010).

The first scientific publication on the potential link between MBIs and attainment was designed as a pre-post design without control group and consisted of a 5-week Mindfulness-Based Stress Reduction (MBSR) program for 34 volunteer pupils with learning difficulties aged 13–16 (Beauchemin, Hutchins, & Patterson, 2008). Teachers participating alongside the students rated their academic performance indirectly via a behavior survey on student functioning, with t-ttests suggesting a significant improvement, despite considerable measurement bias (no effect size was given). Subsequently, Sibinga et al. (2011) conducted a 9-week MBSR program for 59 HIV-infected and at-risk urban youth and used qualitative interviews with 10 participants to point to self-perceived improvements in school achievement (Sibinga et al., 2011). Furthermore, in Wisner and Norton's (2013) small uncontrolled pilot study, mindfulness meditation was added to an 8-week school counselling program with 28 volunteer student participants, and t-tests indicated a significant improvement in various wellbeing-related outcomes including school functioning with moderate to large effect sizes. However, it is impossible to say whether any of these positive changes were due to the MBIs under study or rather to non-specific group effects.

Four peer-reviewed research studies with control group designs examined the link between MBIs and academic achievement. A non-randomized MBSR feasibility study by Bennett and Dorjee (2015) examined attainment among 23 sixth-form volunteer participants aged 16–18, and reported a non-significant difference in grade achievement for the 13 volunteers in the MBSR condition compared to the 11 students in the control group three months after completing the course. In addition, no significant group differences could be detected immediately after completing the 8 MBSR sessions. Another non-randomized trial using technology-enabled mindfulness training among elementary students (N = 191) found that in the four classrooms assigned to the intervention group, quarterly grade performance increased significantly compared to the four classrooms in the control group in two subjects (Reading and Science; small effect size), but the grade trajectory remained constant across the other subjects examined (Bakosh et al., 2015).

Franco, Mañas, Cangas, and Gallego (2011) published the first RCT assessing the impact of a MBI on academic achievement with a volunteer sample of 61 high school students from three schools in Spain who participated in 10 weekly mindfulness sessions. This study reports very large effect size increases for overall quarterly grades and for Spanish language, yet different effect sizes for philosophy (large effect size) and in foreign language (medium effect size), and its authors encourage further research to examine potential differential effects of mindfulness on different subject types. The most recent peer-reviewed RCT was conducted with 99 Canadian 4th and 5th graders in 4 classrooms across 4 schools, and compared the effect of a 12-week mindfulness program on Math grades compared to an active control condition (Schonert-Reichl et al., 2015). The authors reported a small (non-significant) growth trend in Math for the intervention participants, yet echoed prior scholarly calls for follow-up research with larger samples.

1.2. Addressing practical implementation challenges of MBIs in schools through technology

Scholars reviewing MBIs in schools have increasingly called attention to the potential moderating effects of intervention administration characteristics, such as dosage of the training, or instructor characteristics (Klingbeil et al., 2017; Renshaw & Cook, 2017).

For instance, Renshaw, Fischer, and Klingbeil (2017) suggest that it is yet unknown how much training or experience is necessary for teaching mindfulness in classrooms with fidelity. The large majority of MBIs in schools are delivered by mindfulness experts whose expertise has developed over several years. Out of the seven studies reviewed in the previous section, external trainers had facilitated four MBIs (Bennett & Dorjee, 2015; Franco et al., 2011; Sibinga et al., 2011; Wisner & Norton, 2013). Many mindfulness scholars suggest that a mindfulness program must be taught with fidelity to the underlying principles and foundations to be successful (Crane et al., 2011; Kabat-Zinn, 2003), which suggests that a person needs to go through extensive training to become proficient in passing mindfulness skills on to others. This requirement may work against more MBIs being embedded in schools, with some schools unable to develop mindfulness expertise in-house or to hire external expert mindfulness teachers.

One research avenue to pursue in this context relies on technology as delivery vehicle for mindfulness training and ongoing mindfulness practice. A consistent formal practice is a primary driver of improved outcomes in mindfulness programs (Biegel, Brown, Shapiro, & Schubert, 2009; Kabat-Zinn, 2003). Therefore, technology-based intervention administration may be a helpful enabler of effective MBIs in schools, for at least two reasons: first, schoolchildren may be particularly open to technology-enabled mindfulness training especially in its capacity to foster consistent mindfulness practice; and second, such intervention delivery modes may help embed mindfulness in schools without the resources available to train or bring in mindfulness teachers. In fact, emerging evidence suggests that technology-based mindfulness training interventions may be as effective as face-to-face mindfulness instruction (Hulsheger, Feinholdt, & Nubold, 2015; Krusche, Cyhlarova, King, & Williams, 2012; Querstret, Cropley, & Fife-Schaw, 2016; Wolever et al., 2012). A recent meta-analysis specifically of online MBIs revealed that this delivery format tends to generate small yet significantly improved mental health outcomes for participants, especially stress reduction (Spijkerman, Pots, & Bohlmeijer, 2016). If technology can be leveraged for this purpose, then more schools may benefit from the potential that mindfulness represents for their students and teachers.

1.3. The present study

While the evidence-base linking MBIs with attainment is still unreliable, there is nonetheless some prior evidence supporting our overall proposition that a MBI may generate a small positive effect on

academic attainment, expressed via grade increases post intervention (Klingbeil et al., 2017), and that technology may serve as viable delivery mode of generating improved outcomes for participants in such an intervention (Spijkerman et al., 2016).

We therefore propose the following hypotheses for this study:

Hypothesis 1: Measures of academic achievement will be higher for students in classrooms participating in a technology-enabled MBI compared with students in classrooms allocated to the waitlist control condition.

Hypothesis 2: Teachers will be able to embed such a technology-enabled MBI with fidelity and without the need for externally hired mindfulness expertise.

2. Methods

2.1. Intervention overview: technology-enabled MBSR-based program for children

One of the study authors (XXX), an experienced MBSR teacher, developed the mindfulness program used in this study in collaboration with another experienced MBSR trainer. Both have decade-long meditation practices, and have been leading MBSR training programs for community members for years. The program was based on the extensively researched MBSR protocol originally developed by Jon Kabat-Zinn and colleagues at the Center for Mindfulness at the University of Massachusetts Medical School. Its content closely followed MBSR but was adapted for a child audience to encourage the competencies associated with the development of mindfulness. The MBSR-adapted program is comprised of a series of mindfulness practices delivered by 90 MP3 audio-guided tracks, each approximately 10 min in length, and included a journaling integration exercise for the last 2 min of the recording. The guided audio tracks facilitated a daily formal mindful awareness practice. Basic didactic information was included throughout the series, covering how to sit, why to practice, and what to expect from the practice. A more detailed outline of the program design is available from (XXX).

The audio-guided series included: (1) breathing and focusing practices meant to help students attend to their direct experiences, leading to self-awareness; (2) relaxation and sense awareness practices that reduce the flight fight response and interrupt auto-pilot reactivity, leading to improved self-management; (3) thought and emotion awareness practices that create space between stimulus and response, fostering responsible decision making; and (4) gratitude, kindness and forgiveness practices, towards self and others, connecting students to the larger community.

2.2. Participants

The sample for this study consisted of 337 students, in 16 classrooms, in two U.S. elementary schools, School 1 and School 2.

School 1 is located in a suburban area in Illinois, in one of the largest districts in the state. Table 1 shows that the student sample at School 1 was predominantly Hispanic (74%) with 68% of students eligible for free or reduced lunch, indicating lower than average Socio-Economic Status (SES). A total of 131 students (52 girls) were members

Table 1
Study school demographics.

Project schools	Race and ethnicity				SES: % of free or reduced lunch
	% H	% W	% B	% O	
School 1 (IL)	74	18	2	6	68
School 2 (NY)	1	97	0	2	14

H = Hispanic; W = White; B = Black; O = Other; SES = Socioeconomic Status.

Table 2
Student sample by grade and group status.

Project schools	N (Students by grade)					Total
	1	2	3	4	5	
School 1 (INT)		47			17	64
School 1 (WLC)		48			19	67
School 2 (INT)	20	39	22	22		103
School 2 (WLC)	18	21	45	19		103
Total (INT)	20	86	22	22	17	167
Total (WLC)	18	69	45	19	19	170
Total sample						**337**

INT = Intervention group; WLC = Waitlist Control group.

of the participating classrooms. Six teachers volunteered their classrooms for participation in the study out of 22 classes in total, with three classrooms (2 s grade, 1 fifth grade) in each of the study groups.

In contrast, School 2 is located in a rural area in upstate New York, in one of the smallest districts in the state. Table 1 shows that the student sample (N = 206; 109 girls) was predominantly White with only 14% of students eligible for free or reduced lunch. Ten teachers volunteered their classrooms for participation in the study out of 21. The intervention group included one first grade class, 2 s grade classes, one third grade class, and one fourth grade class; and the waitlist control group included one first grade class, 1 s grade class, two third grade classes, and one fourth grade class. Table 2 shows details of number of students in each grade and study group.

2.3. Randomization process

Teachers were invited to volunteer their classrooms to take part in this study. Randomization into the INT and WLC conditions was completed at grade level.

2.4. Procedure

Classrooms from each school were randomized, by grade, into either the Intervention (INT) or Waitlist Control (WLC) conditions. Students in classrooms allocated into the INT condition were exposed to 10 weeks of the MBSR-adapted program during term time. Classrooms allocated to the WLC condition would be exposed to the intervention in the following school term. Student grades in a variety of subjects (see 'Measures'), along with overall Grade Point Average (GPA), were assessed before the study started (T1) and again 10 weeks later at the end of term, after the study completed (T2). We also assessed fidelity of implementation (see 'Measures').

A 60-min training session was held prior to the planned launch at each of the participating schools. All teachers participated in the first 30 min of training, which included a review of general information related to mindfulness and the research protocol. Both INT and WLC classroom teachers were given instructions on how to provide student grade assessments for the study, and were asked to supply this from the term that had just ended (T1), and again at the end of the term after the study had completed (T2). WLC teachers only attended the first 30 min of the training. During the remaining 30 min, the researcher provided instructions for the research protocol for assessing fidelity of implementation. Teachers were also provided with an overview of the MBSR-adapted program and a Teacher's Guide.

The INT classrooms each received a classroom kit, which was on loan for the duration of the study. The kits included the preloaded iPod MP3 player with 90 MBSR-adapted tracks, a docking station with speakers, Teachers' Guide, parent letter student journaling notebooks, as well as a few classroom tools including a rain stick and glitter ball. The researcher demonstrated how to use the rain stick to reengage students into a mode of mindfulness, as well as how to use the glitter

ball to enable pupils to allow strong thoughts and emotions to settle, like the glitter, so that clearer choices can be made.

The INT classrooms participated in the 10-min-per-day audio-guided mindfulness program, from the 90-track series. Each day, the classroom teacher selected and played one track, in sequential order (1–90), using the preloaded MP3 player and speaker system in the classroom. Teachers were encouraged to pick a normal transition time to run the program, for instance, after lunch or recess or in between two intense subjects. During the last 2 min of each 10-min recording for the older students, students were instructed, while still quiet, to take out their journals and write or draw about their experience with the practice that day in order to integrate any insights. This was done specifically to keep the overall time within the 10-min target and substituted group sharing which forms part of the standard MBSR protocol. Teachers were encouraged to participate in the program, along with students, by sitting and listening to the recording each day.

2.5. Measures

2.5.1. Academic outcomes

Each classroom teacher or the School administrator completed a grades tracking sheet at T1 and T2. For School 1, student grades in the following subjects were collected: Math, Science, Social Studies, Reading, Writing, and Spelling. For School 2, student grades in the following subjects were collected: Math, Science, Social Studies, Writing, Reading, and Verbal Communication. Each School also provided a measure of overall student academic attainment, operationally defined as students' GPA; an average of quarterly term grades. It is important to note that the two schools had very different grading systems (see Tables 3 and 4). In particular, School 1 used a grading system of 0–100%. In contrast, School 2 used a grading system of 1–4 for all grades, with 1 being the lowest grade and 4 being the top grade. In this school, the quarterly grades that served as basis for this study were computed as the sum total of 5 different sub-grades collected during the term (thus the grade spread for School 2 was from a low of 5 to a top score of 20).

2.5.2. Intervention fidelity/implementation outcomes

Program fidelity data were collected daily throughout the study. INT Teachers reported: 1) their ability to run the program each day; 2) if they participated in the program with students; 3) if they accomplished the planned curriculum; and 4) if there were any issues related to the program, including student participation. This data assessed the practical feasibility of running this technology-enabled program every day without changing the planned curriculum, as well as the fidelity of

implementation across the different classrooms without further external support.

2.6. Data analytic strategy

Data from the two schools were analyzed separately because the scores provided were the results of radically different testing and marking procedures in the two schools (see Tables 3 and 4 for means and standard deviations for all subjects). In addition, the two schools were completely different in terms of sociodemographic profiles, with School 1 students being predominantly Hispanic and from a lower socioeconomic background than students in School 2, who were predominantly White. In addition, data was provided for Grades 2 and 5 for School 1 but for Grades 1, 2, 3 and 4 for School 2, potentially introducing instability into an Analysis of Variance model if controlling for Grade in a combined analysis.

For baseline comparisons pre-intervention scores were used despite some concerns about homogeneity of variance. However, for the main analysis pre- to post-intervention change scores were used as these better satisfied the assumption of homogeneity of variance. Models were fitted to the data including condition (Intervention vs. Waitlist Control) and Grade as independent variables using Stata Version 14 (StataCorp, 2015). Significance levels were calculated using robust standard errors which take account of intra-class correlation, necessary because the intervention was randomized at class level. Finally, the results from the two schools were combined pictorially using Forest Plots in order to give a visual representation of the effect of the condition across the grades at both schools. Forest Plots are typically used to pictorially combine standardized results across several studies for meta-analysis so this is an appropriate method for combining the results given the differences in scoring in the two schools (Bradburn, Deeks, & Altman, 2016). The standardized effect sizes shown in the Forest Plots are Cohen's d.

3. Results

3.1. Comparison of academic scores between classrooms allocated to receive the intervention compared with classrooms allocated as waitlist controls

Since School 1 and School 2 were analyzed separately, we present the results of these analyses sequentially. As Table 5 indicates, in School 1 the main effect of the MBSR-adapted intervention was statistically significant for Math scores (p = .05), for Social Studies (p = .008), and on GPA scores (p = .01). For School 2, the main effect of the intervention on Math scores was statistically significant for Math (p = .001)

Table 3
Means and standard deviations for Math, Science, Social Studies and Grade Point Average by condition and time.

School	Grade	Group	N	Math		Science		Social Studies		GPA	
				T1 Mean (SD)	T2 Mean (SD)	T1 Mean (SD)	T2 Mean (SD)	T1 Mean (SD)	T2 Mean (SD)	T1 Mean (SD)	T2 Mean (SD)
1	2	INT	47	93.02 (6.59)	94.04 (5.17)	94.55 (7.21)	100 (0.00)	90.29 (8.25)	95.21 (4.75)	91.07 (6.41)	94.60 (4.33)
		WLC	48	95.06 (5.26)	90.68 (7.18)	94.27 (7.36)	93.75 (8.53)	96.35 (6.23)	96.58 (5.63)	92.10 (5.78)	92.43 (5.75)
	5	INT	17	86.05 (6.51)	86.82 (6.79)	86.82 (6.55)	87.76 (7.17)	83.52 (7.94)	87.11 (5.77)	86.45 (5.56)	87.22 (4.63)
		WLC	19	98.00 (2.66)	99.68 (0.47)	95.73 (4.98)	96.31 (4.95)	99.73 (4.13)	96.52 (3.37)	96.39 (3.02)	95.73 (2.01)
2	1	INT	20	13.25 (2.80)	13.75 (3.38)	6.00 (0.00)	5.90 (0.31)	9.00 (0.00)	9.00 (0.00)	2.02 (0.27)	2.07 (0.31)
		WLC	18	13.11 (3.05)	13.00 (3.43)	6.00 (0.00)	6.00 (0.00)	9.00 (0.00)	9.00 (0.00)	2.03 (0.27)	2.02 (0.30)
	2	INT	39	14.15 (1.84)	14.33 (2.13)	5.84 (0.43)	5.71 (0.68)	8.76 (0.62)	8.74 (0.78)	2.16 (0.20)	2.18 (0.20)
		WLC	21	14.09 (4.15)	13.52 (4.13)	5.66 (0.65)	5.57 (0.81)	8.57 (0.81)	8.47 (1.12)	2.10 (0.38)	2.07 (0.38)
	3	INT	22	13.77 (3.65)	14.00 (3.86)	7.91 (1.95)	8.24 (1.66)	10.40 (2.26)	11.90 (3.26)	1.95 (0.47)	2.04 (0.47)
		WLC	45	13.08 (3.53)	12.64 (3.26)	9.50 (0.74)	10.18 (0.79)	9.15 (2.42)	10.53 (3.10)	1.80 (0.36)	1.88 (0.35)
	4	INT	22	15.00 (2.63)	15.50 (2.19)	9.50 (0.74)	10.18 (0.79)	12.36 (0.95)	11.86 (0.83)	2.14 (0.18)	2.14 (0.16)
		WLC	19	14.89 (2.37)	14.73 (2.57)	9.38 (0.76)	8.79 (1.58)	12.15 (1.30)	11.57 (1.30)	2.08 (0.26)	2.01 (0.29)

GPA = Grade Point Average; INT = Intervention group; WLC = Waitlist Control group; T1 = scores before start of term; T2 = scores at end of term; SD = Standard Deviation.

Table 4
Means and standard deviations for Reading, Writing, Spelling and Verbal Communications by condition and time.

School	Grade	Group	N	Reading		Writing		Spelling		Verbal Communication	
				T1 Mean (SD)	T2 Mean (SD)	T1 Mean (SD)	T2 Mean (SD)	T1 Mean (SD)	T2 Mean (SD)	T1 Mean (SD)	T2 Mean (SD)
1	2	INT	47	90.42 (9.54)	96.14 (6.26)	85.74 (9.19)	88.93 (8.91)	92.42 (7.03)	93.31 (6.68)	n/a	n/a
		WLC	48	88.75 (11.69)	92.12 (10.77)	83.58 (9.48)	87.22 (9.05)	94.62 (6.93)	94.20 (6.36)	n/a	n/a
	5	INT	17	86.17 (5.13)	87.82 (5.29)	88.52 (7.21)	89.41 (5.25)	87.58 (6.55)	84.41 (5.69)	n/a	n/a
		WLC	19	94.31 (6.53)	94.63 (3.53)	95.52 (5.50)	93.63 (4.65)	95.05 (3.59)	93.63 (2.73)	n/a	n/a
2	1	INT	20	15.65 (3.73)	15.85 (4.36)	12.95 (2.60)	13.6 (2.66)	n/a	n/a	13.45 (1.82)	13.6 (1.63)
		WLC	18	15.27 (2.86)	15.27 (3.87)	13.05 (2.75)	13.05 (2.73)	n/a	n/a	14.11 (1.49)	13.94 (1.83)
	2	INT	39	17.51 (2.50)	17.92 (2.37)	14.00 (2.27)	14.23 (1.95)	n/a	n/a	14.64 (1.22)	14.64 (1.26)
		WLC	21	16.71 (4.94)	17.00 (4.66)	13.85 (2.85)	13.14 (2.88)	n/a	n/a	14.14 (1.90)	14.14 (1.82)
	3	INT	22	10.72 (2.71)	10.95 (2.53)	13.36 (3.65)	13.72 (3.95)	n/a	n/a	11.59 (1.91)	11.72 (1.95)
		WLC	45	10.37 (2.38)	10.60 (2.29)	11.57 (2.85)	12.53 (2.45)	n/a	n/a	10.84 (2.09)	11.26 (1.95)
	4	INT	22	11.81 (1.62)	11.54 (1.59)	14.31 (1.12)	13.90 (1.54)	n/a	n/a	11.77 (0.75)	11.86 (0.63)
		WLC	19	11.52 (1.89)	11.10 (1.99)	13.84 (2.50)	13.05 (2.85)	n/a	n/a	11.21 (1.54)	11.21 (1.39)

INT = Intervention group; WLC = Waitlist Control group; SD = Standard Deviation.

but none of the main effects on other grades reached statistical significance.

Fig. 1 shows the pattern of effects of the intervention for each grade in each school. The center of each horizontal line indicates a standardized difference between intervention arms (Cohen's d). Lines to the right-hand side of the vertical line indicate greater improvements in scores in the INT group. These show that for Math, Social Studies, Reading and the GPA the effect sizes generally indicated improvements in the intervention group relative to the WLC group. This pattern was not apparent for the other subjects. Fig. 1 also indicates that the Math scores in School 2 consistently indicated medium to large effect sizes in favor of the intervention group. For Social Studies, Fig. 1 shows better improvement in the intervention group. However, for School 2 all the effect sizes were very close to 0. The effect sizes for Reading were all above zero but very small and with confidence intervals crossing zero.

As outlined above, GPA is an aggregate of the academic subject scores and Fig. 1 suggests that all effect sizes indicated greater improvements in the MBSR-adapted program INT group. In addition, most of the confidence intervals are above zero. However, the variation in the effects for School 2 resulted in a significant effect on GPA scores only being found for School 1 (p = .01), as outlined above.

3.2. Feasibility of technology-enabled MBI program implementation

There was little to no reported impact of the mindfulness-based intervention on day-to-day teaching operations for participating classrooms in both schools. School 1 had 45 available days and School 2 had 44 available days to run the program, excluding holidays, field trips, and teacher institute days. Out of the school days that the intervention was run, participating teachers implemented the program on 95.5% of available days. Teachers also indicated on the daily tracker that they had been able to accomplish their planned curriculum 99% of the time (the range was 98%–100%). These data suggest that teachers can implement and embed a technology-based MBI every day and that teachers seem to consistently be able to make the choice to participate in the mindfulness practices along with their students. The recorded data also suggest that the intervention had almost no adverse impact on day-to-day classroom activities. Furthermore, teachers did not report any issues associated with running the program.

4. Discussion

In this study, we assess the effect of a brief, audio-recorded MBI adapted from MBSR on academic achievement of primary school pupils. Two hypotheses were tested. Hypothesis 1 predicted an increase in academic achievement for participating classrooms, and the results showed that this hypothesis was only partially supported because we did not see consistent improvement in student results in all classrooms exposed to the MBSR-adapted intervention, compared to the WLC. Hypothesis 2 predicted that teachers would be able to implement such a

Table 5
Baseline between-groups comparisons; and main and interaction effects of the intervention on all subjects.

	Math	Science	Social Studies	Reading	Writing	Spelling	Verbal Comm'n	GPA
School 1								
Main effect of intervention (p)	**.05**	.10	**.008**	.56	.76	.49	n/a	**.01**
Mean difference[a]	3.66	4.43	5.26	2.07	0.43	0.47	n/a	2.72
95% CI (for effect size)	−0.12, 7.45	−1.25, 10.11	2.10, 8.43	−6.51, 10.65	−3.07, 3.94	−1.19, 2.13	n/a	0.94, 4.51
Interaction effect (group x grade) (p)	**.003**	.09	.24	.83	.11	**.001**	n/a	.08
Baseline Between-Group differences (p)	.15	.62	.07	.86	.92	.05[b]	n/a	.35
School 2								
Main effect of intervention (p)	**.001**	.48	.63	.60	.90	n/a	.66	.43
Effect size (mean difference)[a]	0.68	-.22	−0.26	0.08	0.05	n/a	−0.07	0.03
95% CI (for effect size)	0.36, 1.00	−0.47, 0.90	−1.45, 0.92	−0.25, 0.41	−0.96, 1.07	n/a	−0.40, 0.27	−0.05, 0.10
Interaction effect (group x grade) (p)	.84	**.054**	.87	.69	.33	n/a	.32	.81
Baseline Between-Group differences (p)	.23	.12	.11	**.03**[c]	.09	n/a	.09	**.02**[d]

Bold means "significant effect at p = .05 level".
[a] Unstandardized effect size for main effect of intervention;
[b] Higher scores at baseline in the WLC group;
[c] Higher scores at baseline in the INT group;
[d] Higher scores at baseline in the INT group; Comm'n = Communication.
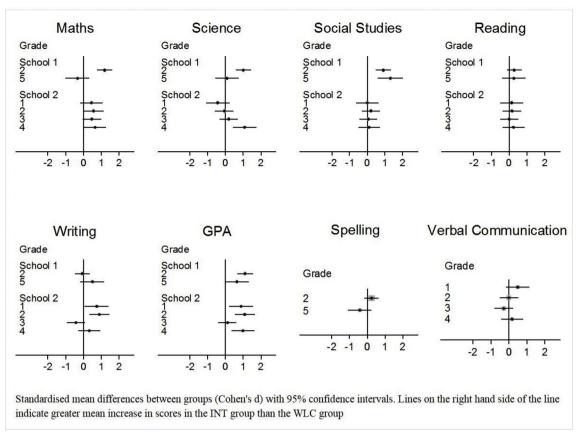
Fig. 1. Forest Plots for all subjects and grades.

technology-enabled MBI with fidelity and without the need for externally hired mindfulness expertise, and the results support this hypothesis. We discuss our findings below in detail.

4.1. Contributing to theory-building on mindfulness and academic achievement

Maynard et al.'s (2017, p. 5) systematic review concluded that there is some indication that MBIs can improve cognitive and socio-emotional outcomes among children but found no support for consistent improvement in academic achievement. Translation of cognitive and socio-emotional effects into academic performance does not therefore appear to be straightforward without paying attention to the context in which any cognitive and/or socio-emotional effects may occur.

Overall, while the present study is to the best of our knowledge one of the largest RCTs exploring the link between MBI and academic achievement, the lack of consistent statistically significant results presented here should not be interpreted as a failure to produce "positive results", but instead examined in the context of a need for more careful studies that do not underreport "negative results" (Coronado-Montoya et al., 2016). Specifically, our results indicate some potentially promising effects of the MBSR-adapted MBI for Social Studies, GPA, and especially Math scores. However, because the results varied considerably in effects these results have to be interpreted tentatively.

While our results are in line with previous research which also found some indication of an effect on Math, that study merely reported a non-significant trend (Schonert-Reichl et al., 2015). Hence our first contribution to building theory on the link between mindfulness and academic achievement is to encourage more research on the effects of mindfulness-based interventions on Math ability in particular (and potentially through that global performance). If we consider that mindfulness is a form of mental training, enabling focus and 'being in

the moment', and that Math, comparatively more abstract and conceptual, requires a higher cognitive load than subjects such as Reading or Writing, then this potential linkage should be explored further. There is some prior evidence that executive control capacity among children, in particular related to managing impulsive behavior, may be particularly conducive to increasing Math skills (Cerda et al., 2015), hence scholars could choose to follow up by comparing different aspects of mindfulness training in their effectiveness on executive control and ultimately Math performance. In addition, it would be useful to gain a better understanding of what types of Math performance are particularly variable in response to mindfulness practice, and the extent to which demographic or gender(ed) factors may moderate any potential effect.

The Forest Plot pattern of results across primary school grades in both schools suggested a generally positive trend across the majority of subjects, indicating some possible advantages of mindfulness on academic achievement, but the results are not conclusive. The diverse grade pattern points to follow-up investigations exploring to what extent academic performance in earlier grade levels really does measure the same concepts or skills as a measure of performance does for older school children, even in the same subject areas. By way of example, pupils in grades 1 and 2 are taught more specifically the socio-cognitive skills of how to learn, how to interact with others productively, and how to manage themselves, across many subjects they study. It may in fact be misleading to exclusively measure "academic outcomes" in earlier years, rather than behavioral outcomes, when assessing the socio-cognitive impact of mindfulness training. This means that we may need different focal points of mindfulness training programs targeting pupils across their developmental stages. Perhaps a more socio-emotional skills focus is helpful for MBIs in earlier grade levels and a more focused attention/concentration focus may be most effective in later school stages, when these skills are more unequivocally assessed. A

prior MBI in schools (Bakosh et al., 2015) measured behavioral incidents as an additional outcome variable examining the effectiveness of a mindfulness intervention in generating academic achievement, suggesting that the incidence of adverse behaviors in classrooms decreases when pupils participate in mindfulness programs.

A related, follow-up research avenue in this context would consist in further research to examine the meaning of mindfulness training on academic performance across grades in (primary and beyond) school. We wonder if the intervention under study here may have been too 'homogenous', not being sensitive enough to developmental differences in the students in different grades. While we don't see a pattern in the results in this study suggesting that students in specific Grades were responding differently to the intervention, further empirical work is advised to assess whether or not younger and older primary school aged students can effectively engage with the same intervention.

Our field study included data from two schools which varied dramatically in terms of their socio-demographic profiles; they employed different grading systems for measuring academic achievement; and there were also different Grade levels included in the study from each of the schools. Each of these contextual factors may have individually or cumulatively interacted with any potential treatment effect and introduced variability into test scores. These factors also meant that it was not possible to conduct the analysis across both schools but that we conducted it for each school independently. However, our novel use of Forest Plots does allow the reader to get a sense of effect sizes across the different grades in the different schools, which enabled a visual comparison. Nonetheless, researchers should strive for future field research collaborations in this domain that enable them to work with more comparable student samples. Carefully conducted follow-up research opportunities, enabling researchers to close the research gaps identified here and by other scholars intent on furthering "truth in advertising" in mindfulness research (van Dam et al., 2018) will genuinely extend mindfulness theory relevant for schools. In addition, scholars should consciously build contextual data collection into their research designs in order to improve the interpretability of any (positive or negative) effects (van Dam et al., 2018); for example, recording school-related event data, characteristics of teachers and pupils, practice and other implementation-relevant details.

Our findings may also relate at least in part to the increasing number of mindfulness thought leaders urging scholars and mindfulness enthusiasts to exercise caution when considering any mandatory exposure to this type of intervention in schools. At least 20 case reports have been published documenting adverse effects of mindfulness meditation experiences (van Dam et al., 2018) and this type of intervention may not work for everyone (Farias, Wikholm, & Delmonte, 2016). Hence, the possibility of MBIs generating counterproductive consequences for some students cannot be ignored. And indeed the results in our study may suggest that some students may have been adversely affected; for example, the Forest Plots for the different subjects suggest that some classrooms appeared to be adversely affected by exposure to the intervention, or may for a variety of (unreported) reasons not have used the program as intended. Schools need to consider carefully the most appropriate mode of introducing and integrating this type of intervention. We recommend that future studies are designed in a way that enables questions around *who* these interventions are most effective for, and indeed who they may be detrimental for.

4.2. Implications for practice

Despite the general enthusiasm for MBIs, there have been several reports of SELs (Durlak et al., 2011) and MBIs (Van de Weijer-Bergsma, Langenberg, Brandsma, Oort, & Bögels, 2014) whose reported gains reduce in magnitude over time, purportedly related to practical concerns such as extensive up-front investment in teacher time and resources to set up an initiative. One way to help schools in this endeavor is to develop interventions that can be implemented easily, consistently and sustainably, and with little or no teaching resource implications. In an era where curriculum requirements are already stretched to capacity, and teachers are time-poor, this seems a sensible approach. We sought to do that in our study with the development of an MBSR-adapted intervention designed to be implemented with minimal training and resource outlay, in the course of the normal school day, and with apparently minimal impact to 'formal' curriculum-based teaching. The implementation fidelity results suggest that teachers reportedly found this an easy intervention to implement, and that it seemed to have had little impact on day-to-day teaching operations. This is encouraging but further empirical work is needed before any firm conclusions can be drawn. For example, other reporting mechanisms may be helpful to include in future investigations around implementation efficacy, beyond teachers' self-reports. It is conceivable that teachers may have overstated their own fidelity to their curriculum, for fear of recrimination if they had reported anything else.

4.3. Limitations

Beyond the limitations already mentioned in the previous section, several other limitations in our study should be acknowledged. Firstly, while a considerable strength lies in the randomized controlled study design, our study was a waitlist control design which does not allow us to evaluate the current intervention against other active interventions, so we cannot rule out the possibility that any of our findings represent a general treatment effect. Including an active control condition in future studies would help. And given the resistance of some proponents of mindfulness regarding the effectiveness of non-traditional formats of delivery, conducting an RCT assessing our intervention against a more traditionally delivered face-to-face group-based intervention would help to understand the relative contribution of the social support component.

Secondly, another limitation relates to our randomization procedure. While the students in the study were randomized by classrooms volunteered by specific teachers, there still may have been self-selection bias that impacted our results. It is conceivable that the teachers whose classrooms were were randomized into the intervention condition may have graded their students more favorably, and/or the teachers whose classrooms were randomized into the control condition may have graded more negatively. It is possible that bias influenced some of the grading. Future studies could match standardized test scores to other assessments in those subjects, to assess if student performance is consistent for each subject. Furthermore, it is evident that randomizing by classroom did not remove the baseline differences between the INT and WLC groups for some subjects. However, this was the most sensible option due to the nature of the intervention and plan for implementation. Nonetheless, in future research, randomizing at the individual level, across classrooms, may be advisable.

Declaration of interest

Laura S. Bakosh, PhD is the co-founder of Inner Explorer, a non-profit organization that develops and distributes audio-guided mindfulness-based training programs similar to the program examined for the present study. However, Dr Bakosh and Janice Houlihan, who co-founded Inner Explorer with Dr Bakosh, do not own this organization and do not benefit financially in any way from any income received by the Inner Explorer non-profit organization.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.learninstruc.2018.04.012.

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