ARTICLE

Impact of Experiential Neuroscience of Meditation Course on Attitudes Toward Meditation and Science

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An interdisciplinary, intensive, and experiential course on Neuroscience of Meditation was designed to fulfill a general education science requirement. Class activities included lecture, class discussion of the textbook and scholarly articles, laboratory experimentation, and practicing 15 different forms of meditation. Laboratory investigations included sheep brain dissection, physiological measurements of the autonomic nervous system, electroencephalogram, salivary enzyme assays, attention testing, and psychological questionnaires. The Determinants of Meditation Practice Inventory (DMPI) and My Attitude Toward Science (MATS) scales were administered at the beginning and conclusion of the course; barriers to meditation were reduced and positive attitudes toward school science were increased. Comments on course evaluations praised this incorporation of contemplative pedagogy into a neuroscience course.

Key words: education; contemplative pedagogy; neuroscience; meditation; mindfulness; contemplative neuroscience

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Approximately 11 – 24% of college students state that they have meditated in the previous twelve months (Versnik Nowak and Hale, 2012; Versnik Nowak et al., 2015). According to PubMed results by year for the keywords *meditation* and *mindfulness*, the annual numbers of biomedical research papers on contemplative practices have increased 10- to 20-fold since 1998. The study of the meditating brain is a rich interdisciplinary field, with contributions from neuroscience, religion, psychology, philosophy, and others. For students hesitant to study science, approaching it through meditative practice may provide a novel "hook" to reduce their fear.

One of the core elements that all students should gain from an undergraduate education is an understanding of how scientific knowledge is made and revised (AACU's National Leadership Council for Liberal Education and America's Promise, 2007). Students who are non-science majors have been shown to be more intimidated by course material, less motivated to study, and less interested in a science course; additionally, they performed more poorly on assessments (Knight and Smith, 2010). Attitudes toward science courses are a predictor of academic achievement (Ilgan, 2013). Thus, teaching in ways that can improve attitudes toward science can help nonmajors become competent in scientific reasoning.

The 2008 "blueprint" on undergraduate neuroscience education called for the development of interdisciplinary curricula that emphasized the connections between neuroscience and other liberal arts (Wiertelak and Ramirez, 2008); such courses are critical for interdisciplinary "Neuroscience Studies" majors or minors (Wiertelak et al., 2018). The American Association of Colleges and Universities identified one of the seven principles of excellence in education as: "Engage the big questions…Study in the arts and sciences should provide students with opportunities to explore the enduring issues, questions, and problems they confront as human beings—questions of meaning, purpose, and moral integrity" (AACU's National Leadership Council for Liberal Education and America's Promise, 2007). There is great potential for the development of curricula that integrate these goals with the traditional study of neuroscience.

Many institutions have a holistic approach in their mission, including statements about ethical or moral development (Taylor and Morphew, 2010) or "personal perspectives, values, and moral character" (Meacham and Gaff, 2006). Some of the explicit aims of the University of Redlands are to provide a "reflective understanding of our world" and to educate both minds and hearts (University of Redlands' Mission Statement and Welcome from the President, 2018). Meditation has been welcome in the University's academic culture for many years. The University built a beautiful walking meditation labyrinth on campus in 2004, and the Meditation Room, one of the first "contemplative classroom" spaces in the country, opened in 2007. Academic-based courses offered in this space, bearing credits and counting toward degrees, include Introduction to Meditation, Meditation and Writing, Seminar on Compassion, and Neuroscience of Meditation. Each course integrates contemplative methods, such as silent sitting meditation, mindfulness, body movement, compassion practices, and nature observation into the academic work of a college class, and the inclusion of these practices has been transformative for students (Grace, 2011a; Ko et al., 2018).

In addition to the fall and spring semesters, the University of Redlands' academic schedule includes a one-month May term. This term is designed for experiential and immersive coursework; students enroll in a single course worth three credits (a typical fall or spring semester course is worth four credits). This paper describes and assesses an innovative May term course that examined the neuroscience underlying the cultural and religious practice of meditation combined with

Body scan	Track 5 from https://itunes.apple.com/us/album/mindful-meditations/288584839 and Track 3 from https://www.meditationoasis.com/new-products/pure-relaxation
Breath meditation	Counting breaths and focusing on the sensation of the breath
Mindfulness meditation	Being aware of thoughts, feelings, and sensations of the current moment without judgement and allowing them to pass
Equanimity-focused meditation	Pages 110-111 (Hanson and Mendius, 2009)
Tai Chi	A local Tai Chi instructor provided a demonstration and lesson
Positive mood induction	Remembering or imagining a happy time, or drawing/journaling about things that make one happy
Loving-kindness (*metta)* meditation	Generating feelings of warmth and goodwill for a loved one, oneself, an acquaintance, a stranger, an enemy, and the entire world. A faculty colleague recorded a guided meditation that we used
Candle meditation	Focusing concentration on viewing a candle flame
Zazen	Zen Buddhist sitting meditation; a faculty colleague who is a long-term practitioner provided us beginner's instruction
Chanting	A student who practiced Mahayana Buddhism shared her daily practice with us. https://www.youtube.com/watch?v=KfRcUpoPl7w&t=27s
Walking meditation	University of Redlands labyrinth
Centering Prayer	From the Christian tradition; https://contemplativeoutreach.org/
Tonglen (sending and receiving)	Breathing in another's suffering, breathing out love and hope. A faculty colleague recorded a guided meditation that we used
Bearing witness	Being present in another person's suffering without distancing oneself. One student volunteered to share about a personal hardship, while the rest of the class practiced eye contact and intensive listening without mind wandering
Hello/goodbye meditation	Reflecting on impermanence and constant change, and how every ending is a beginning of something else. We did this meditation on the last day of the term, which was also the last day of college for the graduating seniors in the class

Table 1. Forms of meditation practiced during the term and resources used.

contemplative methods and laboratory investigations. The goals of the course were for students to explore how meditation affects the brain and the body with the following methods: 1) Learning from *oneself* by participating in various meditation practices and observing how one responds; 2) Learning from *one another* by using experimental methodology to measure classmates' physiological and neurological parameters and participating in class discussions regarding their experiences in meditation; and 3) Learning from *scholars* by listening to lectures and reading what scientists have published about the neuroscience of meditation, the stress response, and basic functional neuroanatomy. I hypothesized that the course would not only help students see the value of internal meditative inquiry as a method to understand the world, but would improve their attitudes toward scientific inquiry as well.

MATERIALS AND METHODS

This study was approved by the University of Redlands' Institutional Review Board and participants provided informed consent. Seventeen students enrolled in the Neuroscience of Meditation course with no recruitment other than the availability of the course during the typical registration period. All students consented to participate in the study, including the use of comments on course evaluations and meditation logs in a publication. Two students withdrew from the course for reasons unrelated to the study. All students were non-science majors. The course met the University's general education requirements for a natural science course, including the collection and analysis of measurable, empirical data, as well as the requirements for an embedded quantitative reasoning experience (due to the use of statistics).

During the first hour of class, students provided information on their previous and current meditation practice, and completed two questionnaires. The Determinants of Meditation Practice Inventory (DMPI) yields scores that range from 17 – 85, with higher scores indicating more barriers to meditation practice (Williams et al., 2011). Participants rate how much they agree with statements such as "I can't sit still long enough to meditate," "I don't have time," and "It is a waste of time to sit and do nothing" on a five-point scale. The My Attitudes Toward Science (MATS) instrument (Hillman et al., 2016) tests four subscales; the "attitude toward school science" subscale was used for this analysis. Scores on this subscale range from 14 – 70, with higher scores indicating more positive attitudes. Participants rate how much they agree with statements such as, "Studying science is something that I enjoy very much," "I like science classes," and, "It scares me to have to study science" (reverse scored) on a five-point scale. The same questionnaires were administered during the final class session.

All statistical analyses were performed using IBM SPSS statistical software (International Business Machines

Breathing Awareness Meditation and LifeSkills® Training Programs Influence Upon Ambulatory Blood Pressure and Sodium Excretion Among African American Adolescents	(Gregoski et al., 2011)
Baseline and Strategic Effects behind Mindful Emotion Regulation: Behavioral and Physiological Investigation	(Grecucci et al., 2015)
Alterations in Brain and Immune Function Produced by Mindfulness Meditation	(Davidson et al., 2003)
Experienced Mindfulness Meditators Exhibit Higher Parietal-Occipital EEG Gamma Activity during NREM Sleep	(Ferrarelli et al., 2013)
Tai Chi Chuan and Baduanjin Increase Grey Matter Volume in Older Adults: a Brain Imaging Study	(Tao et al., 2017)
Short-term Meditation Training Improves Attention and Self-regulation	(Tang et al., 2007)
Effect of Seminar on Compassion on Student Self-compassion, Mindfulness and Well-being: A Randomized Controlled Trial	(Ko et al., 2018)
The Measurement of Regional Cerebral Blood Flow during the Complex Cognitive Task of Meditation: a Preliminary SPECT Study	(Newberg et al., 2001)
A Randomized Controlled Trial of Tong Len Meditation Practice in Cancer Patients: Evaluation of a Distant Psychological Healing Effect	(Pagliaro et al., 2016)
Measuring the Immeasurable? Compassion Under a Microscope	(Grace, 2015)
Wholeness and the Implicate Order, Chapter 1	(Bohm, 1980)

Table 2. Articles read during the term.

Corporation, Armonk, NY). Means were compared for pre- and post-course scores using paired t-tests. To assess whether an interaction existed between the change in barriers to meditation and whether participants began the course with an existing meditation practice, a 2-way mixed ANOVA was performed (within subjects: DMPI pre- and post-course scores; between subjects: current meditation practice). Correlations were tested using Pearson's product-moment correlation. All tests used an alpha level of $p = 0.05$.

The course, Neuroscience of Meditation, was offered by the Biology department for a four-hour period, four days per week, for a total of 14 class sessions plus a field trip. The required textbook for the course was *Buddha's Brain: The Practical Neuroscience of Happiness, Love, and Wisdom* by Rick Hanson (Hanson and Mendius, 2009). I have found this inexpensive paperback book to have an excellent combination of reference-backed evidence while using accessible language for non-science majors. It also includes instructions for various forms of meditation that the reader can implement at home. The 15 forms of meditation taught in the course are described in Table 1. The major lecture topics in the course included: an introduction to methods in neuroscience, parts of a neuron, action potentials, synaptic transmission, functional neuroanatomy, the stress and relaxation responses, the default mode network, the basis of attention, experimental design, and statistical analysis.

Students were assessed on a meditation log, homework questions on scholarly articles, participation, a mid-term short answer exam, a field trip analysis, and a laboratory notebook. Each student's meditation log was set up as a discussion thread on the course's learning management system site. Students were required to log at least 15 meditation sessions during the term, many of which occurred during class time. Students could choose which types of meditation to log and practice at home, but sessions during class were intended to expose them to a variety of practices (Table 1). There was no minimum time requirement per session, as long as the student truly attempted the practice. Students were asked to log the time, date, and location of each session, with a description of the meditation type and their experience and reflections. Students were encouraged to read and comment on one another's meditation logs, and these comments could be used to enhance their participation grade.

The mid-term exam, consisting of multiple choice, matching, labeling, and short-answer questions, focused on neuroanatomy, cell biology/neurotransmission, interpreting bar graphs with error bars, and the meaning of a *p*-value. Nine scholarly articles, one popular article, and one book excerpt were assigned during the term. In some cases, I assigned only excerpts of the article to help students focus on critical aspects and not become overwhelmed with technical details. For each article (Table 2), students answered three to five assigned questions that helped them focus on how the figures and tables supported specific conclusions.

The mandatory field trip occurred on a Saturday and we drove to the Zen Center of Los Angeles Buddha Essence Temple. Our gracious hosts allowed us to participant in a chanting service, zazen practice, silent tea, and community council, and we met personally with the abbess for a question and answer period. Students were allowed to choose a format for their field trip analysis. The requirement was for students to connect their observations and experiences on the field trip to at least five separate concepts from the course. Most students submitted brief papers (three to six pages); three students submitted drawings or paintings along with artist statements; one student created a video.

The laboratory notebook was assessed on methodological detail, data analysis (including the creation of figures and appropriate statistical testing), and conclusions of each experiment. For several of the laboratory exercises, the class brainstormed and debated experimental designs, and then voted on a protocol to follow. The labs are described in Table 3.

The syllabus explicitly addressed that contemplative practices can be compatible with and illuminate any

Lab	Emphasis
Sheep brain dissection (Carolina Biological Supplies Company, Burlington, NC)	Basic functional neuroanatomy, directional terms
*Blood pressure before and after breath/body scan meditation (Omron Healthcare BP7911T monitor, Lake Forest, IL)	Physiological basis for blood pressure measurement, autonomic nervous system, bar graphs, error bars, and paired t-tests
Pulse plethysmography tracked with respiration (iWorx Systems, Inc., Dover, NH)	Introduction to iWorx/Labscribe physiology software; demonstration of heart rate variability and respiratory sinus arrhythmia
*Skin conductance and respiration rate recovery from a scary video clip by equanimity meditation versus distraction on phone (iWorx Systems, Inc., Dover, NH)	Sympathetic nervous system, bar graphs, error bars, unpaired t-tests
Positive and Negative Affect Scale (Watson et al., 1988) before and after positive mood induction	Scoring of psychological questionnaires
Positive and Negative Affect Scale (Watson et al., 1988) and Five Facet Mindfulness Questionnaire (Baer et al., 2008)	Scatterplots, correlation coefficients, correlation versus causation
EEG (https://www.emotiv.com/epoc/)	Brief explanation of EEG technology and demonstration
*Correlation of salivary alpha-amylase (Bañuelos et al., 2017) to Compassion Scale (Pommier [2010] The compassion scale. Unpublished PhD thesis, US: The University of Texas at Austin) and Distress Tolerance Scale (Simons and Gaher, 2005)	Enzyme assays, micropipetting, spectrophotometry, autonomic nervous system versus hypothalamus-pituitary-adrenal axis
*Attention testing (Homack and Riccio, 2006) after candle meditation in silence or with music	Basis of attention
*Bearing witness and state anxiety (Spielberger et al., 1970)	Broadening the goal of meditation from personal calm to benefiting others

Table 3. Laboratory exercises during the term. *Students were taught how to measure the physiological parameter, and then allowed to design the experiment, choose controls, etc.

religious tradition or be practiced in a secular context. Although we discussed connections between specific meditative practices and both Buddhist and Christian concepts, it was emphasized that students could adapt particular practices (changing a mantra, for example) to feel more comfortable if needed. Students were also allowed to opt out of any particular meditation exercise if they did not want to participate (none informed me that they were opting out for this reason, although there were some absences from class). Three students opted out of the sheep brain dissection due to moral objections and did the offered alternative assignment, which was drawing from photographs and labeling structures.

RESULTS

When comparing pre- to post-course DMPI means (barriers to meditation) from the entire class, the reduction did not reach the level of statistical significance (n = 15, p = 0.13). However, a two-way mixed ANOVA (within subjects: DMPI pre- and post-course scores; between subjects: current meditation practice) revealed an interaction effect between the change in barriers to meditation and whether participants began the course with an existing meditation practice (Figure 1; p = 0.024). Post-hoc tests showed a reduction in barriers to meditation among students who were not practicing meditation prior to the course (n = 10, p = 0.016). Among those who had a current meditation practice prior to the course, barriers to meditation did not change (n = 5, p = 0.36).

Scores improved significantly from pre- to post-course on the attitude toward school science MATS subscale (Figure 2; n = 15, p = 0.028). There was no interaction effect between MATS scores and whether the participants began the course with an existing meditation practice.

At the pre-course time point, there was no correlation between barriers to meditation and attitude toward science (Figure 3). At the post-course time point, a strong correlation (r = -.813, p < .001) supported the conclusion that as positive attitudes toward science increased, the barriers to meditation decreased (Figure 4).

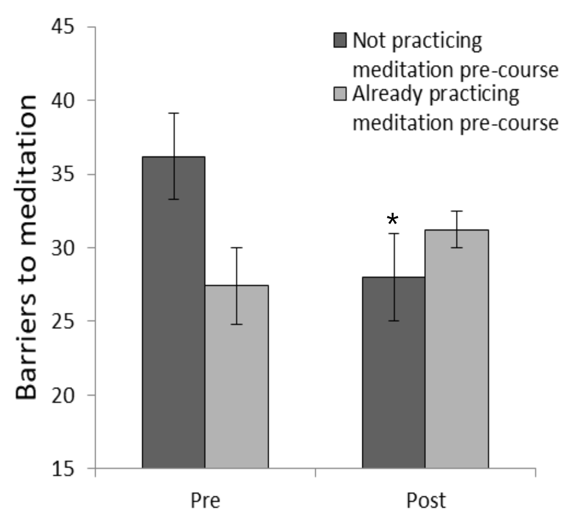

Figure 1. Barriers to meditation reduced pre- to post-course in students who were not already practicing meditation. In students who stated that they had a current meditation practice prior to the course (light gray bars), barriers to meditation did not change (n = 5, p = .36). In students who were not currently practicing meditation at the beginning of the course (dark gray bars), barriers to meditation were reduced (n = 10, p = 0.016). *statistically significant compared to pre-course time point.

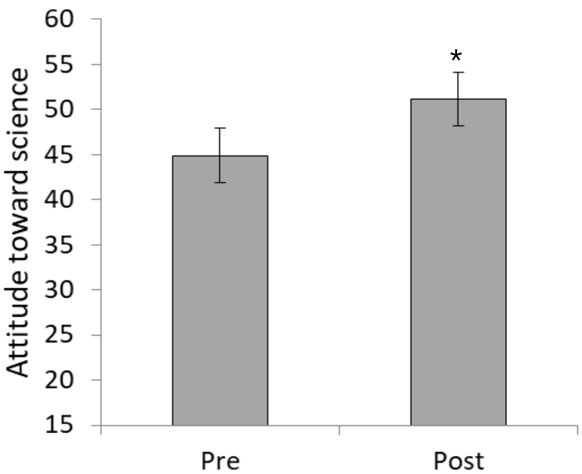

Figure 2. Attitude toward science improved from pre- to post-course. Error bars represent standard error. *statistically significant compared to pre-course time point, n = 15, p = 0.028.

Student engagement in the course was substantial. Most students consistently recorded their meditation logs and all students attended the field trip. As a measure of neuroscience knowledge, the mid-term exam assessed students' understanding of the cell biology of neurons, neuroanatomy, and the stress/relaxation response at a level appropriate for non-science majors. The average score on the exam was 82.5%. These foundational concepts were then applied in the guided discussions of scientific articles, giving novices an opportunity to interact with the primary literature.

Students' laboratory notebooks demonstrated that most were able to formulate and articulate appropriate null and alternative hypotheses, document methodology in detail, collect and statistically analyze data, and make appropriate conclusions. Students commented on the end-of-term course evaluations that laboratory activities were key to their learning.

Additionally, comments from student evaluations highlighted the distinctive nature of the course being a combination of academic learning and internal inquiry, for example:

> "Stretched me both scientifically and personally."

> "This class was personal and experimental."

> "Overall, this course for me wasn't just about learning a ton of facts (with the neuroscience). It was also very much about learning to be a better person and figuring out the best ways to take care of myself on a mental and emotional level and why it is that those techniques work so much. I found this class the perfect balance between talking about things in theory and actually putting what is talked about into practice."

Regarding the assigned scientific articles that students read, one wrote that "Homework assignments were exciting and interesting," and another mentioned that "The in-class meditations helped me understand what many of the articles we read were relating to." Overall, the course evaluations were almost universally positive, with two students stating that this was one of their favorite classes they had ever taken in college.

Two students explicitly mentioned in course evaluations that this course reduced their fear of science:

> "I was so nervous to take a science class but she made it fun and exciting…I was excited to come to class."

> "Traditionally I've been afraid of science classes…it gave me a completely different outlook on science."

In one student's meditation log for the last wee of the course, she wrote:

> "I can't believe I made it through a whole month of taking a science class and actually doing well. During this meditation, I thought about the first day of class and how scared I was to be taking a class that was anything remotely related to science and then I reflected on today and how far I've come. I actually did well in science and I enjoyed it. Learning all these new concepts wasn't as bad as I thought it was going to be…I'm going to miss all of our experiments and trying out new forms of meditation. I'm no longer intimidated by studies and graphs."

DISCUSSION

This was an innovative and experiential Neuroscience of Meditation course in a compressed one-month format. It was highly successful in engaging the non-major student population. The course resulted in improved attitudes toward both science and meditation, with higher positive attitudes toward science correlated to lower barriers to meditation practice.

Previous researchers have suggested that to improve scientific understanding among non-majors, it may be more important to change student attitudes rather than increasingly focus on course content (Knight and Smith, 2010). The finding that the Neuroscience of Meditation course improved attitudes toward science supports the development of interdisciplinary courses that can draw

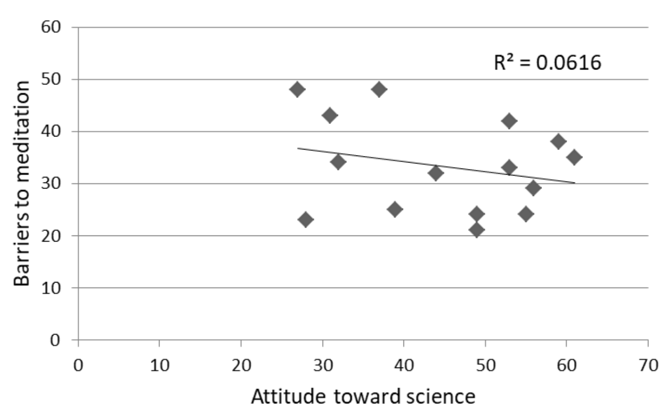

Figure 3. Absence of a correlation between attitudes toward science and barriers to meditation, pre-course. n = 15, p = 0.37.

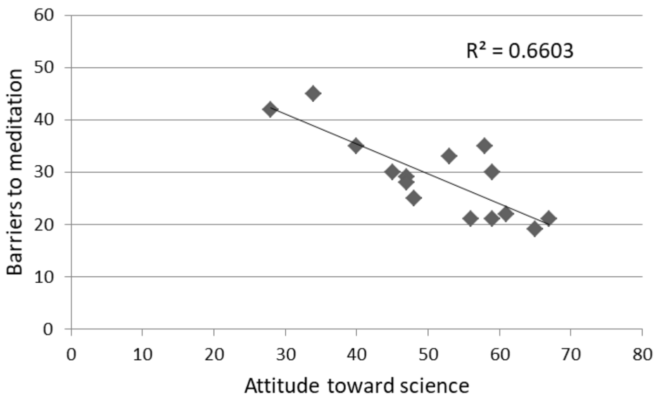

Figure 4. Strong negative correlation post-course: as the positive attitude toward science increased, the barriers to meditation decreased. $n = 15$, $p < 0.001$.

students who might not be inclined to take a course strictly focused on science. Although one could undertake the scientific study of meditation without personally experiencing it, the power of an interdisciplinary course is in viewing a topic from different lenses. The practice of various forms of meditation was particularly helpful to inexperienced students in reducing their barriers to meditation. The finding that, at the end of the course, more positive attitudes toward science correlated with fewer barriers to meditation could be interpreted in several ways. For example, it could be that as students embraced the practice of meditation, they became more open to new experiences such as scientific knowledge. However, based on comments such as the one below, I hypothesize that more exposure and comfort with science material helped students see evidence for the effectiveness of meditation:

> "I am a person that is practical and logical to a ridiculous extent, and the concept of taking anything on faith alone is simply impossible to me. This neuroscience course has really opened my eyes to the practical power of meditation…Being able to read studies about everything we are learning in this course, and even performing some experiments ourselves, has been a powerful experience for me in establishing rational confidence in these teachings and ideas."

Not only was this course effective in its goals, it was enjoyable to teach. Class time was spent in a combination of lecture, meditation, class discussion of the textbook and articles, and lab experimentation; students commented that the four-hour time blocks passed quickly. In my fifteen years as a professor, it was one of the best teaching experiences I have ever had.

Factors that may have influenced effectiveness

Although I have moderate experience with several of the meditation practices listed in Table 1, in others I am a complete novice. Inviting guests from the community to teach us particular meditation styles added variety to the instruction, and I shared with the students that I was learning alongside them. There are many commercial meditation CDs available, as well as podcasts and guided meditations on youtube.com. I would encourage faculty that one does not need to be an expert in meditation to teach this course. Students appreciated that we experienced a wide variety of meditation styles, as some connected with certain methods but not others. One student wrote in her meditation log:

> "My attitude towards meditation has definitely increased over this past month because of this class, and especially because we have learnt so many different styles that I was unaware of."

I believe one aspect that was critical to the success of this course was the sense of community. This was fostered by the small class size (seventeen students initially enrolled, which is a typical size at our institution for a science course) and the intensive schedule. However, course policies also enhanced a feeling of community. Each meditation period was followed by an open discussion for students to share their experience, and they were encouraged to read and comment on one another's meditation logs as well. Particularly for those new to meditation, it was helpful to hear and read from their classmates that having difficulties with intrusive thoughts, boredom, etc. during meditation periods was normal and expected. I also made informal public comments on student logs, mentioning that it was OK to dislike a particular type of meditation, that I had struggled on a particular day as well, or connecting their comments to course information ("Sounds like your default mode network was particularly stubborn today!"). In this way, each meditation period became a personal experiment for students, an opportunity for them to observe how they reacted, and to share with each other.

This level of honesty and support for one another culminated during our field trip to the Zen center. We were invited to participate in the community council, where an individual who desires to speak holds an object to indicate one's uninterrupted time to express his or her thoughts. Anything shared during the council is confidential. Attendees at the council were invited to speak on their response to the precept of the day, the prohibition on lying. I assumed my students would simply observe as the monks took turns speaking. To my surprise, over half of my students shared their personal convictions, experiences, and struggles, many of which were intensely personal. I was amazed at their willingness to be vulnerable to both strangers at the Zen center and their classmates. I think it was made possible by having spent the previous three weeks often out of their comfort zone, whether that was trying a new form of meditation, making a graph and using statistics, or dissecting a brain. Creating an atmosphere in which the discomfort of trying new things was embraced was an important component of the course.

The meditation types were roughly ordered through the course (Table 1) to begin with the least intimidating and progress to more challenging forms, with a few exceptions for scheduling needs. Additionally, we built from 5- to 10-

minute sessions to 20- to 30-minute sessions. Many students were familiar with the concept of a body scan (focusing attention progressively through various body parts, sometimes paired with intentionally relaxing that part) and paying attention to the breath, and these could be practiced without any associated religious concepts. The unfamiliarity of Buddhist chanting and the strict physical form of zazen (Zen sitting meditation) were more challenging to students, but by that point in the course they were willing to attempt the practices. Most students began the term with the assumption that the goal of meditation is to relax or focus, with the benefit solely to the meditator. The idea that meditation can benefit others was introduced with a loving-kindness (*metta*) meditation that included compassion for the enemy and culminated with the practices of *tonglen* and bearing witness. These forms of meditation invite the meditator to draw closer to suffering, and challenge the idea that meditation is always relaxing (Grace, 2009).

Laboratory exercises

Student comments on course evaluations indicated that labs were an important component in learning neuroscience material. This was the case even when many of our laboratory exercises did not support the students' hypotheses. Given the small sample size of the class and the variables that could not be controlled, it is not surprising that student-designed experiments often have ambiguous results. For example, in one laboratory, students hypothesized that accuracy rate and response time on an attention test (Homack and Riccio, 2006) would be better in students who had meditated with music compared to those who meditated without music. I brought up some issues to consider as they debated and voted on the protocol, such as how they would choose a music type and whether there was a need for a non-meditation control. They made their choices and were very enthusiastic about this particular experimental design. Given the sample size of $n = 7$ and 8, it is not surprising that the groups showed no statistical difference. In discussing our results, they realized that confounding variables such as sleep, caffeine, noise in the room, attention deficit diagnoses, and prescription medication probably greatly increased the variability of the data. This experience of inquiry-based science can provide more depth of learning than pre-planned expository labs with more certain results (Domin, 1999; Karelina and Etkina, 2007).

Designing small-scale experiments that we could attempt in the laboratory was well-paired with the reading of scientific articles that had larger sample sizes, better control of confounding variables, and more sophisticated equipment. Students were even able to use their experience in the laboratory to critique the designs of published studies. I included one article that showed a lack of effect of meditation (Pagliaro et al., 2016), which helped support the understanding that scientists truly do not know what the results of an experiment will be, and often the data does not support a hypothesis.

Our final two readings (Bohm, 1980; Grace, 2015) essentially challenged the entire premise of the course: can an experience like meditation even be studied in a reductionist, scientific way, or does the attempt to quantify meditation spoil the effect? My goal in introducing these ideas was to respect the interdisciplinarity of the course and acknowledge different ways of knowing, as well as explore the underlying philosophy of science and its limits (Burbules and Linn, 1991).

Contemplative pedagogy

Over multiple decades, educators have realized the value of incorporating peer discussions, technology, and active learning in the classroom, and meditation is another method that can enrich student learning (Grace, 2011b). "Contemplative pedagogy" is being implemented in a wide variety of fields, including Art, English, Economics, and Geology (Center for Contemplative Mind in Society, 2015). Within the field of neuroscience, Levit Binnun and Tarrasch integrated meditation into an undergraduate psychology course called "Brain, Cognition, and Emotion" as an optional bonus track, and it was associated with enhanced memory of course material (Levit Binnun and Tarrasch, 2014). Others have integrated neuroscience and yoga practice in a two-credit health class (Wolfe and Moran, 2017). To my knowledge, a laboratory course such as the one reported here that combines the scientific study of meditation with its practice has not been described in the literature. With evidence of its effectiveness in improving attitudes toward science, a contemplative approach to teaching neuroscience is encouraged as creative and meaningful pedagogy, and the data presented here can be used to demonstrate the value of this methodology to colleagues and administrators.

REFERENCES

Baer RA, Smith GT, Lykins E, Button D, Krietemeyer J, Sauer S, Walsh E, Duggan D, Williams JM (2008) Construct validity of the five facet mindfulness questionnaire in meditating and nonmeditating samples. Assessment 15:329-342.

Bañuelos MS, Musleh A, Olson LE (2017) Measuring salivary alpha-amylase in the undergraduate neuroscience laboratory. J Undergrad Neurosci Educ 16:A23-27.

Bohm D (1980) Fragmentation and Wholeness. In: Wholeness and the Implicate Order. London, England: Routledge.

Burbules NC, Linn MC (1991) Science education and philosophy of science: congruence or contradiction? Int J Sci Educ 13:227-241.

Center for Contemplative Mind in Society (2015) Available at http://www.contemplativemind.org/resources/higher-education/syllabi.

Davidson RJ, Kabat-Zinn J, Schumacher J, Rosenkranz M, Muller D, Santorelli SF, Urbanowski F, Harrington A, Bonus K, Sheridan JF (2003) Alterations in brain and immune function produced by mindfulness meditation. Psychosom Med 65:564-570.

Domin DS (1999) A review of laboratory instruction styles. J Chem Educ 76:543-547.

Ferrarelli F, Smith R, Dentico D, Riedner BA, Zennig C, Benca RM, Lutz A, Davidson RJ, Tononi G (2013) Experienced mindfulness meditators exhibit higher parietal-occipital EEG gamma activity during NREM sleep. PLoS One 8:e73417.

Grace F (2009) Breathing In: Suffering Breathing Out: Compassion. Spirit High Educ 5(2):1-10.

Grace F (2011a) Meditation in the Classroom: What Do the

Students Say They Learn? In: Meditation and the Classroom: Contemplative Pedagogy for Religious Studies (Simmer-Brown J, Grace F, eds), pp 237-250. Albany, NY: SUNY Press.

Grace F (2011b) Learning as a path, not a goal: Contemplative pedagogy–its principles and practices. Teach Theol Relig 14:99-124.

Grace F (2015) Measuring the Immeasurable? Compassion Under a Microscope. Huffington Post. Available at https://www.huffingtonpost.com/dr-fran-grace/measuring-the-immeasurabl_b_6407794.html.

Grecucci A, De Pisapia N, Thero DK, Paladino MP, Venuti P, Job R (2015) Baseline and strategic effects behind mindful emotion regulation: Behavioral and physiological investigation. PLoS One 10:e0116541.

Gregoski MJ, Barnes VA, Tingen MS, Harshfield GA, Treiber FA (2011) Breathing awareness meditation and LifeSkills Training programs influence upon ambulatory blood pressure and sodium excretion among African American adolescents. J Adolesc Health 48:59-64.

Hanson R, Mendius R (2009) Buddha's Brain: The Practical Neuroscience of Happiness, Love, and Wisdom. Oakland, CA: New Harbinger Publications.

Hillman SJ, Zeeman SI, Tilburg CE, List HE (2016) My Attitudes Toward Science (MATS): The development of a multidimensional instrument measuring students' science attitudes. Learning Environ Res 19:203-219.

Homack S, Riccio CA (2006) Conners' Continuous Performance Test (2nd ed.; CCPT-II). J Atten Disord 9:556-558.

Ilgan A (2013) Predicting college student achievement in science courses. J Baltic Sci Educ 12:322-336.

Karelina A, Etkina E (2007) Acting like a physicist: Student approach study to experimental design. Phys Rev Spec Top-Phys Educ Res 3:020106.

Knight JK, Smith MK (2010) Different but equal? How nonmajors and majors approach and learn genetics. CBE—Life Sci Educ 9:34-44.

Ko CM, Grace F, Chavez GN, Grimleya SJ, Dalrymple ER, Olson LE (2018) Effect of Seminar on Compassion on student self-compassion, mindfulness and well-being: A randomized controlled trial. J Am Coll Health, in press.

Kuncl RW (2018). Welcome to the University of Redlands: A message from University of Redlands President Dr. Ralph W. Kuncl. Redlands, CA: University of Redlands. Available at http://www.redlands.edu/meet-redlands/office-of-the-president/.

Levit Binnun N, Tarrasch R (2014) Relation between contemplative exercises and an enriched psychology students' experience in a neuroscience course. Front Psychol 5:1-16

Meacham J, Gaff JG (2006) Learning goals in mission statements: Implications for educational leadership. Liberal Educ 92:6-13.

National Leadership Council for Liberal Education and America's Promise (2007) College learning for the new global century. Washington, D.C.: American Association of Colleges and Universities.

Newberg A, Alavi A, Baime M, Pourdehnad M, Santanna J, d'Aquili E (2001) The measurement of regional cerebral blood flow during the complex cognitive task of meditation: a preliminary SPECT study. Psychiatry Res 106:113-122.

Pagliaro G, Pandolfi P, Collina N, Frezza G, Brandes A, Galli M, Avventuroso FM, De Lisio S, Musti MA, Franceschi E (2016) A randomized controlled trial of tong len meditation practice in cancer patients: Evaluation of a distant psychological healing effect. Explore: J Sci Healing 12:42-49.

Simons JS, Gaher RM (2005) The Distress Tolerance Scale: Development and validation of a self-report measure. Motiv Emotion 29:83-102.

Spielberger C, Gorsuch R, Lushene R (1970) Manual for the state-trait anxiety inventory. Palo Alto, CA: Consulting Psychologists Press.

Tang YY, Ma Y, Wang J, Fan Y, Feng S, Lu Q, Yu Q, Sui D, Rothbart MK, Fan M, Posner MI (2007) Short-term meditation training improves attention and self-regulation. Proc Natl Acad Sci U S A 104:17152-17156.

Taylor BJ, Morphew CC (2010) An analysis of baccalaureate college mission statements. Res High Educ 51:483-503.

Tao J, Liu J, Liu W, Huang J, Xue X, Chen X, Wu J, Zheng G, Chen B, Li M (2017) Tai Chi Chuan and baduanjin increase grey matter volume in older adults: a brain imaging study. J Alzheimers Dis 60:389-400.

University of Redlands (2018). Mission statement. Redlands, CA: University of Redlands. Available at http://www.redlands.edu/meet-redlands/mission-statement/.

Versnik Nowak AL, Hale HM (2012) Prevalence of complementary and alternative medicine use among US college students: A systematic review. Am J Health Ed 43:116-126.

Versnik Nowak AL, DeGise J, Daugherty A, O'Keefe R, Seward S, Jr., Setty S, Tang F (2015) Prevalence and predictors of complementary and alternative medicine (CAM) use among Ivy League college students: Implications for student health services. J Am Coll Health 63:362-372.

Watson D, Clark LA, Tellegen A (1988) Development and validation of brief measures of positive and negative affect: the PANAS scales. J Pers Soc Psychol 54:1063-1070.

Wiertelak EP, Ramirez JJ (2008) Undergraduate neuroscience education: blueprints for the 21st century. J Undergrad Neurosci Educ 6:A34-39.

Wiertelak EP, Hardwick J, Kerchner M, Parfitt K, Ramirez JJ (2018) The new blueprints: Undergraduate neuroscience education in the twenty-first century. J Undergrad Neurosci Educ 16(3):A244-251.

Williams A-l, Dixon J, McCorkle R, Van Ness PH (2011) Determinants of meditation practice inventory: development, content validation, and initial psychometric testing. Altern Ther Health Med 17:16-23.

Wolfe U, Moran A (2017) Integrating brain science into health studies: An interdisciplinary course in contemplative neuroscience and yoga. J Undergrad Neurosci Educ 16:A77-82.

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