from the laboratory, all plants were remo ed the day prior to en ironmental testing All tests were performed during the same time of the day, and formaldehyde testing badges were worn by the same dissector indi idual to keep the relati e position of the testing strip the same for all tests (Figure A) Laboratory temperature was consistently measured to be degrees F and downdraft entilation (estimated to be air changes per-hour) was engaged for all experimental conditions All testing strips were immediately sealed and shipped to Assay Technologies for analysis (Figure B) For the -hour Time eighted A erage (T A) formaldehyde test, a single measurement was taken for the with plant condition and was ualitati ely compared to a separate -hour T A formaldehyde test with no plant exposure Temperatures, entilation, and approximate distance of the testing badge are belie ed to be consistent between measured conditions Note the Aldehyde monitor is closed for the picture All testing were performed at the same time of day and laboratory temperatures were consistently set to degrees F Dissection downdraft entilation was consistent for all conditions and was set to air changes per-hour Aldehyde monitors were sealed and shipped to Assay Technology immediately after data were collected (B)

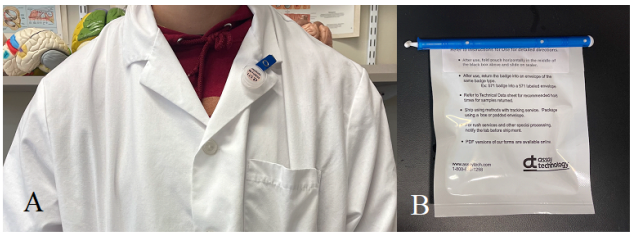

Figure 3: The Aldehyde monitor badge was clipped to the lab coat collar of the same individual for each test (A), to keep consistent position of the badge from the Cadaver.

Data Analysis

Three dependent samples t-tests were performed between plant exposure and non-plant exposure for student Acute STAI scores, General STAI scores, and student laboratory exam scores. Data were averaged by testing week where testing section was assigned to the experimental condition and where students were given the control condition; this helped to account for the difficulty of examinations and by course content. A dependent samples t-test was performed for laboratory formaldehyde levels comparing plant exposure and non-plant exposure for the 15-minute STEL test. For the 8-hour PEL formaldehyde test, not enough data were obtained for quantitative analysis; however, a qualitative comparison of the means is reported. Post-hoc analysis was completed to determine effect size and power adjustments needed for further research.

RESULTS

Student Questionnaires and Laboratory Exam Performance

The results of the dependent samples t-test for the Acute STAI score revealed that individuals who were exposed to plants did not (p=0.35) demonstrate significantly reduced stress or anxiety

	Mean (SD)	Mean (SD)		
Acute STAI	41.8 (8.5)	43.2 (8.9)	0.35	0.16
General STAI	39.9 (7.5)	39.6 (8.1)	0.71	0.04
Test Score	76.3% (8.5)	73.5% (11.0)	0.27	0.28

Table 1: Results of Dependent Samples T-tests for student questionnaires and laboratory testing scores.

Air-Quality Tests

Results of our dependent samples t-test for the -minute STEL re ealed significant differences between plant and no-plant laboratory en ironment conditions, where without plants the anatomy laboratory a eraged ppm ( ) and the with plants a eraged ppm ( ) and had an effect si e (Cohen s D) of Both measurements were below the ppm OSHA limit (Figure)

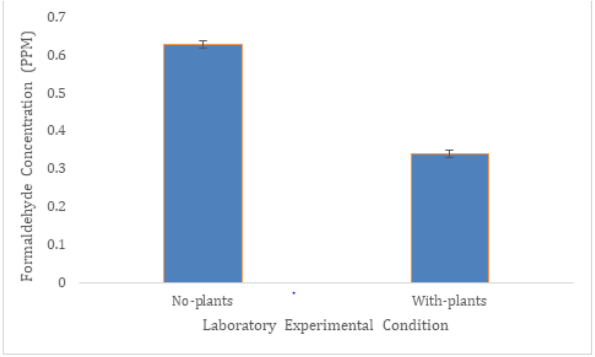

Figure : Formaldehyde concentrations (ppm) for the human anatomy laboratory with and without plant e posure.

DISCUSSION

To our knowledge, our study is the first to examine the effect of plant exposure on student testing performance, anxiety, and stress in a laboratory setting. Further, we are the first to report preliminary findings on the influence of plant formaldehyde removal in an anatomy laboratory setting. Our data indicate that with the introduction of plants to the human anatomy laboratory, formaldehyde STEL was significantly reduced by approximately 50% (Figure 4). OSHA defines the 15-minute STEL limit of formaldehyde concentration to be 2 ppm. Our data for both with plant (0.34 ppm) and without plant (0.63 ppm) settings were both well below this 15-minute STEL limit. Reducing student exposure to potentially toxic chemicals is one of the chief objectives of laboratory safety. Adding well ventilated cadaver tables has been identified in the literature as one of the most important factors in reducing toxic gas exposure

in the cadaver laboratory [10]. Our data suggests adding a high volume of plants to the periphery of the laboratory space, in addition to well ventilated cadaver tables, can further reduce the exposure to these dangerous compounds. Our study fails to identify meaningful statistical insights for the 8-hour Time Weighted Average (TWA) exposure to formaldehyde gas. OSHA defines the TWA limit for formaldehyde to be 0.75 ppm. Our single sample for the with-plant condition indicates an 8-hour TWA of 0.021 ppm and 0.048 ppm for the without-plant condition. These qualitative results may indicate a similar trend to the 15-minute STEL tests where the plant condition exposure was nearly half that of the non-plant condition. Further, our results encourage the use of plants to further reduce long-term exposure to formaldehyde when other safe practices, such as down-drafted ventilation, frequent wetting application to the cadavers and cool room temperature control are already in place.

Student academic success is negatively associated with anxiety level, where high test-anxiety students tend to do poorer and have a higher dropout rate than low anxious people [15]. The State-Trait Anxiety Inventory (STAI) self-report questionnaire has produced high degree of reliability and validity with an alpha coefficient of 0.92 [20]. In controlled environments, the exposure of anxious peoples to plants shows strong positive impacts on performance and STAI anxiety levels [21]. However, little is known about the influence of plants on student academic success or stress in high stress and less controlled environments such as the human anatomy laboratory. In the current study, we measured STAIs immediately after weekly laboratory examinations of our undergraduate human anatomy class over the course of six weeks. Half of the examination times, students were randomly assigned into one of two conditions, with and without plants, which were placed in view or removed from view (depending on assignment) during their weekly examinations. Results from our study indicate a high degree of variability in student STAI responses for both the acute and general tests. Due to this high degree of variability and our small sample size (25 students), we failed to see statistical differences between the experimental (plant) and control (without plant) environments. However, our data indicate a positive trend, where students may experience small reductions in stress when exposed to plants with a small effect size (Cohen's D) of 0.16. It is possible that with the inclusion of many more students, statistical differences can be established. Our post-hoc analysis of power indicates that differences could be determined with the inclusion of 500 students. Universities with larger class sizes could make use of this estimate of power to confirm the small influence of plants on student test anxiety using the Acute and General STAI.

LIMITATIONS

We have identified several limitations to our study design and analysis which may influence the interpretation of our results. While we did measure statistic differences to the 15-minute STEL our limitations to funding prevented us from generate enough samples for the 8-hour TWA tests. Our results for the 8-hour TWA test are qualitative only and should not be considered statistically significant. We aimed to control other factors associated with air quality, such as ventilation rate, laboratory temperature and distance of the chemical assay strip from the source (cadaver). For student test performance and STAI tests a high degree of variability in student performance and in student responses contributed to the small effect size of the experimental condition. Further, it is possible that our plants, which were placed in the periphery of the room, were not as visible during laboratory testing as opposed to the controlled conditions described in the literature. Our plants were each relatively small in size as they were recently purchased from a local nursery. It is possible that with larger plants students may be more likely to be influenced by their presence during laboratory testing. Future studies could incorporate larger plants and plant placement (with respect to testing materials) to investigate their influence on student performance and anxiety.

CONCLUSION

Based on the results of this study, we recommend the use of plants in conjunction with the Human Anatomy cadaver program. Cadaver laboratory programs should aim to reduce the exposure of students to formaldehyde wherever possible. While our results demonstrate that plants are associated with a small reduction in the total concentration of formaldehyde (by an average difference of 0.027 ppm) we believe, every opportunity should be taken to mitigate these risks.

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