EQuALS – Environmental quality in active learning spaces

Tom Collins[1]

[1]Ball State University, Muncie, IN

ABSTRACT: The past 25 years has seen the emergence of active learning classrooms on higher education campuses. The goals of these spaces are to: improve student learning outcomes; change the way instructors engage with students; and offer increased flexibility and access to technology. In short, active learning classrooms aim to provide new, innovative, and state-of-the-art learning environments. Research on active learning classrooms tends to focus on the virtual learning environment independent from the physical classroom conditions. However, there is limited evidence that physical environmental factors in classrooms can influence (help and/or hinder) student performance outcomes, perceptions, and behavior. The study addresses a gap in the literature by examining indoor environmental quality (IEQ) parameters (e.g. air quality, comfort, lighting, and acoustics) in five refurbished active learning classrooms.

This mixed methods study relies on two frameworks for field studies of existing indoor environments: post-occupancy evaluation and the ASHRAE Performance Measurement Protocol (PMP). Data collection involved: interviews with stakeholders and observations in the classrooms; occupant surveys to gauge satisfaction levels with the physical environment; and spot measurements in the classrooms as a way of comparing existing conditions to industry metrics and benchmarks.

Findings suggest that the classrooms meet or exceed industry benchmarks for IEQ. Several surprising outcomes also emerged from the study. Classroom users do not appear to take advantage of opportunities to adjust IEQ conditions in the classrooms. Furthermore, retrofitted classrooms present spatial and environmental constraints for active learning environments. The five active learning classrooms examined provide satisfactory IEQ conditions, but these spaces may not be achieving their full potential. Additional research is needed to optimize these spaces and inform future classroom design and classroom research.

KEYWORDS: active learning, indoor environmental quality

INTRODUCTION

Over the past 25 years, active learning classrooms have emerged on campuses as a way of rethinking and challenging dominant pedagogical paradigms in higher education. Active learning classrooms encourage students to engage with peers and faculty, to collaborate, to move around, to use multi-media in the learning process, etc. This differs dramatically from the traditional college classroom predicated on passively listening to lecture presentations. In some ways, these classrooms look quite different from traditional classrooms primarily because of their flexible/movable furnishings and the prevalence of technology including projectors, LCD screens, etc. However, in other ways these classrooms have many of the same architectural features, layouts, and controls as typical college classrooms.

Research in active learning classrooms tends to focus on the virtual learning environment rather than on physical classroom environment. Indeed, the extent to which physical environmental factors impact occupant use of the spaces or student learning outcomes is not well understood. One barrier to a better understanding of these relationships is a lack of empirical data related to how active learning classrooms perform in terms of indoor environmental quality (IEQ) parameters (comfort, lighting, acoustics, and air quality) and how these parameters compare with industry benchmarks. This study sought to establish baseline IEQ performance in five active learning classrooms at Ball State University as a first step toward informing classroom operations, design, and future inquiry.

1.0 BACKGROUND

1.1. Active Learning Classrooms

Active learning classrooms emerged in the early 1990s when NC State University implemented their SCALE-UP program to reconfigure classrooms to change large lecture class instruction. Since then, other institutions have followed-suit including: MIT's TEAL Project, University of Minnesota's ALCs, University of Iowa's TILE initiative, and Stanford's Wallenberg Hall (Sun and Chiang 2015). Recently, Ball State University reconfigured five existing classrooms as part of their ILS Initiative (Straumsheim 2014).

Research in active learning classrooms has primarily focused on the virtual learning environment conditions (e.g. student motivation/space attractiveness (Strange and Banning, 2001) and space suitability for activities (Whiteside, Brooks, and Walker 2010). However, the prevailing attitude that learning takes place independently of physical space (Temple 2008) appears to be changing (Oblinger, 2006; Chang, 2010; Woolner and Hall, 2010). Nevertheless, Sun and Chiang (2015) still note "a paucity of systematic research examining the effects of these environments on teaching practices and student learning."

Research examining the physical environmental and spatial conditions in classrooms is limited and predominantly occurs in K-12 schools (Leung and Fung, 2005; Woolner and Hall, 2010). However, there is emerging evidence that specific physical environmental parameters in classrooms can influence learning outcomes (Jensen, 2005; Higgens et al., 2005). The literature suggests a need for research that provides a better understanding of physical environmental conditions in higher education classrooms.

1.2. Ball State University's active learning classrooms

Ball State University currently has five active learning classrooms. These spaces were retrofitted existing classrooms deployed in two stages and are referred to internally as "Interactive Learning Spaces" (ILS). The design of these spaces were a collaboration between the university's facilities group, the Office of Educational Excellence (OEE), and Steelcase Corporation (a primary furnishings vendor for the campus). OEE manages these spaces and oversees an ILS cohort or learning community of faculty from many colleges and departments who apply to teach in the classrooms each academic year.

Figure 1: Before (left) and after (right) images of BB109.

The five ILS classrooms are located in three preexisting campus buildings: Teacher's College (TC), Burkhardt Building (BB), and Robert Bell (RB). These buildings are typical academic classroom buildings with spaces located off of double-loaded corridors and unilateral side lighting (one window wall). All of the retrofitted ILS classrooms have carpeted floors, gypsum board walls, and acoustical tile ceilings. The classrooms differ in size, arrangement, layout, and other architectural features. TC 411 is the smallest and the most eclectic/colorful in terms of furnishings including lounge-type chairs and movable tables and chairs. TC 412 has 24 node chairs (movable chairs with tablets), a raised floor, and has a breakout space attached to the main classroom. TC 414 is a "Mediascape" classroom with 4 fixed multimedia tables and movable chairs and the finishes are very similar to TC 412. RB 109 is a larger occupancy room with a long, narrow layout with node chairs/work tables. This classroom was previously two separate spaces. BB 109 is the largest ILS classroom and is long, narrow with high ceilings and large windows. This classroom went through, perhaps, the most dramatic alteration having previously been a lecture-style set-up with tiered seating and no daylighting. In the retrofitted space, the tiered seating was removed and the large windows uncovered. The room now has an open ceiling with acoustical clouds and soffit. See Figure 1 and Table 1.

Table 1: Ball State University's ILS active learning classrooms.

	TC411	TC412	TC414	RB109	BB109
Occupancy	18	24	24	36	76
Floor Area	451 SF	1,069 SF	883 SF	1,042 SF	1,368 SF
Glazing Area	52 SF	87 SF	87 SF	82 SF	176 SF
Ceiling Height	8'-9"	8'-4"	8'-5"	8'11"	10'-8"
Glazing to Floor Area	11.5%	8.1%	9.9%	7.9%	12.9%
Completed	2015	2012	2012	2015	2015

2.0 RESEARCH QUESTIONS

This research asked three primary questions of the Ball State University ILS active learning classrooms:

(1) Do the measured IEQ parameters meet established industry standards for IEQ performance?

(2) Do the measured IEQ parameters satisfy the criteria used as the basis of design for the spaces?

(3) Are the occupants satisfied with the existing IEQ conditions?

3.0 RESEARCH METHODS

The proposed mixed methods study can be characterized as a post-occupancy evaluation (POE) in which an existing building is systematically examined after occupancy (Preiser et al. 1988). However, this study is at the scale of specific spaces within a building rather than at the scale of the whole building. POE procedures emphasize collecting a variety of data (e.g. observations, surveys, etc.) to assess performance outcomes holistically (Preiser 2001). The ASHRAE Performance Measurement Protocol (PMP) (ASHRAE 2012) provides additional guidance on procedures for measuring physical environmental parameters (Hunn et al. 2012; Hunn and Bochat 2015). Basic-level evaluation procedures were used to: observe the space characteristics and occupant behavior; survey occupants on their satisfaction; and to take spot measurements of IEQ parameters (Ibid; Kim 2012). The procedure was duplicated in each classroom.

3.1. IEQ Survey Methods

This study used a standardized IEQ survey developed and administered by the UC Berkeley Center for the Built Environment (CBE). The ASHRAE PMP suggests the CBE IEQ survey instrument because the data can be compared with IEQ benchmarks in their extensive database of buildings. The survey questions were edited for their applicability to this study (e.g. whole-building related questions were removed since the study focused on specific classrooms) and the questions focused on IEQ and user satisfaction. A question was added for respondents to choose their classroom so that the data could be analyzed separately for each space. A new consent page was added for respondents and the survey received IRB approval. Faculty in each of the classes using the five ILS classrooms shared the link to the online survey with students.

3.2. Physical Measurement Methods

Physical spot measurements were taken in each of the five classrooms related to the four IEQ parameters: thermal comfort, indoor air quality, lighting/daylighting, and acoustics.

Thermal Comfort: Dry-bulb (air) temperature and relative humidity (RH) measurements were taken in each classroom. For the purposes of this study, MRT is considered to be the same as the dry-bulb temperature, and the air movement is 20 FPM. Metabolic activity in the classrooms is low at 1.1 MET and the clothing insulation for occupants is set at 1 CLO for winter dress. Temperature and relative humidity were measured using an Onset HOBO U12 logger with an accuracy of 0.63°F between 32°F and 122°F and +/- 5% RH typical. Measurements were logged over a 7-day period in each ILS classroom at 30" above the floor and mounted to the teaching wall. Measurements were taken in degrees Fahrenheit and % RH at 10-minute intervals. The data were plotted on the ASHRAE comfort zone using the online CBE Comfort Tool, which verifies compliance with ASHRAE Standard-55 (thermal comfort standard).

Indoor Air Quality: The ASHRAE PMP provided limited guidance on the IAQ assessment as the study was at the scale of the individual classroom and did not include mechanical spaces or systems. Air quality in indoor spaces can be difficult to measure due to the complex mixture of gases and particles in the air. Carbon dioxide (CO_2) concentrations are relatively easy to measure and can be used as a means of evaluating indoor air quality (IAQ) and ventilation rates in spaces because occupants breath and release CO_2 into the air. When this CO_2 accumulates in a space, it is an indication of insufficient air change from the building ventilation system. CO_2 was measured using an Onset HOBO MX-1102 logger with an accuracy of +/- 5-PPM at 77°F. Measurements were logged over a 7-day period in each ILS classroom at 30” above the floor and mounted to the wall. Measurements were taken in parts per million (PPM) at 10-minute intervals.

Lighting: Illuminance (or light level) on a horizontal work plane is the most common type of lighting measurement. Illuminance was measured using a handheld Konica Minolta T-10A illuminance meter with a relative spectral responsivity of within 6% and a cosine of within 3%. Measurements were taken on a 2 foot by 2 foot grid at 30” above the floor at three different lighting levels: Full electric lighting plus daylight from windows, dimmed electric lighting plus daylight from windows, and daylight from windows only. All lighting measurements were taken in diffuse overcast sky conditions common for about half the days each year.

Acoustics: Ambient background noise was measured using a Cirrus CR162A Class 2 integrating sound level meter with an omnidirectional condenser microphone and a tolerance of +/-1.4 dB at middle range. Measurements were taken in 5 locations in each space at 30” above the floor. Measurements were equivalent continuous sound level (Leq) over a 30 second measurement period that resulted in one A-weighted dB measurement per ASHRAE PMP. A-weighted dB measurements exclude frequencies above and below the human hearing range.

3.3. Physical Observations & Interview Methods

Physical observations of a sample of the occupied ILS spaces occurred during class time. Observations focused on how students and faculty used technology within the spaces, moved around the classroom during the class period, and other physical conditions present in the learning environment. These observations were documented using annotated floor plans and written notes.

Interviews were conducted with individuals associated with the planning, design, and operations of the ILS classrooms. They included a classroom design consultant, an architect, and a day-to-day manager of the spaces. Interviews were conducted in person, were audio recorded for analysis, and lasted approximately 30-45 minutes. Interviews were transcribed and analyzed using qualitative data analysis procedures to reveal recurring ideas and themes in the narratives.

4.0 RESULTS

4.1. IEQ Survey Results

The survey ran for 2 weeks in November 2016. 171 participants completed the survey. The sample was 65.5% female, 33.3% male, and 1.2% transgender. The average time to complete the survey was 5.5 minutes. 94% of the sample was 30 years old or younger. Most respondents spent less then 10 hours per week in their classroom and only for the previous several months.

Compared with the CBE benchmark, the ILS classrooms received high scores from occupants related to general satisfaction and indoor environmental quality parameters. Respondents rank thermal comfort and acoustics quite high on a scale of 1-7 (1 is very dissatisfied and 7 is very satisfied) compared to benchmark buildings at an average of 5.7 out of 7 and 5.8 out of 7 respectively. Lighting and general satisfaction are still higher than benchmarks, but receive the lowest scores among the IEQ parameters. In terms of general satisfaction, occupants seem less satisfied in TC 411 and most satisfied in TC 412 and TC 414. Thermal comfort scores seem consistent across the classrooms except for in TC 411, where it is slightly higher than the benchmark. Air quality scores are consistent for the TC classrooms, which use the same HVAC system on the same floor of the building. BB109 also scores high. RB109 scores lower on this parameter. Occupants appear quite satisfied with the lighting in all classrooms with TC 411 scoring slightly lower than the others. Occupants appear satisfied with the acoustics in the spaces with TC 411 scoring slightly lower than the others. Overall, occupants rank TC 412 highest for IEQ and TC 411 lowest. The other three classrooms score very similarly somewhere in between. See Table 2 below.

Several open-ended questions generated useful feedback about the ILS classrooms. Occupants complain about glare from the windows. Evidence of this issue can be seen in the classrooms where window blinds are often closed during the day. However, four of the five classrooms face east or west, problematic orientations for glare. In addition, the lack of a defined teaching wall and the mobile nature of the furniture makes glare mitigation challenging. Occupants like having white boards for working during class, but they wish there was more storage space. Also, the technology in the classrooms can be challenging to operate. Perhaps most interestingly, when asked which features of the classroom occupants adjust, 35% said the window shades/blinds, 30% said the door, and 49% said none. Very few respondents said they adjust the thermostat. 5% of occupants said that they make other adjustments to technology and furnishings. The ILS classrooms offer greater opportunities for user adjustment, but the occupants do not appear to take full advantage of these spatial affordances to improve their conditions for learning or comfort.

Table 2: Survey Results and benchmark comparisons.

	Benchmark Mean	Ball State Mean	TC411	TC412	TC414	RB109	BB 109
General Satisfaction	5.08	6.13	5.33	6.36	6.33	6.00	6.10
Thermal Comfort	4.09	5.70	4.33	5.85	5.80	5.70	5.71
Air Quality	4.60	5.84	5.67	6.04	5.93	5.43	6.00
Lighting	5.23	6.17	5.67	6.20	6.07	6.25	6.16
Acoustic Quality	4.04	5.80	5.33	6.00	5.80	5.70	5.85

*Scores on a scale of 1-7: 1 = very dissatisfied, 4 = neutral, and 7 = very satisfied

4.2. Physical Measurement Results

Thermal Comfort:

In BB 109, the average dry-bulb temperature and relative humidity fall slightly below the ASHRAE Standard 55 comfort zone. However, the average temperature and relative humidity during class times fall within the comfort zone. Conditions tend to fall to the cool side of the comfort zone during unoccupied times and are never too hot. In RB 109, the average dry-bulb temperature and relative humidity fall within ASHRAE comfort zone. The average temperature and relative humidity during class times also fall within the comfort zone. Conditions tend to fall to the cool side of the comfort zone for about 9% of the measurements and to the hot side of the zone only several times. In TC 411, the average dry-bulb temperature and relative humidity fall within ASHRAE comfort zone. The average temperature and relative humidity during class times also fall within the comfort zone. Conditions tend to fall to the cool side of the comfort zone for about 30% of the measurements and never to the hot side of the comfort zone. These measurements align with the lower survey scores for thermal comfort in this space. In TC 412, the average dry-bulb temperature and relative humidity fall within ASHRAE comfort zone. The average temperature and relative humidity during class times also fall within the comfort zone. Conditions do not fall outside the comfort zone for this space. These measurements align with the high survey scores for thermal comfort in this space. In TC 414, the average dry-bulb temperature and relative humidity fall within ASHRAE comfort zone. The average temperature and relative humidity during class times also fall within the comfort zone. Conditions do not fall outside the comfort zone for this space. However, the relative humidity measurements are somewhat higher than usual for a classroom space. These measurements align with the overall high survey scores for thermal comfort in this space. See Table.

Table 3: Thermal comfort measurements.

	TC411	TC412	TC414	RB109	BB109
Ave Temp (°F)	69.4	70.2	72.3	71.2	68.4
Ave RH (%)	51.3	45.3	61.2	33.0	31.2
Ave Temp (During Class Time) (°F)	70.3	70.4	72.9	71.6	70.4
Complies with ASHRAE-55	Yes	Yes	Yes	Yes	Yes

Indoor Air Quality:

ASHRAE Standard-62.1 recommends that maintaining a differential at or below 700 PPM of CO_2 above outdoor ambient conditions (e.g. 400 PPM) results in at least 15 CFM of ventilation air per person, which is the benchmark ventilation rate for classrooms. This study sets a benchmark of 1,100 PPM of CO_2 or below for compliance with the standard.

The average CO_2 concentration in the ILS classrooms ranged from 557.1-724.0 PPM and from 638.0-1038.2 during class times (8am to 8pm Monday through Friday). The averages during occupied times did not exceed the ASHRAE 62.1 recommendation of 1,100 PPM. However, 3 of the 5 classrooms had measurements that exceeded this threshold for 2.9-16.3% of the measurements. BB109 had the highest concentrations. The data suggests that overall the ILS classrooms are providing adequate fresh air to occupants and, in some cases, are likely over ventilated compared with the benchmarks. However, at peak occupancy times, concentrations in some rooms exceed the recommendations. Varying occupant numbers in the classrooms may explain some of this difference. These findings align with the high scores on air quality from occupants compared with CBE benchmark data in other buildings. Interestingly, TC 412 and TC 414 received he highest scores from occupants, which align with the CO_2 measurements. However, BB109 received favorable occupant scores while CO_2 measurements indicate potentially under ventilated conditions. The qualitative analysis suggests that air quality, while a consideration in terms of optimizing student engagement, was not a parameter that the design team could easily alter given that the classrooms were retrofitted spaces with existing HVAC systems and no operable windows. See Table 4 below.

Table 4: Indoor air quality measurements.

	TC411	TC412	TC414	RB109	BB109
Average CO_2 (PPM)	611.5	583.1	557.1	724.0	714.0
Ave Class Time CO_2 (PPM)	762.9	682.9	638.0	718.4	1038.2
CFM/Person	>15	>15	>15	>15	>15
Maximum CO_2 (PPM)	1506.0	1080.0	965.0	2397.0	2303.0
% above threshold	2.9	0	0	8.4	16.3

Lighting:
The ASHRAE PMP references the Illuminating Engineering Society (IES) benchmarks for classroom lighting: 40 maintained foot-candles and a range of 30-50 foot-candles. Daylight factor is the ratio of indoor illuminance to outdoor illuminance expressed as a percentage. Recommendations vary, but the industry standard for classroom daylight factor would be no less than an average of 2% with 5% as well daylit.

The average illuminance in classrooms with full electric lighting and daylighting ranged from 42.8-72.4 fc. BB109 and TC 411, at the low end of these measurements, meet the IES criteria for classroom illuminance while the other 3 classrooms appear to be overlit in the full electric lighting condition. All five ILS classrooms have adjustable electric lighting (switching and/or dimming). In the half electric light plus daylight condition, the average illuminance ranged from 13.5-47.6 fc. In this scenario, RB 109, BB 109, and TC 411 were underlit compared with the benchmarks. In the daylight only condition, all five classrooms performed poorly in terms of sufficient illuminance levels. However, in terms of daylight factor, BB109, TC 412, and TC 411 all appear inadequate as daylit only spaces. TC 414 and RB 109 had average daylight factors above 5% under diffuse sky conditions suggesting that they are usable without the electric lighting. See Table 5.

Table 5: Lighting illuminance measurements and daylight factors.

	TC411	TC412	TC414	RB109	BB109
Full Light (average fc)	45.0	72.4	70.8	59.0	42.8
Half Light (average fc)	26.7	47.6	37.0	13.5	21.5
Daylight (average fc)	4.77	12.3	9.2	8.38	7.93
Daylight Factor (% DF)	2.71	2.06	5.50	5.06	1.92

Acoustics:
The ASHRAE PMP provided benchmarks for ambient background noise in classroom spaces as 35 dB-A for ideal conditions and 45 dB-A as a high condition. The average ambient background noise in the ILS classrooms ranged from 34.6 to 38.9 dB-A. No single measurement in any classroom reached the 45 dB-A "high" threshold. TC 411 was the only classroom with an average background noise below the 35 dB-A "ideal" benchmark with all others slightly above ideal. TC 411 and BB109 also had the smallest range of measurements throughout the rooms. The other 3 classrooms had larger ranges, particularly at measurement locations near an HVAC diffuser. Overall, acoustics in the 5 classrooms varied, but appear in-line with ambient noise benchmarks. This finding is, perhaps, unsurprising given the prevalence of acoustically absorptive materials like carpet and ceiling tile in the spaces. This finding also aligns with the high scores on acoustics from occupants compared with benchmark data in other buildings. And, finally, the qualitative analysis suggests that acoustics were a priority for the teams that designed the classroom retrofits. However, several spaces, such as RB109 and BB109 are long, narrow spaces where some students and faculty may be located a long distance from others, which may result in speech intelligibility issues when the dB drop across the room falls below ambient background noise. See Table 6.

4.3. Physical Observations & Interview Results
Three interviews were conducted with individuals associated with the design and/or operations of the Ball State ILS classrooms. These individuals included an architect with the campus facilities group, a classroom administrator from OEE, and a classroom design consultant from outside the university. Results indicate that

Table 6: Acoustical measurements.

	TC411	TC412	TC414	RB109	BB109
Average Sound Level (dB-A)	34.6	38.9	34.4	38.6	37.8
Range Sound Level (dB-A)	1.7	3.8	5.4	4.5	1.6
Benchmark Exceeded	No	No	No	No	No

students and faculty are using the classrooms in different ways than a typical college classroom would be used. Learning is more active, students/faculty move around, collaboration is occurring, and occupants appear satisfied and comfortable in these settings. However, there is limited interaction with controls or other opportunities to change or adapt physical conditions within the spaces. For example, few occupants adjust the window blinds; few turn lighting on, off, up, or down. This aligns with the occupant survey responses.

Analysis of the interview data revealed seven salient themes that emerged from interviews:

(1) The importance of getting students and faculty to feel that they have some ownership of the classroom, which impacts space use
(2) Active learning classrooms should be student-centered or focused on student learning
(3) It is important to empower faculty to make the learning experience more engaging for the students
(4) Satisfactory or even good indoor environmental quality (IEQ) is a basic prerequisite for active learning in classrooms—students need it to thrive
(5) Some IEQ parameters rise to the top in the design goals such as acoustics and lighting
(6) Improvements to ILS spaces are ongoing—it's a learning process
(7) Spatial constraints such as existing buildings, structure, etc. impact the realization of the design vision and goals—there are certain things that can't be done or done easily

The interview data suggests that stakeholders involved in the design and operations of the ILS classrooms recognized the importance of optimal IEQ conditions for active learning settings. However, it is also clear that IEQ was not a primary consideration during design nor is it a focus of ongoing enhancements to the spaces. The fact that the classrooms were retrofitted and not designed from the ground-up may explain why IEQ conditions were not emphasized during design. Renovating spaces using standard industry practices for college classrooms appears to provide better IEQ than un-renovated spaces elsewhere on campus.

CONCLUSION

Physical measurements in the five ILS classrooms meet or exceed most established industry standards for IEQ performance. Thermal comfort appears excellent for four of the five spaces, with TC 411 running slightly cool. Average conditions meet the ASHRAE-55 Standards. Indoor air quality as measured by CO_2 concentrations meet ASHRAE 62.1 recommendations for providing sufficient fresh air and ventilation to classrooms. If anything, the classrooms may be over ventilated for the number of occupants, which vary by class. Lighting levels are high for full electric and low for full daylight, but the adjustability of the electric lighting coupled with the glare control from shades/blinds suggests that optimal light levels on work surfaces are possible. Finally, acoustically none of the classrooms meets or exceeds the ASHRAE PMP "high" threshold for background noise and all fall at or slightly above the "ideal" benchmark. Overall, ILS classrooms are performing well with respect to measured IEQ parameters.

Interviews suggest that there were no specific, verifiable design criteria related to IEQ parameters for the ILS classroom retrofits, although good IEQ conditions were important to the design team as a way of supporting active learning. Physical measurements suggest that the classrooms meet or exceed industry standards for IEQ performance in most cases, which would seem to satisfy the initial design intent.

Survey data suggest that occupants are quite satisfied with the IEQ conditions in the classrooms, and respondents score IEQ parameters high compared with the benchmarks from the CBE database. In some cases, as noted above, survey scores and/or open-ended comments align with less optimal physical measurements in the spaces. It was somewhat surprising that TC 411 emerged as a problematic space in both the survey and measured data, but the sample for this space was smaller.

The objectives established for this project were achieved. A performance baseline for the five BSU ILS classrooms now exists. This baseline data can be verified or reconfirmed in the future or compared with other classrooms, and should be useful validation of spatial performance for the university. There were no major deviations from the plans outlined in the original proposal other than the fact that some data collection/analysis procedures outlined in the ASHRAE PMP were deemed unnecessary for a classroom scale evaluation or where no indication of problems were evident from the field observations.

ACKNOWLEDGEMENTS

I would like to acknowledge the assistance of the following people and groups at Ball State University: Gary Pavlechko and Kathy Jacobi, Office of Educational Excellence; the Interactive Learning Space Initiative; ILS faculty; the Department of Architecture; David Post, Facilities Planning and Management; and Megan York. Funding for this research was provided by the Ball State University ASPiRE Junior Grant Program.

REFERENCES

ASHRAE*. Performance Measurement Protocol for Commercial Buildings: Best Practices Guide*. ASHRAE (2012).

Chang, F. H., Y. Y. Li, C. Y. Tsai, and C. R. Yang. "Specific indoor environmental quality parameters in college computer classrooms." (2009): 517-524.

Hunn, Bruce D., and Jim Bochat. "Measurement of commercial building performance." *ASHRAE Journal* 57, no. 1 (2015): 66.

Hunn, Bruce D., Jeff S. Haberl, Hywel Davies, and Brendan Owens. "Measuring commercial building performance: protocols for energy, water, and indoor environmental quality." *ASHRAE Journal* 54, no. 7 (2012): 48-56.

Jensen, Eric. "Teaching with the brain in mind, Association for Supervision and Curriculum Development." *Virginia: Alexandria* (2005).

Kim, Hyojin. "Field-test of the new ASHRAE/CIBSE/USGBC performance measurement protocols for commercial buildings: basic Level." *ASHRAE Transactions* 118 (2012): 135.

Leung, Mei-yung, and Ivan Fung. "Enhancement of classroom facilities of primary schools and its impact on learning behaviors of students." *Facilities* 23, no. 13/14 (2005): 585-594.

Oblinger, D. "Learning spaces (Vol. 2)." *Washington, DC: Educause* (2006).

Preiser, Wolfgang FE. "The evolution of post-occupancy evaluation: Toward building performance and universal design evaluation." *Learning From Our Buildings A State-of-the Practice Summary of Post-Occupancy Evaluation* (2001).

Preiser, Wolfgang FE, Edward White, and Harvey Rabinowitz. *Post-Occupancy Evaluation*. Van Nostrund Reinhold, 1988.

Strange, C. Carney, and James H. Banning. *Educating by Design: Creating Campus Learning Environments That Work. The Jossey-Bass Higher and Adult Education Series*. Jossey-Bass.

Straumsheim, Carl. “Room to Experiment.” *Inside Higher Ed*. (2014).

Sun, Mingze, and Feng-Kuang Chiang. "Active Learning Spaces: New Directions for Teaching and Learning." *Educational Technology & Society* 18, no. 2 (2015): 394-397.

Temple, Paul. "Learning spaces in higher education: an under-researched topic." *London Review of Education* 6, no. 3 (2008): 229-241.

Whiteside, Aimee L. "Conclusion: Advancing Active Learning Spaces." *New Directions for Teaching and Learning* 2014, no. 137 (2014): 95-98.

Whiteside, Aimee, D. Christopher Brooks, and J. D. Walker. "Making the case for space: Three years of empirical research on learning environments." *Educause Quarterly* 33, no. 3 (2010): 11.

Woolner, Pamela, and Elaine Hall. "Noise in schools: a holistic approach to the issue." *International journal of environmental research and public health* 7, no. 8 (2010): 3255-3269.