STRUCTURAL IMPEDIMENTS TO LEARNING: INVESTIGATING LEARNING ENVIRONMENTS INSIDE THE BAHEN CENTRE

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Abstract *– This paper investigates the physical features that affect the learning process of students within the lecture halls in the Bahen centre. The impacts of any drawbacks or shortcomings due to structural design of the Bahen building on students' learning qualities are considered. Primary research including physical measurements and opinion surveys of students and professors comprise the basis of discussion. Results indicate that a number of lecture halls do not meet the University's classroom design standards. Tutorial rooms fare better by design-standards but a lack of electrical access ignores the growing dependency on computers in the classrooms. The authors discuss a set of identified issues – from obstructed viewing angles to damaged accessibility equipment, and list recommendations to address learning challenges. Implementing some of the recommendation will require trivial effort, while future educational structures for others may be considered.*

Keywords: Education, Environment, Learning

1. INTRODUCTION

The purpose of the Bahen Centre for Information Technology at the University of Toronto is to provide a learning and research space for the University of Toronto faculty and students [1]. However, architectural and design considerations may limit the extent to which an instructor can convey information to their students effectively.

The purpose of this investigation is to explore these limitations and encourage optimization of the University's learning spaces. This study will focus on the physical environment of the Bahen Centre as well as its lighting. Analysis of the physical environment will focus on provisions for accessibility, and viewing angles provided in the learning spaces throughout the building. Natural and artificial light levels in the lecture and tutorial rooms were compared to relevant standards, noting similarities and differences.

Previous studies have shown that academic performance improves with specific configurations of physical conditions in areas such as walking corridor widths, room colors, staircases, and shapes of tables and chairs [2]. The ergonomics of chairs and tables can particularly have enormous impacts [2].

Lighting (natural and artificial) and the presence of windows are associated with academic performance as well [3]. Studies have also pointed out that light has a significant effect on an individual's comfort and fatigue [4].

The goal of this study is to explore and draw awareness to the physical environment and lighting factors that may or may not pose limitations to a student's learning in the Bahen Centre or any other educational environment.

2. CONDUCT STUDY

An opinion survey was set up through Google Forms and emailed to professors, teaching assistants and students to quantify user experiences within the Bahen Center and their attitudes towards learning spaces. Figure 1 provides results for three pertinent questions among all the surveyed questions.

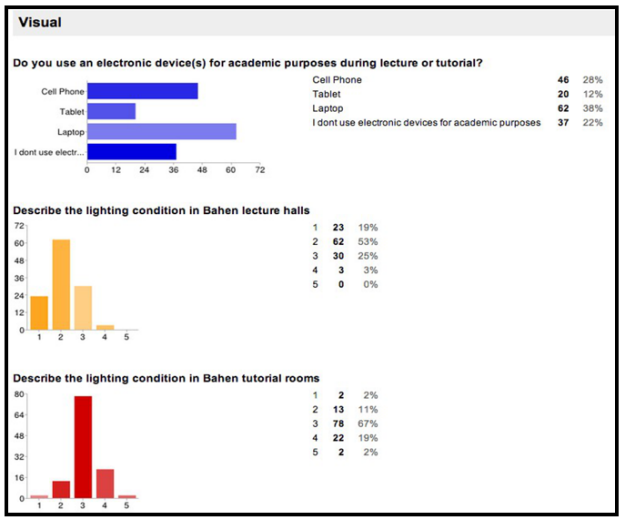

Fig. 1. Student survey responses.

As demonstrated in the results for questions two and three, the majority of students surveyed found that the rooms did not provide sufficient lighting (a rating of one indicates "poor" and five indicate "very good"). Lecture halls, seminar rooms and tutorial rooms in the building were measured for illumination (in lux) to provide a metric for analysis. Each room was divided into one metre square blocks in which an illumination value was recorded. Table 1 shows the grid dimensions used for each room-type measured.

Table 1: Grid dimensions used for illumination measurements.

Room	Grid Size	Room	Grid Size
Extra Large Lecture Hall (1160)	16 x 24	Large Tutorial Room (2145, 2155, 2165,2175, 2185, 2195)	7 x 6
Tapered Lecture Hall (1130)	14 x 19	Small Tutorial Room (2139, 2159, 3116)	7 x 4
Large Lecture Hall (1170, 1180, 1190)	14 x 14	Large Seminar Room (2135)	6 x 7
Medium Lecture Hall (1200, 1210, 1220)	11 x 11	Regular Seminar Room (B24, B25, B26, 2179)	4 x 5
Small Lecture Hall (1230, 1240)	8 x 11		

The purpose of the next test was to determine if the accessibility stations are easily operable by the users. In order to do the test, the subject will sit in a chair at the accessibility station and attempt to operate the adjustment controls. This will involve releasing the lock and adjusting the table up and down. Where applicable, the forward and backward control will also be in the same manner. A station could be assigned one of three possible grades:

- *Functional*: The tester was able to operate the adjustability controls from a seated position without assistance.
- *Difficult*: The tester was able to operate the adjustability controls, but only with assistance from another person (e.g. lifting the table, balancing the movement between slides to prevent twisting).
- *Defective*: Physical damage to the pistons or sliding mechanisms prevented the tester from operating the adjustability controls, even with assistance.

"Viewing angle" refers to the total angle at which a person must turn their head and/or eyes to see the object of interest in its entirety. The viewing angles of blackboards and projector screens were included in our investigation. Shadows appearing on the blackboard in the lecture rooms can obstruct the visibility of information and detract from a student's learning experience. A table of shadow sizes was recorded each room. To conduct the study, we moved all sliding blackboard panels to their uppermost position, and noted the length of the shadow and inset distance from the front of the blackboard to the rear blackboard on the writing surface of the fixed blackboard in order to calculate the angle of attack. Two illumination measurements were recorded (one inside the shaded area and one outside) to quantify the difference in the shaded area.

3. RESULTS AND DISCUSSION

According to the classroom guidelines [5], illumination at desk-level is required to be 538 lux (50 fc). The chart (Table 2) plots the measured minimum, maximum and average illuminance levels for each of the tested classrooms. The standard deviation indicates the variance of illumination.

Table 2: Classroom lighting results.

Room	Min. (lux)	Max. (lux)	Avg. (lux)	Std Dev.		Room	Min. (lux)	Max. (lux)	Avg. (lux)	Std Dev.
1130*	7	243	44	39		B26	61	771	271	230
1160	27	351	110	52		2135	218	666	433	116
1170						2179	116	922	406	245
1180	35	194	104	37		2139	170	577	375	105
1190	23	180	97	38		2159	38	591	338	143
1200	36	390	117	61		2145	204	630	494	97
1210*	4	333	89	62		2155	95	653	357	140
1220	32	336	118	53		2165	167	493	350	88
1230**	58	904	199	147		2175	196	595	416	92
1240**	26	1252	215	196		2185	225	660	485	115
B24	58	638	242	184		2195	328	840	550	121
B25	38	772	289	189						

*A light switch in the room does not appear to function.
**An outdoor window is the reason for exceptional maximum values.

Illuminance variation occurs typically at the front of the lecture halls, along aisle-ways, and around the walls of the room. Windows also create variance in measured values. The intensity of lighting in a learning space is a key factor in assessing how well information may transfer from educator to student. Low lighting levels impede on the abilities of students and instructors to give, receive, or record information. Research suggests that more intense lighting in a learning environment may significantly improve a student's mood and academic performance, particularly in the absence of natural light [6].

Surveyed students were unsatisfied with the lighting condition of lecture halls in the Bahen Centre. Students' desks in the lecture halls have an average illuminance significantly below the 300 lx to 500 lx recommended by IESNA [7], even for tasks performed on computer monitors [8]. These results also do not meet the standards of fifty foot-candle (approximately 500 lx) published by the University of Toronto [5].

The average illuminance in the tutorial rooms of the Bahen Centre meets the IESNA's standards but only one room exceeds the University of Toronto's 50fc light level standard. Further research on the Bahen Centre should focus on determining which level of illumination best facilitates student learning, and whether to reconsider adhering to relevant standards in the future.

With regards to accessibility testing - Bahen Centre lecture halls require two wheelchair accessible stations, excepting the large lecture halls (which require three) and room 1160 (which requires four) [9]. All of the rooms meet this requirement. However, we noted of a number of mechanical problems with the accessibility stations (at the time of testing, July 2013). Of the 39 accessibility stations tested:

- Twelve (12) stations were fully functional.
- Nine (9) stations were difficult to operate for a single seated user.
- Eighteen (18) stations were defective or damaged. Figure 2 illustrates some examples of damaged stations.

Fig. 2. Malfunctioning or damaged accessibility stations.

The activation controls for the accessibility stations (shown in Figure 3) were all unmarked, difficult to locate, and confusing to operate. The root cause for some these malfunctions could not be clearly identified (i.e. it was challenging to determine if the control had not been activated or if the piston itself had failed).

Fig. 3. Accessibility table operation.

According to accessibility design standards, the University prohibits the use of custom-built accessibility tables [9]. The same standards also require that each station be equipped with an electrical receptacle for assistive devices. The distance of the nearest outlet to the

accessibility station ranged from 0.76m (1230, 1240) to 5.54m (1130 - rear station). In contrast to the accessibility power requirement [9], the accessibility stations in the large lecture halls are the only seats in the front row without an installed electrical outlet.

According to the University guidelines [9], classroom accessibility for all the students is a primary concern. Many of the stations are currently in poor condition and require immediate repair. They are either difficult to operate (23%) or are damaged (46%).

A lack of electrical outlets at the accessibility stations presents additional difficulties. For example, the only seat in the first rows of rooms 1180 and 1190 that do not have an electrical outlet provided is the accessibility station. Cords must therefore run to the nearest outlet; if the nearest outlet is across a walkway, it will present a tripping hazard. According to the University guidelines, accessibility stations should have electrical outlets readily available [9].

With respect to the lecture hall's information systems, the mechanical function of the blackboards in combination with the lighting arrangement presents an obstruction concern to a varying degree for all of the lecture halls. Because the three blackboards are set at different planes, there is a maximum overhang between the front most and rear-most blackboard of 95mm (visible in Figure 4).

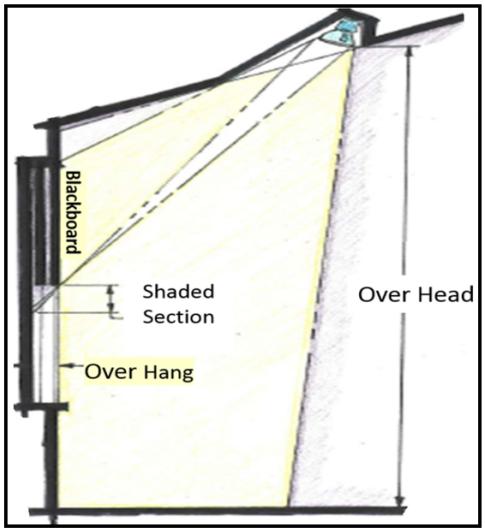

Fig. 4. Blackboard (side view).

Due to various angles for overhead lighting for each size of lecture hall, the shadow height is different for each size of room. The shadow produces an illumination variance between 57 to 96 lux, affecting visibility of the chalkboard. Figure 5 provides an example of this effect. Four percent of survey respondents addressed this issue in their additional comments of the survey. Table 3 quantifies the shadows sizes cast on the blackboards. Figure 5 illustrates the difficulty in attempting to read the two sentences on a blackboard, with one obscured by such a shadow. One potential solution to this problem could be installing light fixtures at the bottom corners of the blackboards such light shines upward, cancelling the shadow (though this might interfere with the lecturer). Another approach is to simply attached LED flashlights under the outer blackboards. This will also shine light on the shadowed area and eliminate it.

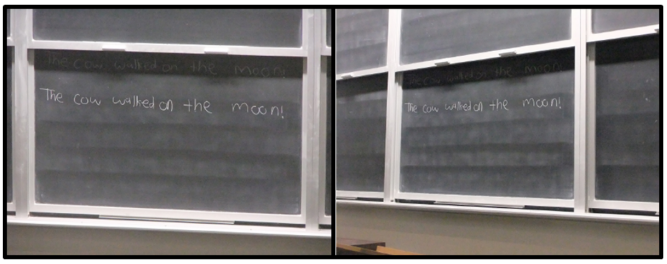

Fig. 5. Obstructive Chalkboard Shadowing.

Table 3: Blackboard interference, illumination.

Blackboard Shadow in Room:	**Shadow Length (mm)**
Seminar Rooms (B024)	92
Small Lecture Halls (1240, 1250)	80
Medium Lecture Halls (1200, 1210, 1220)	146
Large Lecture Halls (1130, 1160, 1170, 1180, 1190)	210

Another source of concern is with the projector screen. The projector screens in the lecture halls should be positioned in such a way that 100% of student seating falls within its viewing cone [5]. As shown in Figure 6, this is not currently the case.

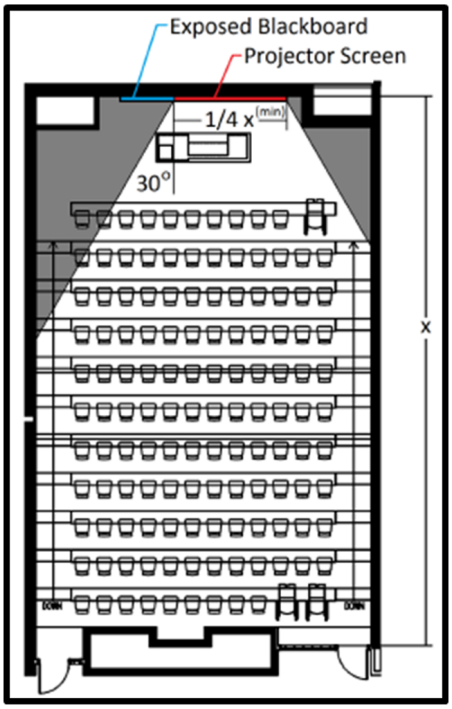

Fig. 6. Projector Viewing Cone.

The seminar rooms and large lecture halls do not currently meet the University of Toronto's Design Criteria standard [5]. Additionally, the projector screens in lecture halls drape in front of the blackboards. Although there is no simple solution to this problem, in room 1190 the projector screen obstructs 68% of the blackboard and 82% in room 1130. This leaves a 0.9m to 1.9m strip of exposed blackboard beside the projector screen. In room 1160, the projector screen only obstructs the upper blackboards, but it casts a 508mm shadow on the lower boards. This obstruction is depicted in Figure 7. As a result, instructor's ability to simultaneously employing blackboard and the projector for teaching purposes becomes limited.

Fig. 7. Projector Screen Shadow, Room 1160.

In observation of the small lecture hall, room 1240, the entrance door and the storage closet are inset such that the walls present a physical barrier that blocks a portion of the writing surface that in turn limits students' viewing zone, shown in Figure 8. Table 4 outlines the percentage of blackboard obstruction from the seat nearest the wall in each row.

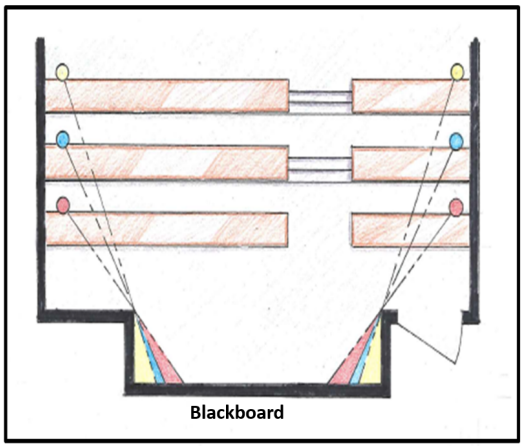

Fig. 8. Obstructed view, Room 1240.

Table 4: Percentage of the blackboard view obstruction, by row.

Row	1st	2nd	3rd	4th	5th	6th
Rm 1230	8%	4%	3%	1%	1%	0%
Rm 1240	17%	11%	8%	6%	4%	3%

In the Bahen center room B24, the crescent focuses the sight cones of an audience directly towards the lecturer as illustrated in Figure 9. In this room (B24), a person positioned at the corner of the front row is 2.2m away from the front wall and, while facing forward in the seat, the viewing angle is 15 degrees off parallel to it.

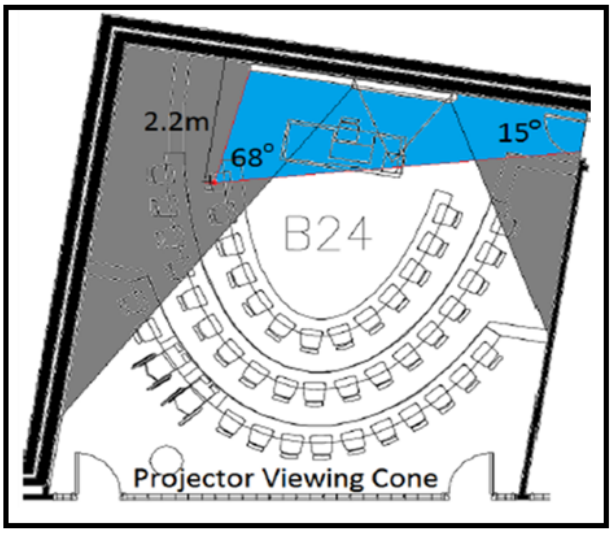

Fig. 9. Seminar Room (B24) Viewing Angles.

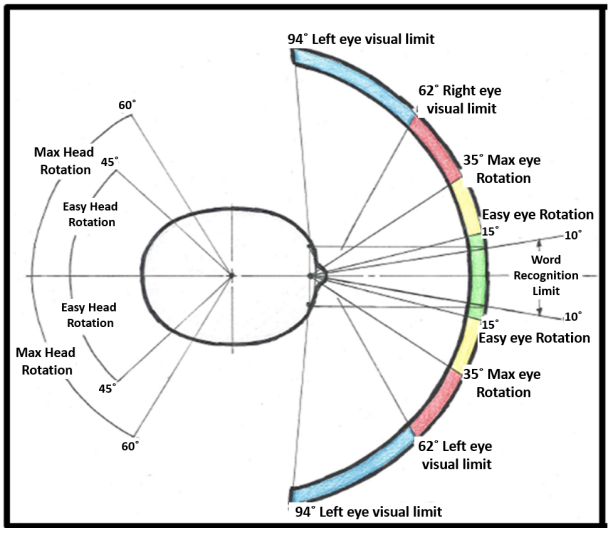

Fig. 10. Eye/Head Rotation Angles.

Figure 10 illustrates comfortable eye and head rotations [10]. Based on measurements taken, the angle of a person reading the blackboard while looking straight forwfard falls outside the comfortable range of eye movement for the seminar rooms such as B24 (Figure 9). Therefore, students are forced to rotate their heads such to see the board. The result is in a maximum angle of head rotation of 68 degrees. This exceeds the comfortable head-rotation and eye-movement of the 55 degrees. No students in the survey indicated that this was a problem. It is also worth noting that many of the seats in the seminar rooms fall outside of the specified projector-viewing cone [5].

4. CONCLUSION

Significant obstacles to student learning exist in the Bahen Centre for Information Technology. The lack of compromise in realization of design versus use-models leads to inefficient performance with the Bahen Centre's classrooms. The building fails to meet aspects of the most recent classroom design standards published by the University of Toronto, as well as other published standards. Particularly in regards to student viewing and accessibility due in part by evident disrepair of the building's fixtures. The quantity of electrical outlets and their location in classrooms are also areas for improvement, especially considering the rising use of electrical devices for learning. Further research is recommended on these issues be conducted to determine if the University's classroom design standards should be more closely adhered to or amended so that the Bahen Centre does not contradict them. We also suggest that further studies gather data from a larger sample of students, as that may reveal additional avenues of interest, and consider the restricted areas of the Bahen Centre such as its labs.

Acknowledgement

Saif Abid and David Almond initially conducted this study during summer of 2013 by, after their first year of studies at the Engineering Department of the University of Toronto. They are now completing their fourth year of engineering studies.

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