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. The study is based on physical measurements, and surveys gathered from students and professors. The results indicate that a number of lecture halls do not meet the University's classroom design standards. Tutorial rooms fared better by design standards, nevertheless, a lack of electrical access ignores the growing dependency on computers in the classrooms. A set of issues – from obstructed viewing angles to damaged accessibility equipment are identified. Several remedies are suggested in order to address these shortcomings. Some of the remedies can be easily implemented while others can be considered for the future educational structures.*

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 the University of Toronto to further optimize its 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 building's learning spaces. Natural and artificial light levels in the lecture and tutorial rooms will be analyzed for light considerations.

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

Academic performance has also been linked to natural light factors, electrical lighting, and the presence of windows [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 which may or may not pose limitations to a student's learning in the Bahen Centre or any other educational environment.

2. CONDUCT STUDY

The study was started by conducting a student survey to quantify students' experiences with the Bahen Center and their preferences regarding learning spaces. For this survey, questions were designed on Google Forms and given to students.

The results for three important questions among all the surveyed questions are presented in Figure 1. Examination of the student survey presented in Figure 1: Q2: "*Describe the lighting conditions in the Bahen lecture halls*" and Q3: "*Describe the lighting condition in Bahen*

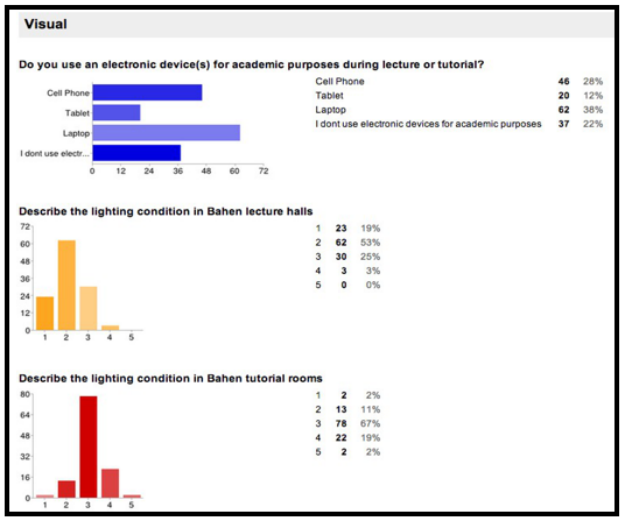

Fig. 1. Student survey responses.

tutorial rooms" both indicated that the majority of students surveyed found that the rooms did not provide sufficient lighting (a rating of 1 was used to indicated "poor" and 5 to indicate "really good"). In order to provide a metric and quantify the level of illuminations, measurements were conducted in various lecture halls, seminar rooms and tutorial rooms in the building. Each room was divided into one metre square blocks in which an illumination value was recorded. The grid dimensions for each room type measured is shown in Table 1.

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 next set of tests were conducted with regards to accessibility stations in the lecture halls. The purpose of this 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. Three gradings are given:

- *Functionality*: The tester was able to operate the adjustability controls from a seated position without assistance.
- *Arduousness*: 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).
- *Defect*: Physical damage to the pistons or sliding mechanisms prevented the tester from operating the adjustability controls, even with assistance.

Tests were also conducted to measure viewing angles as well as shadows appearing on the blackboard in the lecture rooms which would cause an obstruction to a student's learning experience. The purpose of this test is to quantify the amount of space on lecture hall blackboards covered by a shading effect due to overhead lights, and the difference in illumination caused by the phenomenon. In order to conduct this test, all the moveable blackboard panels are pushed to their uppermost position then a length measurement will be taken on the fixed blackboard's writing surface. The inset distance from the front blackboard to the rear blackboard will be recorded so that angle calculations will be possible. Two illumination measurements will be taken (one inside the shaded area and one outside) in order to quantify the difference in the shaded area.

3. RESULTS AND DISCUSSION

According to the classroom guidelines [5], illumination levels 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 is given to indicate the variability 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.

It appears that the 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 can be transferred from an educator to a student, potentially limiting the abilities of both students and instructors to give, receive, or record information. Research suggests that more intense lighting in a learning environment is likely to 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 may focus on determining which level of illumination best facilitates student learning, and whether the relevant standards should be reconsidered or adhered to 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 numerous mechanical problems were noted with the accessibility stations (at the time of testing, July 2013). Of the 39 accessibility stations tested:

- 12 stations were completely functional.
- 9 stations were difficult to operate for a single seated user.
- 18 stations were either malfunctioning or damaged. Figure 2 illustrates conditions of these stations.

Fig. 2. Malfunctioning or damaged accessibility stations.

It is, furthermore, noted that the activation controls, as shown in Figure 3, were unmarked, difficult to locate, and confusing to operate. The source of 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, custom-built accessibility tables are not to be used at the university [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). It should also be noted that, 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] the 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, as a cord must be run from a general maintenance outlet across a walkway, presenting another tripping hazard. According to guidelines, electrical outlets are to be provided at each accessibility station [9]. It should be noted that in rooms 1180 and 1190 the only seat in the first row that does not have an electrical outlet provided is the accessibility station.

Lastly, the multiple blackboard system in combination with the lighting arrangement presents an obstruction issue 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. This is shown in Figure 4.

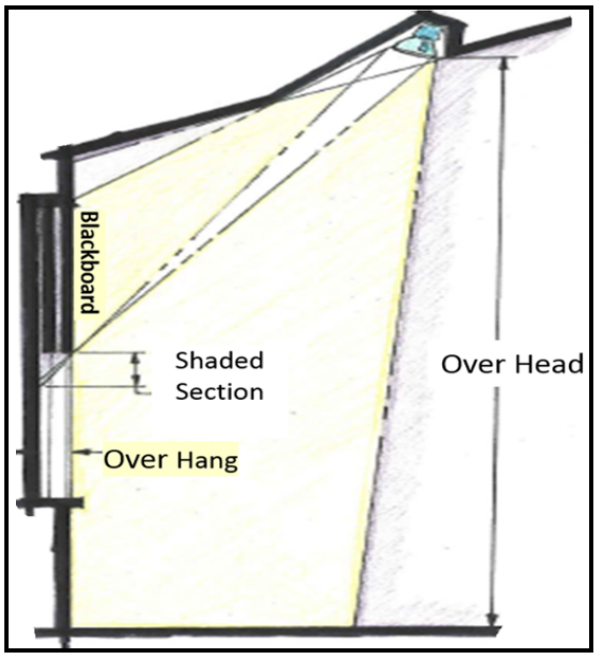

Fig. 4. Blackboard (side view).

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 a 57 to 96 lux variations in illumination, affecting visibility of the chalkboard. This is shown in Figure 5.

There is a 4% of survey respondents that addresses this issue in the additional comments area of the surveys. The measurements of the shadows on the blackboards are presented in Table 3. Various remedies can be considered to resolve the shadowing on the blackboard as shown in Figure 5. One approach is to install light fixtures at the bottom corners of the blackboards such light is shined in the upward directions, hence, the removal of the shadow. Another approach is to simply attached LED flashlights under the outer blackboards. This will also shine light on the shadowed area and eliminate it.

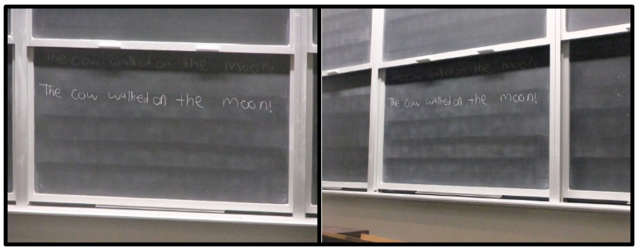

Fig. 5. Obstructive Chalkboard Shadowing.

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.

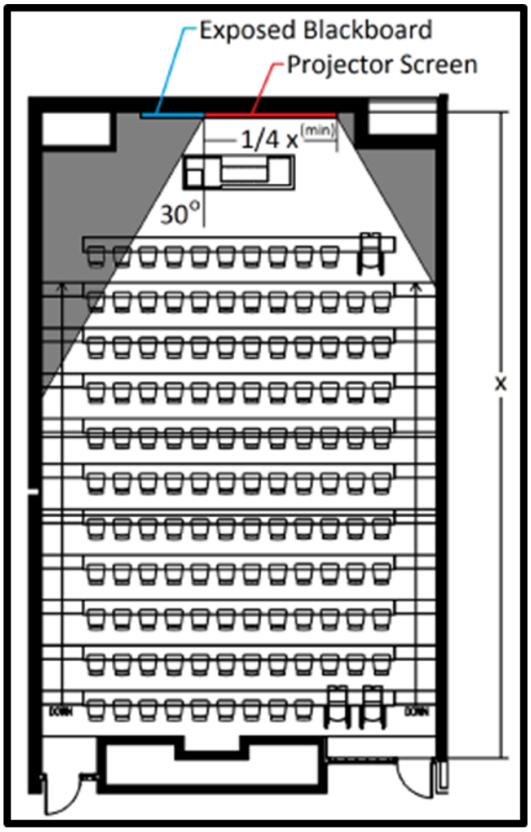

Fig. 6. Projector Viewing Cone.

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 are positioned to lower in front of the blackboards. Although there is not a simple solution to this problem, in room 1190, 68% of the blackboard is obstructed by the screen, and in room 1130, 82% of the blackboard is obstructed. 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 is depicted in Figure 7. As a results, 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. This is shown in Figure 8. From the seat nearest the wall in each row, the blackboard is obstructed by the percentages shown in the Table 4.

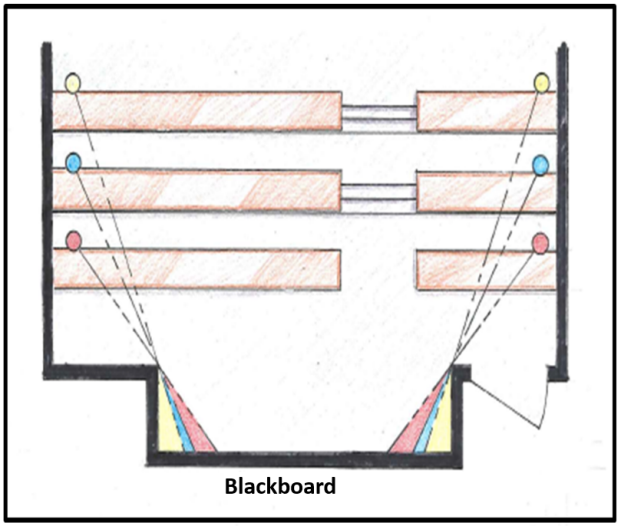

Fig. 8. Obstructed view, Room 1240.

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 sitting at the corner of the front row is positioned 2.2m away from the front wall and, while facing forward in the seat, the viewing angle is 15 degrees off parallel to it.

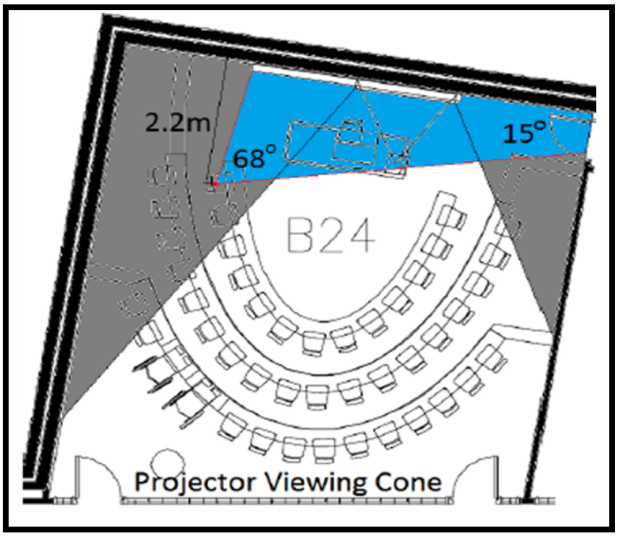

Fig. 9. Seminar Room (B24) Viewing Angles.

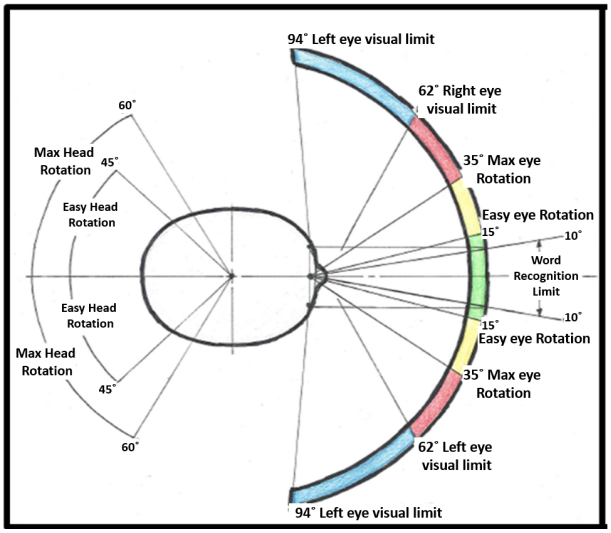

Fig. 10. Eye/Head Rotation Angles.

The Comfortable eye and head rotations are referenced in [10] and provided in Figure 10. Based on measurements taken, the angle of a person reading the blackboard while looking straight forward 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 a mutual realization between designers' and users' conceptual models mainly lead to a series of problems with the Bahen Centre. 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. It is recommended that further research 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. It is also recommended 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

This study was initially conducted during summer of 2013 by Saif Abid, and David Almond 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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