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Absenteeism, Performance and Occupant Satisfaction with the Indoor Environment of Green Toronto Schools

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Key Words

Absenteeism · Green buildings · Indoor environment · LEED · Performance

Abstract

This study aimed to compare a number of quantitative and qualitative aspects of usage across a sample of 10 conventional, 20 energy-retrofitted and three green Toronto schools. Student, teacher and staff absenteeism data, as well as Grade 3 and 6 student performance data on reading, writing and arithmetic tests administered by Ontario's Education Quality and Accountability Office were collected. A survey of 150 teachers was conducted to investigate their satisfaction with the indoor air quality, lighting, thermal comfort and acoustics of their school buildings. The statistical analysis of the data showed that teachers in green schools were in general more satisfied with their classrooms and personal workspaces' lighting, thermal comfort, indoor air quality, heating, ventilation and air conditioning than teachers in the other schools. Nevertheless, they were less satisfied with acoustics. Student, teacher and staff absenteeism in green schools also improved by 2–7.5%, whereas student performance improved by 8–19% when compared with conventional schools. However, these improvements were not statistically significant and could not therefore be generalised to all Toronto public schools. Whether these marginal improvements justify the extra cost premium of green buildings remains an active contentious topic that will need further investigation.

Introduction

Despite the steady increase in the adoption of green building practices, practitioners in today's architectural, engineering and construction industry are still uncertain about investing in these practices. This is mainly because of the additional cost premium associated with the design and construction of green buildings, and their uncertain long-term cost performance. Usage costs in particular,

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deemed to represent a significant portion of long-term costs, continue to be neglected despite their saving potential [1]. These are costs incurred once a building is occupied, in support of the specific purpose for which it was built. They include costs such as salaries of employees, space usage costs, and productivity and health costs [1].

The goal of the study is to document several aspects of usage in a sample of conventional, energy-retrofitted and green Toronto public schools. The study most specifically aimed to analyse second-hand absenteeism and performance data, and assess teachers' satisfaction with different aspects of the schools' indoor environment. The objective was to eventually determine whether green buildings could lead to improvements in any of these aspects in comparison with conventional and energy-retrofitted ones.

This paper presents a short review of earlier work conducted in the field before focusing on this particular study. The paper describes the methods used to collect and analyse the study data, and presents the results of the analysis. It is expected that this study will show how greener indoor environments could lead to significant improvements in student, teacher and staff absenteeism, student performance, and occupants' satisfaction.

Literature Review

A review of the literature shows that aspects of green building design such as increased ventilation, temperature and lighting control could all have an association with improved health, and increased worker productivity and performance. Green buildings have also been associated with a more committed and stable workforce due to happier, healthier and more enjoyable working environments.

A number of older research studies focused on investigating the link between greener indoor environments and productivity. An early study conducted by Heschong [2] showed that students in classes with better daylighting did 20% better on math tests and 26% better on reading tests. Another study [3] noticed productivity improvements of 13% following an increase in natural daylighting in buildings, and 10–25% improvements in test performance of mental function and memory recall when subjected to an ample and pleasant view. A third study [4] concluded that good views could enhance student learning while glare, direct sun penetration, poor ventilation and poor indoor air quality could worsen it. Fisk [5] concluded that greener indoor environments could reduce allergies and asthmas by 8–25%, and reduce sick building syndrome symptoms by 9–20%, leading to savings in lost time and productivity of US $10–35 billion. Miller et al. [6] found through surveying over 2,000 workers in 154 green buildings in the US that 57.5% of all employees felt good and productive in these environments. The study estimated an average productivity increase of 4.8% in these buildings.

Reduction in absenteeism is another potential major benefit of green buildings. A study by Hathaway et al. [7] showed that students in classrooms with natural daylighting attended 3.5 more days per year than students in classrooms with little daylighting. Milton et al. [8] found that green buildings could reduce absenteeism by 35%. Miller et al. [6] concluded that workers in green buildings took, on average, 3 days less sick leave per year.

The literature on occupant satisfaction with green buildings' indoor environment shows, quite unexpectedly, mixed results. Heerwagen and Zagreus [9] found that one Leadership in Energy and Environmental Design (LEED)-certified building rated third overall in general end-user satisfaction among 170 total buildings, 10 of which were LEED-certified buildings. Turner [10] analysed 11 LEED-certified buildings in the Cascadia region, and found that office workers were in general more satisfied with lighting level and air quality, but less satisfied with noise level and sound privacy. Abbaszadeh et al. [11] surveyed occupants of 21 green buildings, and found them to be more satisfied with air quality and thermal comfort, but less satisfied with lighting and acoustic quality than occupants of conventional ones. Paul and Taylor [12] could not prove that one green building had better aesthetics, lighting, ventilation, acoustics and humidity than another conventional one. Occupants of 12 other green buildings reported higher than average satisfaction scores with respect to general building, general workspace, thermal comfort, air quality, lighting, acoustic quality, cleanliness and maintenance, and lower scores with respect to overall acoustics [13]. Lee and Guerin [14] found workers in 15 LEED-certified buildings to be generally satisfied with cleanliness, maintenance, office furnishing quality and indoor air quality, but dissatisfied with acoustic quality and thermal comfort quality. This dissatisfaction with acoustics, lighting and thermal comfort in some green buildings seem all the more important when one realises that the LEED indoor environmental quality category does not include aspects such as artificial and natural lighting, acoustics, and aesthetics [15].

Despite their value, there are a few inherent problems with those studies. Many of the studies used very small

sample sizes that do not allow researchers to generalise their results to larger populations. Some did not elaborate on their exact methods. Those who did; they used more often than not, theoretical rather than actual empirical data. Some used worst case scenarios and compared green indoor environments to very poor atypical environments, instead of comparing them to the vast majority of conventional typical ones. Most studies focused on only one aspect of usage instead of analysing a number of different aspects. Most of those studies focused on buildings in the US as opposed to buildings in other parts of the world, including Canada with its unique climate, standards and regulations.

A few other more comprehensive studies estimated potential long-term health and productivity benefits in green buildings. The first study by Kats et al. [16] predicted that health and productivity cost savings would represent 70–78% of total whole life cost savings. Two other later studies of 30 green schools across the US by Kats et al. [17] and Kats [18] estimated reductions in health costs from reductions in asthmas, and cold and flu symptoms to make up about 73% of total whole life cost savings. The latest study by Kats et al. [19] predicted that 90% of 150 green buildings in the US and 10 other countries would see their cost premiums paid back by energy, water, health and productivity cost savings within five years of operation.

Nevertheless, the methods in addition to the complete findings of this latest study have still not been published. The earlier studies tended to rely mostly on modelled predictions of future costs instead of actual, documented data, making it difficult to validate findings derived using these methods.

Research Methods

This section describes the methods used to collect and analyse the study data.

Data Collection

To address some of the limitations highlighted above, the University of New Brunswick Construction Engineering and Management Group partnered with the Toronto District School Board to analyse 33 of their schools: 10 conventional, 20 energy-retrofitted and three green schools. Energy-retrofitted schools were conventional schools that had undergone lighting and mechanical retrofits to make them more energy efficient. Lighting retrofits involved replacing T-12 lighting systems and magnetic ballasts with T-8 lighting systems and electronic ballasts, and replacing incandescent light bulbs with compact fluorescent bulbs. Mechanical retrofits involved installing a Building Automation System, and primary and secondary loop systems to existing hot water heating systems. Green schools were newer schools that had been built to the Leadership in Energy and Environmental Design Rating System for New Construction (LEED-NC 1.0) standards, administered by the Canada Green Building Council.

The data collection phase was divided into two main parts. The first entailed collecting quantitative usage data kept on file by these schools, while the second entailed collecting additional quantitative and qualitative usage data through a survey of school teachers. Figure 1 summarises the methodology used for this study.

Table 1 shows the specific data collected for the first part of the study. In general, this part involved collecting data about student enrolment and teacher and staff levels for the last five years of every school's life. It also involved collecting student, teacher and staff absenteeism data for the same three-month period of every school term. Student performance data were also collected through the Education Quality and Accountability Office [20] responsible for assessing education quality in all Ontarian public schools.

The second part entailed administering a post occupancy evaluation survey to teachers working in those schools. Of the entire population of approximately 600 school teachers, 150 were surveyed, to ensure a 95% level of confidence and a 7% confidence interval. The survey was administered to either 15% of the total number of teachers in every school, or five teachers per school, whichever was highest. Teachers were selected at random in every school and were asked to complete the questionnaire manually. The survey was made anonymous to protect teachers' privacy and ensure the confidentiality of their responses. Of the 150 surveyed, 103 completed the survey, resulting in a response rate of approximately 69%.

Table 2 summarises the content of the questionnaire. This questionnaire was modelled after the post occupancy evaluation surveys of a number of other studies [9,11,13,14]. It comprised 13 questions: 10 qualitative (opinion) questions and three quantitative ones. Ten of the 13 were closed-ended (e.g. multiple choices, Likert scales). Respondents were asked to indicate their level of satisfaction with a number of aspects related to their schools' indoor environments based on their experience in the 2007–2008 school year. The survey enquired about

teachers' satisfaction with the schools' overall physical condition, and their classrooms and personal workspaces' lighting, heating ventilation and air conditioning, indoor air quality and acoustics. Teachers were also asked to rate more specific aspects of their classrooms' lighting, thermal comfort and acoustics. They were presented with a number of potential challenges, and asked to rank the ones facing their schools in terms of their importance.

Data Analysis

The data collected in Tables 1 and 2 was grouped, compared and analysed per school category (conventional, energy-retrofitted and green). The analysis involved

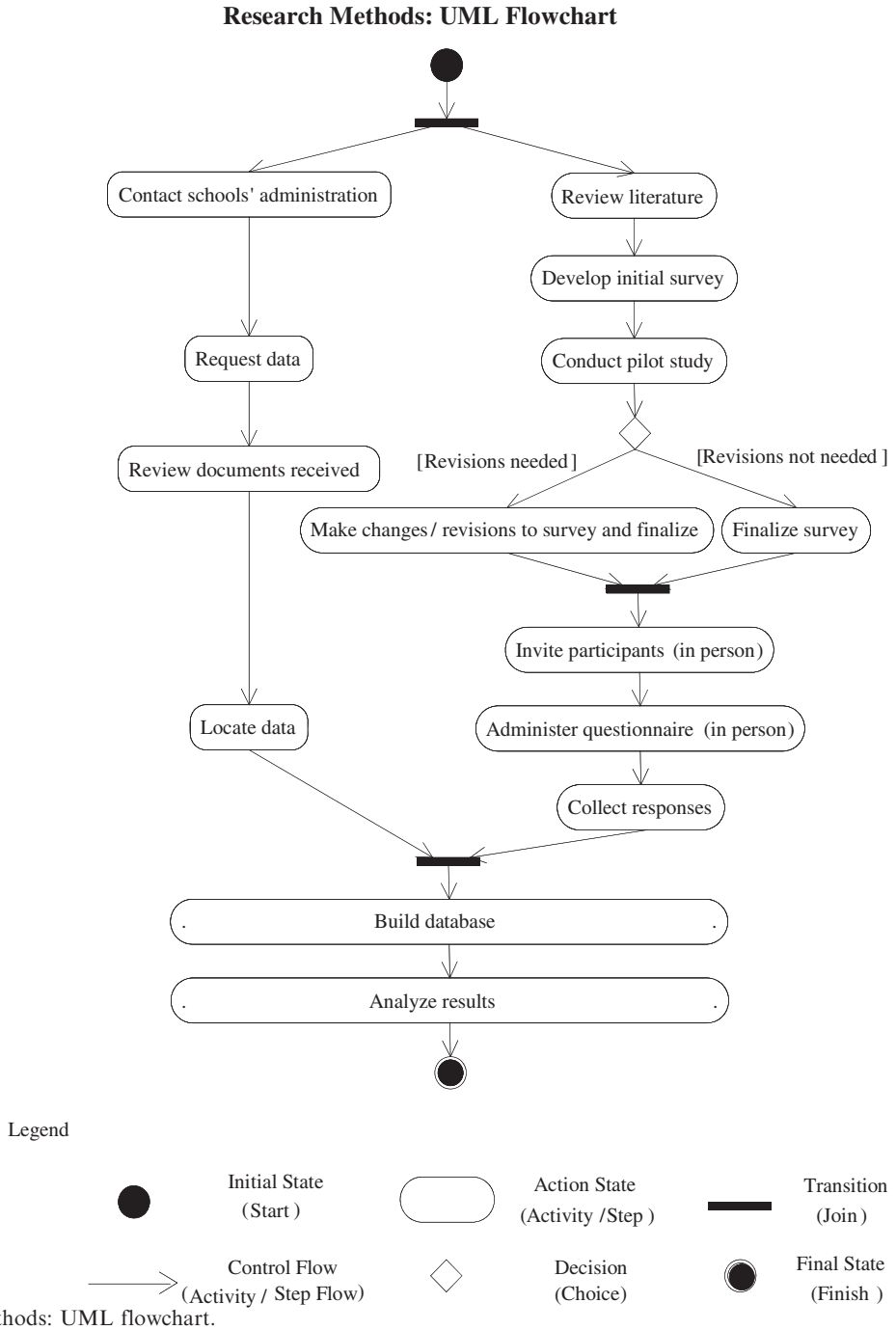

Fig. 1. Research methods: UML flowchart.

computing average means for every school category and analysing the data statistically to test the statistical significance of the difference between every two means for every aspect investigated. Figure 2 summarises the statistical methods used in the analysis.

Variables collected were tested for normality to decide whether parametric tests could be used to analyse them. The relationships between school category; and students', teachers' and staffs' absenteeism; students' grades, and teachers' satisfaction with different aspects of the schools' indoor environment were also statistically tested using the multiple analysis of covariance (MANCOVA) test. The test controlled for the covariates: school age, school floor area per occupant ratio and the average income level of the neighbourhood in which schools were located. An index was developed based on the average income level, as determined by the City of Toronto [21]. If the effect of school category was statistically significant at 95% ($p<0.05$), the analysis of covariance (ANCOVA) test was used to investigate this effect on every dependant variable separately. If this effect was statistically significant, the coefficients of correlation (R) and determination (R^2) were computed. The *post hoc* Tukey test was also used to investigate the statistical significance of the difference between every two means for that effect.

Non-parametric tests were used for the ranking of potential problems facing every category of schools. The Kruskal–Wallis test was used to test the overall effect of school category on the ranking of every potential problem separately. If the effect on a specific problem was statistically significant, a multiple comparison of means test was conducted to assess the statistical significance of the difference in means between every two categories. Within every school category, the Friedman test was used to test overall differences in the ranking of problems. Kendall's coefficient of concordance (CC) was also used to investigate how much teachers in every school category agreed on the problems facing their schools. Whenever the Friedman test showed a statistically significant different (at $p<0.05$), the Wilcoxon Matched Pairs test was used to test the statistical significance of the difference between the ranking means of every two problems.

Table 1. Quantitative data collected [1]

Data collected	Time period required
School capacity data	
All students	
Suspended students	
Expelled students	Yearly
All teachers	
New teachers	From 2003–2004 to 2007–2008
All staff	
New staff	
School absenteeism data	
Students	Daily
Teachers	
Staff	From September 2008 to December 2008
Student performance data	
Grade 3 Reading	
Grade 3 Writing	
Grade 3 Arithmetic	2007–2008
Grade 6 Reading	
Grade 6 Writing	
Grade 6 Arithmetic	

Results

This section presents the results of the data analysis and includes a discussion of those results in the context of existing literature.

Overall Physical Condition

The statistical analysis of the data showed that school category had a statistically significant effect on teachers' satisfaction with the schools' overall physical condition after controlling for the effects of age and floor area to

Table 2. Structure of questionnaire [1]

Question numbers	Question types	Content
Questions 1–3	Open-ended	School name, years of experience in school, number of students in class
Question 4–6	Likert scale	Satisfaction with school's physical condition (building overall), classrooms' and personal workspaces' condition
Question 7–9	Likert scale	Satisfaction with lighting, thermal control, and acoustics in classrooms
Questions 10	Checklist/multiple choice	Students' performance in school
Question 11	Ranking	Problems/challenges facing school
Questions 12	Checklist/multiple choice	General satisfaction with school and work environment
Question 13	Open-ended (optional)	Other general comments

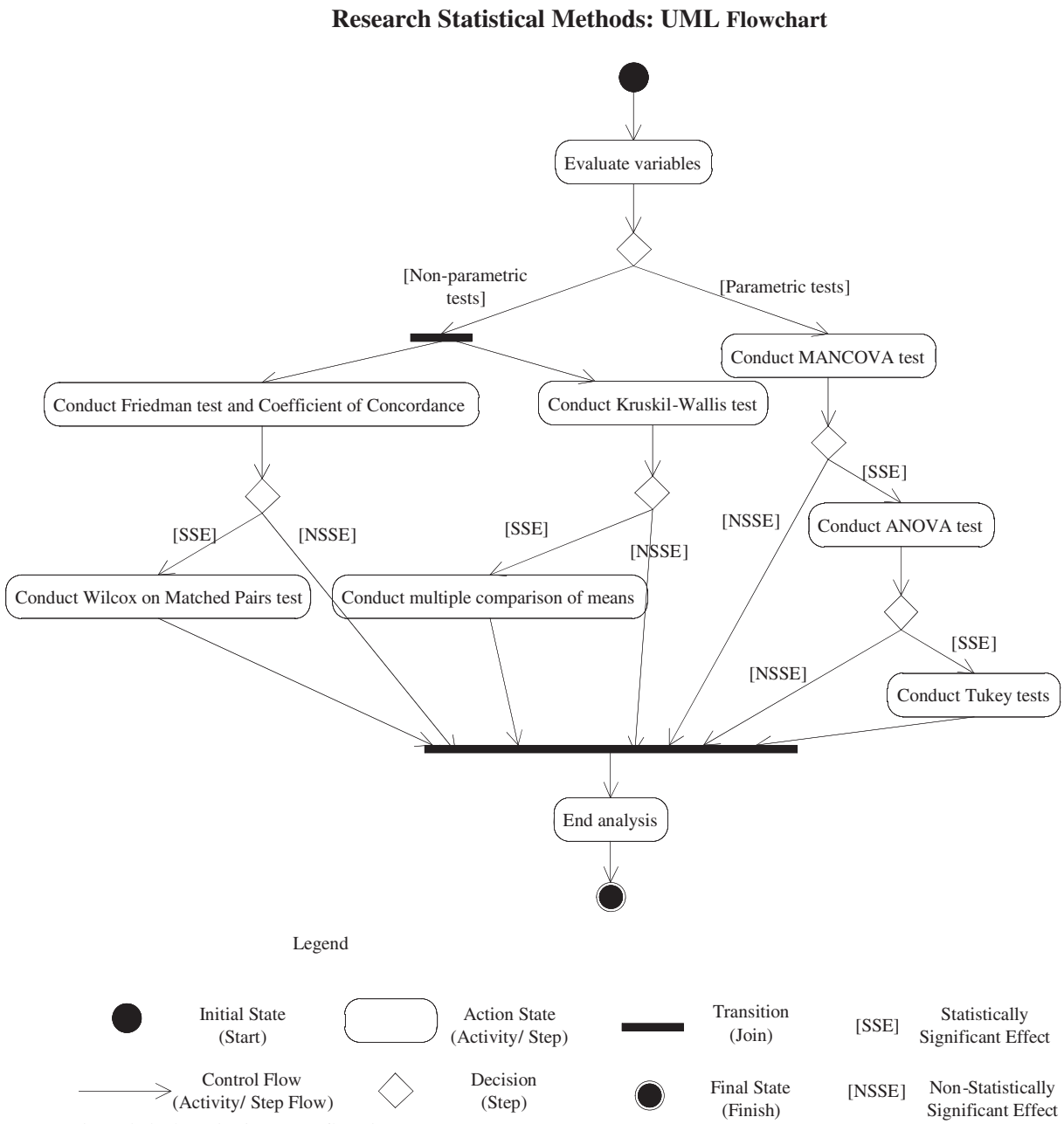

Fig. 2. Research statistical methods: UML flowchart.

number of occupants ($p = 0.00$). School category also had a statistically significant effect on every dependant variable separately after controlling for these same covariates (p between 0.00 and 0.01). Moderate positive associations were found between school category and teachers' satisfaction with every aspect of the schools' overall physical condition (R between 0.32 and 0.43, and $p = 0.00$ for all), except for use and availability of space ($R = 0.23$, $p = 0.06$).

As shown in Figure 3, teachers in green schools were in general more satisfied with their schools' general maintenance and cleanliness than teachers in energy-retrofitted ($p = 0.000$ and 0.001, respectively), and conventional schools ($p = 0.000$ for both). Moreover, teachers in green and energy-retrofitted schools were more satisfied with the aesthetics of their schools than teachers in conventional schools ($p = 0.000$ for both). Teachers in energy-retrofitted schools were also more satisfied with the use and

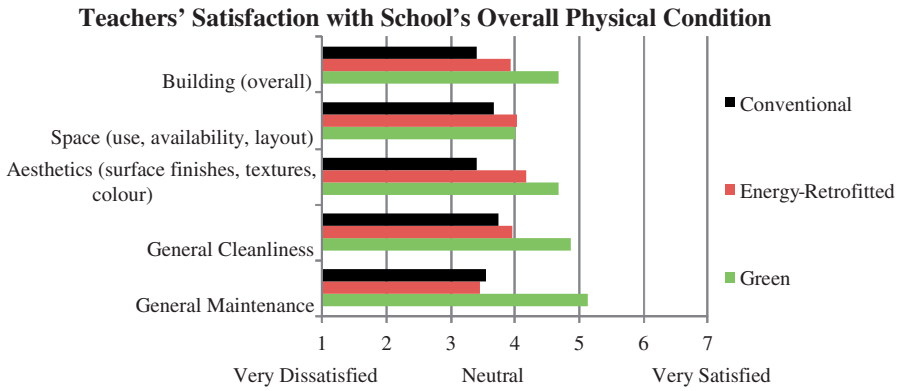

Fig. 3. Teachers' satisfaction with schools' overall physical environment.

availability of space in their schools than teachers in conventional schools ($p = 0.020$).

Classrooms

The statistical analysis of the data showed that school category had a statistically significant effect on teachers' satisfaction with their classrooms' indoor environment after controlling for the age and floor area to number of occupants of schools ($p = 0.00$). School category also had a statistically significant effect on teachers' satisfaction with every aspect of their classrooms' indoor environment (p between 0.00 and 0.03) after controlling for these same factors, except for noise ($p = 0.31$). The relationships between school category and all of these aspects were moderate positive relationships (R between 0.33 and 0.47, and $p = 0.00$ for all), except for the one with classrooms' indoor air quality ($R = 0.22$, $p = 0.07$).

Figure 4 and the *post hoc* Tukey test results showed how teachers in energy-retrofitted schools were more satisfied with their classrooms' space design and layout than teachers in conventional schools ($p = 0.00$). Teachers in green schools were also more satisfied with their classrooms' cleanliness, lighting quality and indoor air quality than teachers in conventional and energy-retrofitted schools (p between 0.00 and 0.04). Teachers in energy-retrofitted schools were also more satisfied with their classrooms' heating, ventilation and air conditioning (HVAC) than teachers in conventional schools ($p = 0.00$), whereas teachers in green schools were more satisfied with their classrooms' HVAC than teachers in conventional and energy-retrofitted schools ($p = 0.00$ for both).

Personal Workspaces

The MANCOVA test results showed that school category had a statistically significant effect on teachers' satisfaction with their personal workspaces after controlling for the age and floor area to number of occupants of their schools ($p = 0.00$). The ANOVA test results also demonstrated how school category had a statistically significant effect on teachers' satisfaction with every aspect of their personal workspaces' indoor environment (p between 0.00 and 0.03), except for space ($p = 0.06$), indoor air quality ($p = 0.18$) and noise ($p = 0.41$) after controlling for these same factors. The associations between school category; and teachers' satisfaction with cleanliness, lighting and HVAC were all moderate positive associations (R between 0.36 and 0.51, and $p = 0.00$).

The *post hoc* Tukey test results showed that teachers in green schools were on average more satisfied with the cleanliness and HVAC of their personal workspaces than teachers in conventional and energy-retrofitted schools ($p = 0.00$ for all). They were also more satisfied with their personal workspaces' lighting than teachers in energy-retrofitted and conventional schools ($p = 0.00$ for both), while teachers in energy-retrofitted schools were more satisfied with lighting than teachers in conventional ones ($p = 0.47$). Figure 4 summarises these results.

Lighting

The MANCOVA test results showed that school category had a statistically significant overall effect on teachers' satisfaction with different aspects of classroom lighting after controlling for the age and floor area to number of occupants of the schools ($p = 0.00$). School category also had a statistically significant effect on every aspect separately ($p = 0.00$), except for the amount and level of natural lighting in classrooms ($p = 0.06$). Moderate positive relationships were found between school category and each of these aspects (R between 0.37 and 0.52, and $p = 0.00$).

The *post hoc* Tukey test and Figure 5 showed how teachers in green schools were usually more satisfied

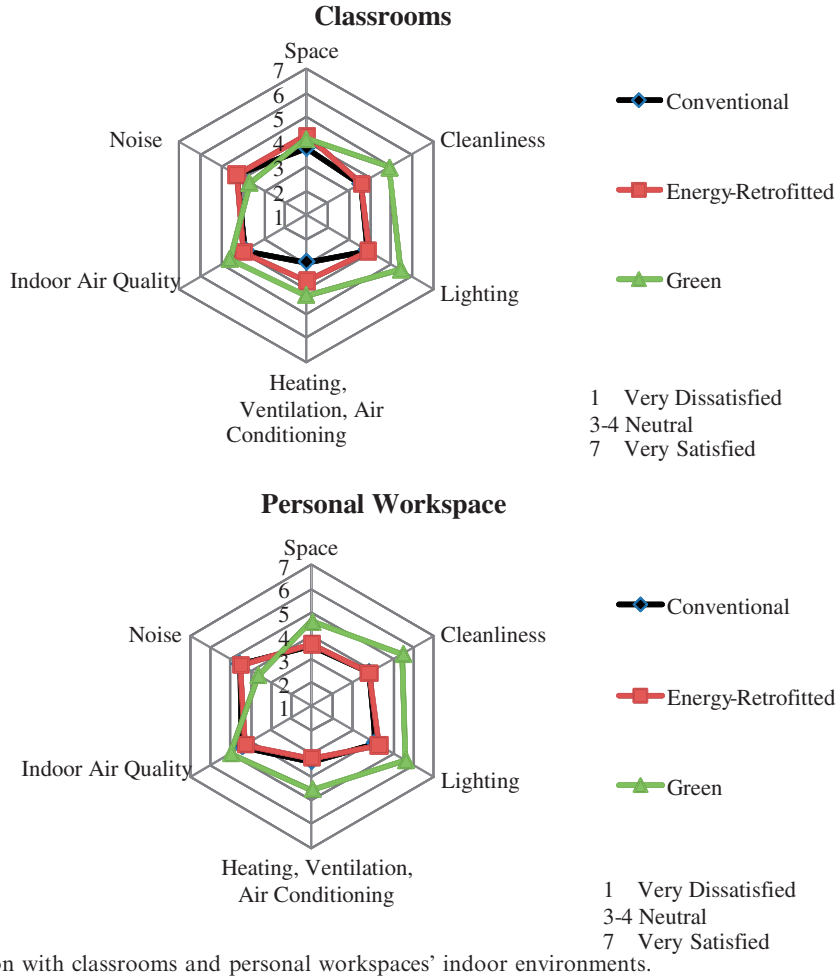

Fig. 4. Teachers' satisfaction with classrooms and personal workspaces' indoor environments.

with their ability to control lighting, glare from artificial lighting and glare from natural lighting in classrooms than teachers in conventional (p between 0.00 and 0.01) and energy-retrofitted schools (p between 0.00 and 0.02). No statistically significant difference was found between how teachers in green schools and teachers in energy-retrofitted schools rated glare from natural lighting ($p = 0.98$) or between how teachers in green schools and teachers in conventional schools rated the level of artificial lighting ($p = 0.96$).

Thermal Comfort

The MANCOVA test results showed that school category had a statistically significant overall effect on all aspects of thermal comfort in classrooms after controlling for the effects of age and floor area to number of occupants ratio ($p = 0.00$). The ANOVA test results showed that school category also had a statistically significant effect on each and every aspect of thermal comfort (p between 0.00 and 0.01). Strong and statistically significant associations were found between school category and each of those aspects (R between 0.31 and 0.51, and $p = 0.00$ for all).

The *post hoc* analysis demonstrated how teachers in energy-retrofitted schools were usually more satisfied with every aspect of thermal comfort than teachers in conventional schools (p between 0.00 and 0.01), except for temperature in the summer ($p = 0.05$). The analysis also showed that teachers in green schools were also more satisfied with every aspect of thermal comfort than teachers in energy-retrofitted (p between 0.00 and 0.50)

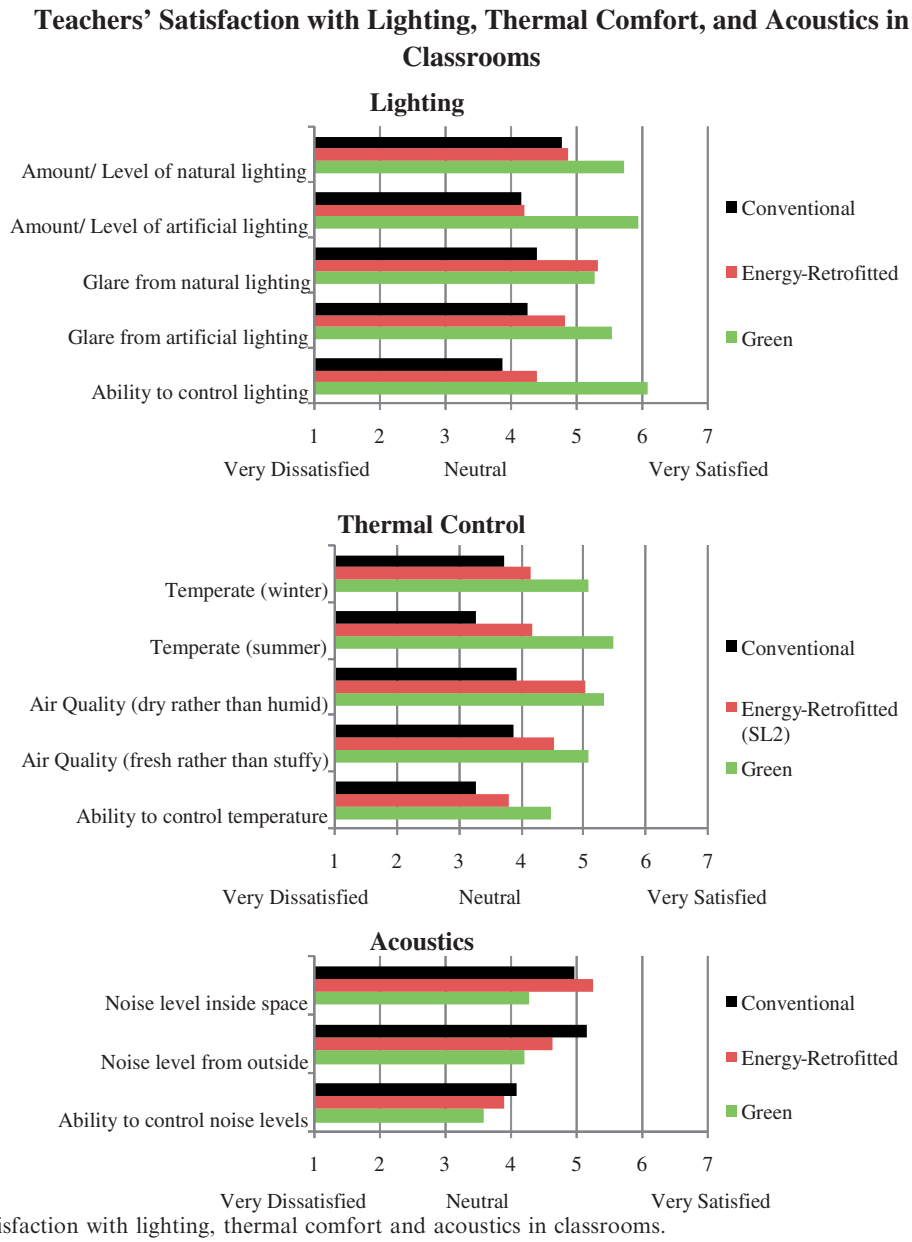

Fig. 5. Teachers' satisfaction with lighting, thermal comfort and acoustics in classrooms.

and conventional schools ($p = 0.00$ for all). Figure 5 depicts these results graphically.

Acoustics

The MANCOVA test results showed that school category had a statistically significant effect on teachers' satisfaction with all aspects of classroom acoustics after controlling for schools' age and the ratio of floor area to number of occupants ($p = 0.00$). The ANCOVA test results also showed that school category had a statistically significant effect on teachers' satisfaction with noise levels inside the classrooms ($p = 0.00$), and outside ($p = 0.02$) but not with their ability to control it ($p = 0.82$). Moderate positive associations were found between school category and teachers' satisfaction with outside noise levels ($p = 0.03$) and their ability to control noise in general ($p = 0.00$). Figure 5 shows how teachers in green and energy-retrofitted schools were less satisfied with noise levels outside classrooms than teachers in conventional schools ($p = 0.012$ and 0.024, respectively).

Absenteeism

The analysis showed that school category had a statistically significant overall effect on school absenteeism after controlling for the effects of school age, and neighbourhood income level ($p = 0.00$). The ANCOVA

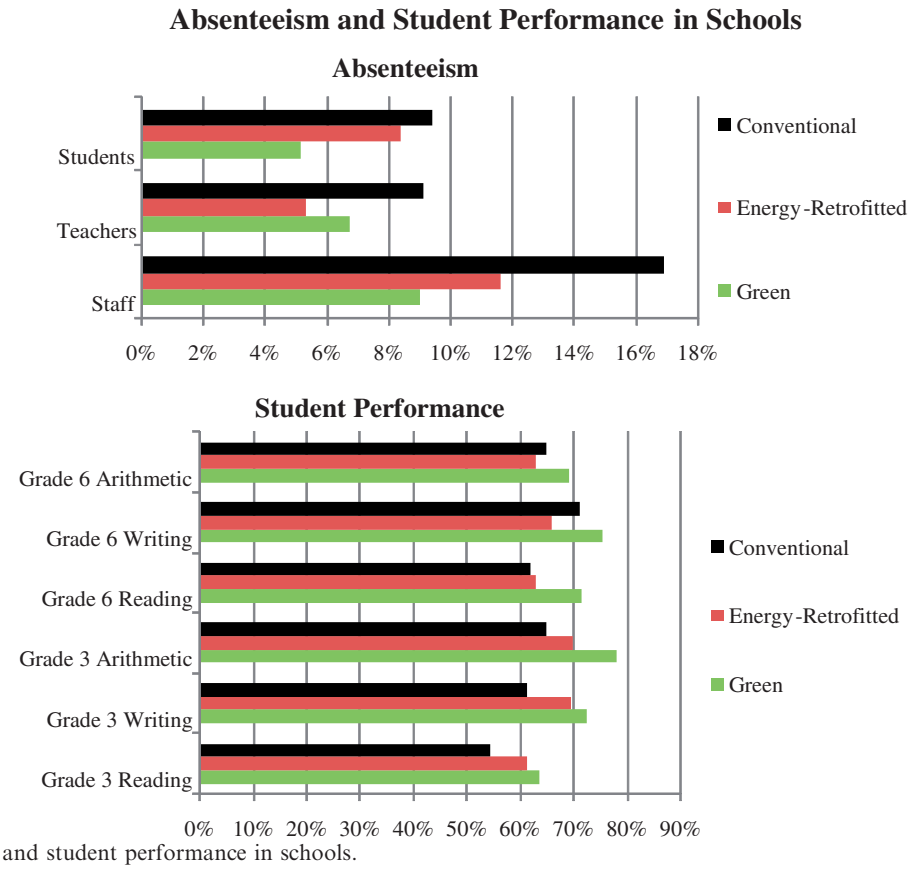

Fig. 6. Absenteeism and student performance in schools.

test results also showed that school category had a statistically significant effect on teacher absenteeism ($p = 0.00$), but not on student ($p = 0.18$), or staff absenteeism ($p = 0.06$). A strong positive association was found between school category and teacher absenteeism ($R = 0.63$, $p = 0.00$). This association is the strongest of all associations investigated in this study. The Tukey test results showed that the only statistically significant difference in teachers' absenteeism is that between energy-retrofitted and conventional schools, with the former being 3.5% lower than the latter ($p = 0.00$).

Even though this is the only statistically significant difference, it is important to note that absenteeism rates do indeed decrease in energy-retrofitted schools and more so in green schools for other groups of occupants. Nevertheless, none of those differences are statistically significant. As shown in Figure 6, students', teachers' and staffs' absenteeism in energy-retrofitted schools was 1%, 3.5% and 5% lower respectively, than in conventional schools. Students', teachers' and staffs' absenteeism in green schools was 3% lower, 1.5% higher and 2.5% lower respectively, than in energy-retrofitted schools. Green schools' student, teacher and staff absenteeism was also 4%, 2% and 7.5% lower than conventional schools'.

Student Performance

The MANCOVA test results showed that school category did not have a statistically significant effect on student grades even though these were higher in some energy-retrofitted schools and in all green schools ($p = 0.73$ for both). Figure 6 shows how Grade 3 students in energy-retrofitted schools did 2.5–8% better on reading, writing and arithmetic tests than students in conventional schools. Grade 3 and 6 students in green schools also did 2.5–17.5% better in all tests than students in energy-retrofitted schools, and 8–19% better than students in conventional schools. Nevertheless, none of those differences were large enough for them to be statistically significant.

Challenges and Problems Facing Schools

The Kruskal–Wallis test results showed how school category had a statistically significant effect on teachers' ranking of three of the five available problems: overcrowding ($p = 0.03$), lack of natural lighting ($p = 0.00$) and poor maintenance, cleaning and repair services ($p = 0.03$). Table 3 shows how teachers in green schools ranked the lack of natural lighting as their least important problem, whereas teachers in conventional schools ranked it as their

Table 3. Challenges facing every category of schools

Ranking	Conventional schools	Energy-retrofitted schools	Green schools
1	Poor maintenance, cleaning, and repair services	Poor HVAC	Poor maintenance, cleaning and repair services
2	Poor HVAC	Poor maintenance, cleaning and repair services	Poor HVAC
3	Lack of natural lighting	Overcrowding	Overcrowding
4	Overcrowding/high noise levels	Lack of natural lighting	High noise levels
5		High noise levels	Lack of natural lighting

third most important. This difference in ranking was the only statistically significant difference between any two school categories for any of the five problems ($p = 0.00$).

The Kendall's CC showed how teachers in every group of schools tended to agree on the specific problems facing their schools (CC = 0.73 for conventional schools, CC = 0.69 for energy-retrofitted schools, and CC = 0.59 for green schools). The Friedman test results also showed a statistically significant overall difference in the ranking of the problems facing every group of schools ($p = 0.00$ for all). The pairwise comparison of ranking means using the Wilcoxon Matched Pairs test showed how teachers in conventional and energy-retrofitted schools saw poor HVAC (p between 0.00 and 0.20 for conventional, p between 0.00 and 0.05 for energy-retrofitted) and poor maintenance, rehabilitation and cleaning (p between 0.00 and 0.20 for conventional, p between 0.00 and 0.05 for energy-retrofitted) as the two most important problems facing their schools when compared with other problems. Teachers in green schools also ranked the lack of natural lighting as their least important problem ($p = 0.02$ for all comparisons). Table 3 shows the ranking of all problems for the three school categories.

Discussion

The results showed statistically significant differences in teachers' satisfaction with different aspects of the indoor environment between every two school categories. This was not true, however, for absenteeism and student performance. Even though absenteeism rates decreased by 2–7.5% and student performance increased by 2.5–17.5% in green schools; most of the differences between every two school categories were not statistically significant. These results cannot therefore be extended to the general population of Toronto schools.

These results showed how occupant satisfaction with the lighting, thermal comfort, indoor air quality, heating ventilation and air conditioning of indoor environments improved in green buildings. However, occupant satisfaction with acoustics decreased. These results are in line with other findings of the literature [9,11,14] and raise therefore legitimate concerns about the quality of acoustics in green buildings. These concerns are justified given that current environmental rating schemes such as LEED do not take into account the quality of acoustics in their assessments. While this might explain why occupant satisfaction with acoustics would not be higher than in conventional ones, it does not explain why it would be lower. One potential explanation could be related to occupant bias. Because of their expectation that green indoor environments would improve acoustics the same way it improved other aspects such as thermal comfort and indoor air quality, occupants might have rated acoustics lower than it deserved to be. Whether this explanation holds true or not, these results confirm the need to incorporate acoustics in current discussions aiming to improve existing sustainability rating schemes.

Despite the statistical significance of the survey results, the difference in teachers' satisfaction levels was not numerically significant. Energy-retrofitted schools only provided a slightly improved environment for teachers than conventional schools, and green schools only provided a slightly improved environment for their occupants than both energy-retrofitted and conventional ones. Whether these small increases in satisfaction levels justified the cost investment required to retrofit and green these schools, remains to be seen.

Given the importance of absenteeism and performance as major indicators of health and productivity, the fact that related results are not statistically significant is disappointing. That observation aside, the results did indeed show that absenteeism rates would decrease and student performance would increase in green buildings for the sample studied. These findings are in line with earlier research findings [2,3,5,6,8]. The lack of statistical significance could be due to the size of the sample studied. A larger sample might have provided the statistical evidence needed to generalise those results to the

population of Toronto schools. Therefore, future research should focus on investigating absenteeism and performance in a larger sample. It should also focus on investigating how potential improvements in health and productivity could affect long-term usage costs, and whether those improvements and related usage cost savings justify the higher cost premium of these buildings.

Conclusion

This study built and expanded on the work of previous studies in the field. The significance of the study stems from it being one of the first to focus on Canadian green buildings, and Canadian green schools in particular. The study was also one of the first to compare quantitative aspects of usage such as absenteeism and student performance between conventional and green buildings. Because of its scope, the study would be of particular interest to practitioners and researchers looking to appraise investments in indoor green environments from a usage occupant perspective.

This study provided the empirical evidence needed to conclude that green indoor environments can and do offer more comfortable environments for their occupants. When compared with more conventional buildings, green buildings offer indoor environments with better ventilation, indoor air quality, better lighting and thermal comfort that could lead to more comfortable environments. These greener indoor environments are also associated with improved health, as evidenced by lower absenteeism rates, and improved productivity, as evidenced by increased occupant performance. Nevertheless, more research is needed to provide the statistical evidence to generalise these benefits of lower absenteeism and improved performance to larger populations. More research is also needed to explore the issue of acoustics, which for some, remains an important area of concern.

This study is part of a larger one conducted by the University of New Brunswick Construction Engineering and Management Group in collaboration with the Toronto District School Board. This larger study aims to analyse the whole life costs of Toronto schools. It aims to address one major barrier to the objective evaluation of the costs and potential benefits of green buildings: that of the lack of quantitative data relating initial investment to whole life costs. This paper provides a stepping stone towards the attainment of such goal.

This study makes the case for the need to objectively re-evaluate the economic long-term performance of green buildings from a usage perspective, away from current efforts focused exclusively on trying to justify the economic viability of green buildings. Since research in this field is still in its early stages, it is important that a healthy debate that incites researchers to explore the different sides of the issue is encouraged. Future research needs to focus primarily on investigating whether any potential improvements in long-term performance of green buildings would justify the additional capital time and cost investments needed to design and construct green buildings.

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