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Research Paper

Perception of daylighting in southern and northern classrooms of a high school in Tabriz-Iran: a questionnaire survey

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Abstract

Orientation of classrooms is an important challenge in architectural design of a school. However, there is a lack of appropriate knowledge about influence of orientation on students' perception of daylighting in classrooms. This paper presents a questionnaire survey that was conducted to compare students' perception and satisfaction with daylighting in classrooms of a high school in Tabriz, Iran. Statistical analysis of responses was done to identify daylight factor and their relationships with satisfaction with daylighting in northern and southern classrooms. In southern classrooms, satisfaction with daylighting had significantly negative and positive correlation with perception of reflected and direct glare, respectively. In northern classrooms, perception of unified daylight and control of sunlight overheating by operable windows had significantly strong and positive correlation with satisfaction with daylighting, respectively. The students' seating location had significant influence on satisfaction with daylighting and perception of direct glare in southern classrooms. In northern classrooms, students' seating location caused different perception of reflected glare. The results showed that orientation did not lead to significant difference between satisfactions with daylighting in northern and southern classrooms. Although, in southern classrooms, the mean votes of satisfaction with daylighting was higher than northern classrooms.

Keywords: *Perception, Daylighting, Southern classrooms, Northern classrooms, High school, Tabriz.*

1. INTRODUCTION

"Lighting and illumination" are main criteria for achieving Indoor Environmental Quality (IEQ). In schools, suitable IEQ helps increase satisfaction and performance of students. According to Yang et al. [1], spatial and ambient attributes constitute student's perception of the classrooms. Their study showed that daylighting and sunlight can impact visibility and thermal qualities of the classrooms. Controlled sunlight prevents unwanted heat gain and subsequent indoor thermal discomfort. Baird (2015) described user's perception of sustainability in buildings. He explained strategies like maximizing daylighting, minimizing glare and preventing unwanted heat gain as lighting related criteria of IEQ [2]. In UAE, Fadeyi et al. showed the lack of use of daylighting and glare control in elementary classroom [3]. A questionnaire survey showed that satisfaction with daylighting, external obstruction as physical factor and perception of uniformity are main factors for luminous comfort in residential buildings [4].

Influence of orientation was investigated in student's dormitory in Serbia [5]. Orientation of classrooms is a challenge for architects in designing of schools. It has considerable impacts on IEQ of classrooms. In this study, it is intended to find out that which orientation of the classrooms is preferred by students with respect to daylighting and what differences can be recognized in the students' perceptions. So, the students' perceptions and their satisfaction with daylighting are explored in a school regarding south- and north- oriented classrooms.

2. DESCRIPTION OF SCHOOL BUILDING

The location of school is in Tabriz, the northwestern city in Iran. Tabriz has been located at 38.06° north latitude and 46.3° east longitude. The city has cold and arid climate. Architecture is taught in the selected girls' high school. The high school building has east-west orientation. It has 6 north- and 6 south-oriented classrooms. The selected classrooms were furnished with

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drafting tables. Walls of the classrooms have plaster coating with white color. There is not any external obstruction preventing penetration of solar radiation to the internal spaces of classrooms. The classrooms have two wooden windows without any shading in the external walls. Window to wall area ratio is 60% for each external wall. The interior wall of each classroom which is in opposite of the exterior wall has small operable strip windows. These windows can be opened to the central court. Window to wall area ratio of these interior walls is around 10%. Daylight level of interior spaces can be controlled with internal curtains. These curtains are used for reduction of glare (direct or reflected) and prevention of overheating caused by sunlight (Fig. 1). Natural ventilation by operable windows is also used to compensate overheating caused by sunlight. Fig. 2 shows second floor plan of the school.

Fig. 1 Daylight control of a classroom with internal curtains and the use of artificial lighting

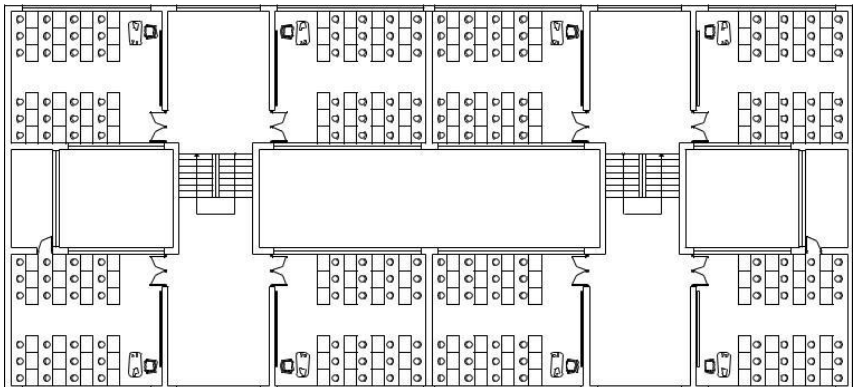


Fig. 2 Second floor plan of the high school

3. LIGHTING ATTRIBUTES INFLUENCING STUDENTS' PERCEPTION OF CLASSROOMS

Based on literature review and the goal of this study, subjects related to daylighting in classrooms can be divided into four issues: 1. Daylight quality, 2. Thermal effects of daylighting, 3. Daylight control, 4. Student's satisfaction with daylighting (Fig. 3).

Unified daylight distribution, direct glare and reflected glare are considered as perceptible factors of the daylight quality. The thermal effects of daylighting are divided into passive heating and sense of sunlight in winter and overheating. In following section, daylight properties and their related issues in this survey are described briefly.

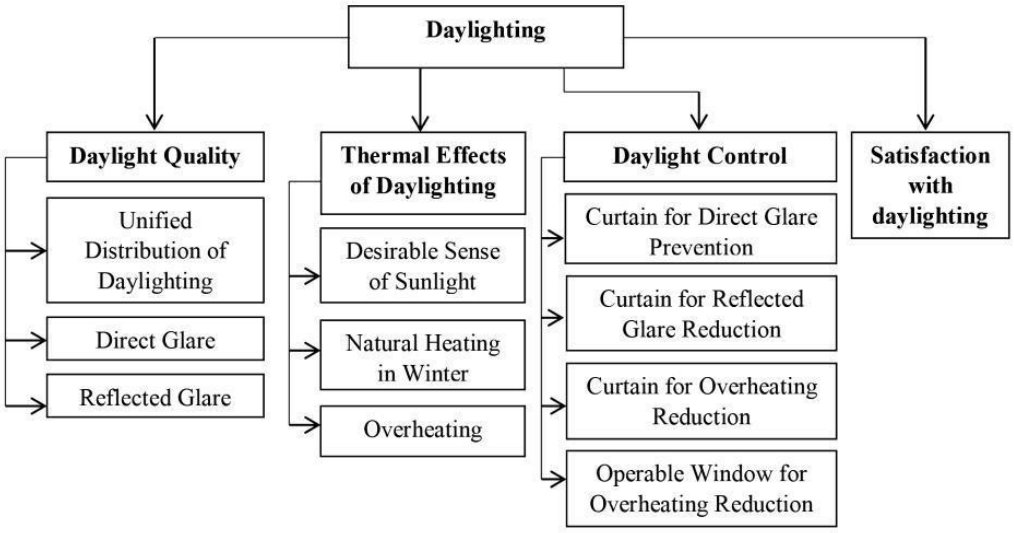


Fig. 3 Subjects related to daylighting in classrooms

3.1. Daylight Quality

The students were asked to indicate their feeling about daylight distribution and glare conditions in the classrooms. Inappropriate daylight distribution and glare can cause dissatisfaction of daylight quality of classrooms and lower students' performance. High unified daylight distribution provides better visual comfort for students. In classrooms, reflected glare can be seen in white/blackboards or other display facilities.

3.2. Thermal Effects of Daylighting

Daylighting and especially sunlight could have effects in buildings and their occupants in terms of thermal comfort, energy consumption, health and occupants' performance. Students can feel thermal effects of natural lighting. Natural heating in winter and desirable sense of sunlight are indicated as thermal benefits of natural lighting. Overheating caused by sunlight is expressed as sunlight thermal disadvantage.

3.3. Daylight control

In the studied school, students used internal curtains for prevention of overheating caused by sunlight. Sometimes, they opened windows for natural ventilation. In the questionnaire, students were asked about the use of curtain and operable windows for overheating reduction caused by sunlight.

4. SURVEY METHODOLOGY

Survey-based investigations were conducted for analyzing the students' daylight perception. Participated groups were freshman, sophomore and junior students of the high school.

The questionnaires were distributed between the students in four sunny days in December 2014. In first, some information was described about the questionnaire. Then, the students were asked to response within half an hour. The students of two classrooms were participated in survey per day. The questionnaire survey was performed from 10 A.M. to 12 P.M.

In the first part of the questionnaire, the students were asked to provide general information like school year and seating location in the classrooms. The students highlighted their seating location in provided plan of their classroom in the questionnaire (Fig. 4). The students' responses were collected to explore the relationship between general information with their daylight perception and satisfaction with daylighting.

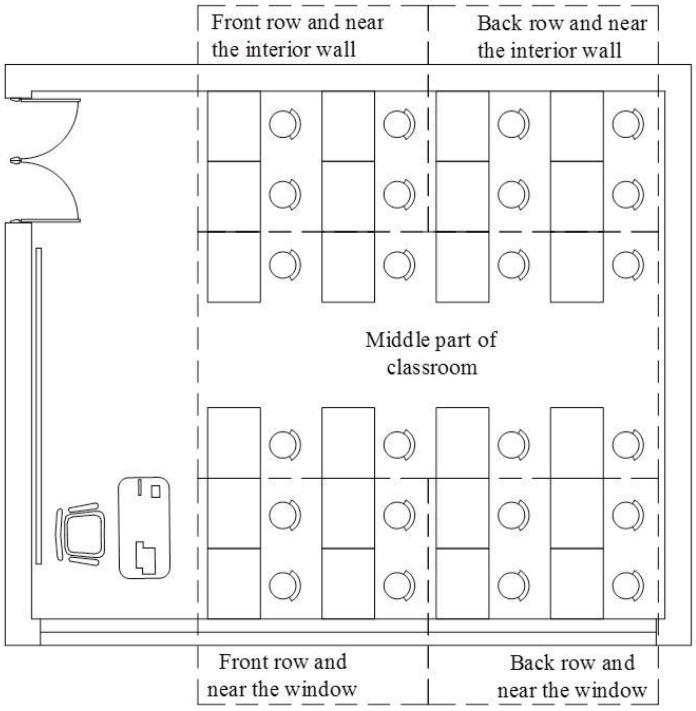


Fig. 4 Plan of the students' seating location in classrooms

Next parts of the questionnaire introduced some questions with five point Likert responses. The second part of the survey, students were asked to rate the satisfaction with daylighting of their classrooms. In following parts, students were asked to assess and identify daylight quality, thermal impacts of daylighting and the use of daylight control.

Fig. 5 shows the questionnaire used in this study.

Questionnaire of Daylighting Perception and Control in Classrooms

Part 1: General Information:

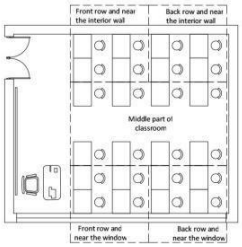
1. Orientation of classroom

Northern classroom □	Southern classroom □

2. Students:

Freshman □	Sophomore □	Senior □

3. Highlight your seating location in below figure



Part 2: Satisfaction with Daylighting

1. How much satisfaction do you feel with daylighting of your classroom?
   1) Very low 2) Low 3) Average 4) High 5) Very high

Part 3: Daylight Quality

2. How much do you feel unified daylight distribution in your classroom?
   1) Very low 2) Low 3) Average 4) High 5) Very high
3. How much do you feel direct glare in your classroom?
   1) Very low 2) Low 3) Average 4) High 5) Very high
4. How much do you feel reflected glare in your classroom?
   1) Very low 2) Low 3) Average 4) High 5) Very high

Part 4: Thermal Effects of Daylighting

5. How much do you feel sense of sunlight heating in your classroom?
   1) Very low 2) Low 3) Average 4) High 5) Very high
6. How much do you feel natural heating (sunlight and daylight) in your classroom?
   1) Very low 2) Low 3) Average 4) High 5) Very high
7. How much do you feel overheating caused by sunlight in your classroom?
   1) Very low 2) Low 3) Average 4) High 5) Very high

Part5: Daylight Control

8. How much do you use curtain for direct glare reduction in your classroom?
   1) Very low 2) Low 3) Average 4) High 5) Very high
9. How much do you use curtain for overheating reduction caused by sunlight in your classroom?
   1) Very low 2) Low 3) Average 4) High 5) Very high
10. How much do you open windows for overheating reduction caused by sunlight in your classroom?
    1) Very low 2) Low 3) Average 4) High 5) Very high

Fig. 5 The questionnaire used in this study

4.1. Population and Sample

The research population was formed of the students of the girls' high school in Tabriz- Iran. A total number of 270 students were identified. 135 students have been located in classrooms of each orientation.

The required sample size could be considered as 100 respondents for each orientation in accordance with Cochran's calculation [6]. With a 95% confidence level, the margin of error is 5%. In other words, the participation of 200 students was needed for this survey. Table 1 shows number of the students' population and their participation in this survey.

Table 1 Number of the respondents involved for northern and southern classrooms

	South- oriented classrooms		North- oriented classrooms		Sample
	Respondents	Population	Respondents	Population	
Freshman students	32	45	32	45	100 respondents out of 135 population for each orientation
Sophomore students	33	44	27	38	
Senior students	35	46	41	52	
Total	100	135	100	135	

4.2. Statistical Analysis

The gathered data was accurately inputted to SPSS19. First, reliability of the questions was tested for determining their consistency. The Cronbach's alpha coefficient was used to estimate internal consistency of the questions. Normality test was performed to determine analysis methods. Based on results of the normality test, none-parametric Mann-Whitney test was applied to show the existence of significant difference between daylight factors in the south- and north-oriented classrooms. Kruskal

Wallis's test was performed to show existence of significant differences in the students' satisfaction with daylighting and daylight perceptions regarding their seating location. Like Dahlan et al. [7], Friedman test, as prioritization method, was used for analysis of the students' perceptions. Friedman test revealed the mean ranks of studied factors in the north- and south-oriented classrooms. Finally, the mean ranks of factors of each orientation were compared.

4.3. Reliability of the Questions

In statistical analysis, the reliability of a psychometric test is performed with Cronbach's alpha. Ten daylight perceptual features of classrooms were involved in this analysis. These features were satisfaction, distribution, direct and reflected glares, desirable sense of sunlight, natural heating, overheating caused by sunlight, glare control, natural heating control and use of natural ventilation. Acceptable amount of alpha in psychometric theory is suggested to be more than 0.7 [8]. SPSS analysis revealed that Cronbach's alpha coefficient is 0.84 for this survey.

This amount represents good reliability and suitable internal consistency of the questionnaire.

4.4. Normality Test

The result of Kolmogorov-Smirnov normality test shows p-values< 0.05 for all factors. So, normal distribution of data is rejected and nonparametric tests are performed for SPSS analysis.

5. RESULTS AND DISCUSSION

5.1. Statistical Scores

Mean votes of daylight perception for southern and northern classrooms are presented in Fig. 6. It shows that the mean vote of daylight satisfaction in southern classrooms is higher than northern classrooms, whilst in northern classrooms, students feel more unified daylight distribution than southern classrooms. Difference between perceptions of reflected glares in south- and north-oriented classrooms is less than difference between perceptions of direct glares in these classrooms. In southern classrooms, students realized thermal function of daylighting more than northern classrooms.

Although, daylighting caused overheating in the southern classrooms, students indicated that they had more desirable sense of natural heating in winter. It could be seen in Fig. 6 that students in southern classrooms used more control of daylighting than their colleagues in northern classrooms. They used curtain for glare prevention more than heat prevention. In northern classrooms, students recovered overheating with the use of natural ventilation rather than the use of window curtains.

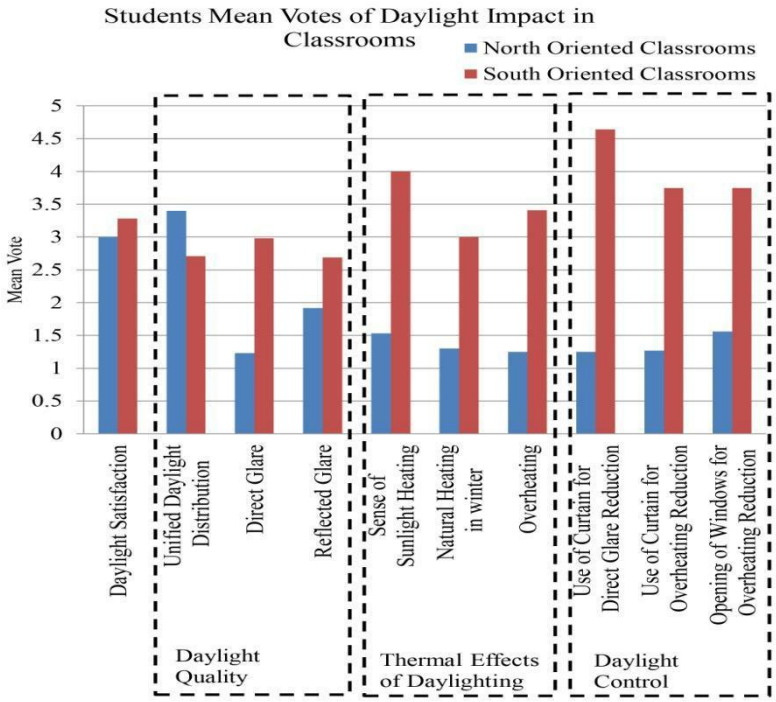


Fig. 6 Comparison of the students' perception and satisfaction mean votes for southern and northern classrooms

5.2. Comparison of Scores Regarding Orientation

Mann-Whitney U tests was done to explore existence of difference between various factors in southern and northern classrooms (Table 2).

The results show that there is no significant difference between satisfaction with daylighting in southern and northern classrooms ($p>.05$). While, the rest of variables have significant difference in their mean ranks related to the orientation ($p<0.05$).

	Orientation	Z	Median	Mean Rank	Sum of Ranks	Mann-Whitney U	Asymp. Sig. (2-tailed)
Satisfaction with daylighting	North	-1.747	3	93.62	9361.50	4312	.081
	South		3	107.38	10738.50		
Perception of unified daylighting	North	-4.894	3	119.60	11960.50	3090	.000
	South		3	81.40	8139.50		
Perception of direct glare	North	-9.369	1	65.11	6511.00	1461	.000
	South		3	135.89	13589.00		
Perception of reflected glare	North	-3.738	2	86.00	8600.50	3550	.000
	South		3	115.00	11499.50		
Sense of sunlight	North	-11.534	3	54.50	5450.50	400.5	.000
	South		4	146.50	14649.50		
Perception of natural heating in winter	North	-9.617	2	63.55	6355.00	1305	.000
	South		3	137.45	13745.00		
Perception of overheating	North	-12.038	2	53.44	5344.00	294	.000
	South		3	147.56	14756.00		
Use of curtain for glare reduction	North	-12.797	3	52.42	5242.50	192.5	.000
	South		5	148.58	14857.50		
Use of curtain for heating reduction	North	-11.988	2	53.43	5343.00	293	.000
	South		4	147.57	14757.00		
Use of operable windows	North	-10.756	2.5	57.66	5765.50	715.5	.000
	South		4	143.34	14334.50		

The mean rank of feeling of unified daylight in northern classrooms is higher than southern classrooms.

The rest of factors in southern classrooms have higher mean rank rather than northern classrooms (Fig. 7).

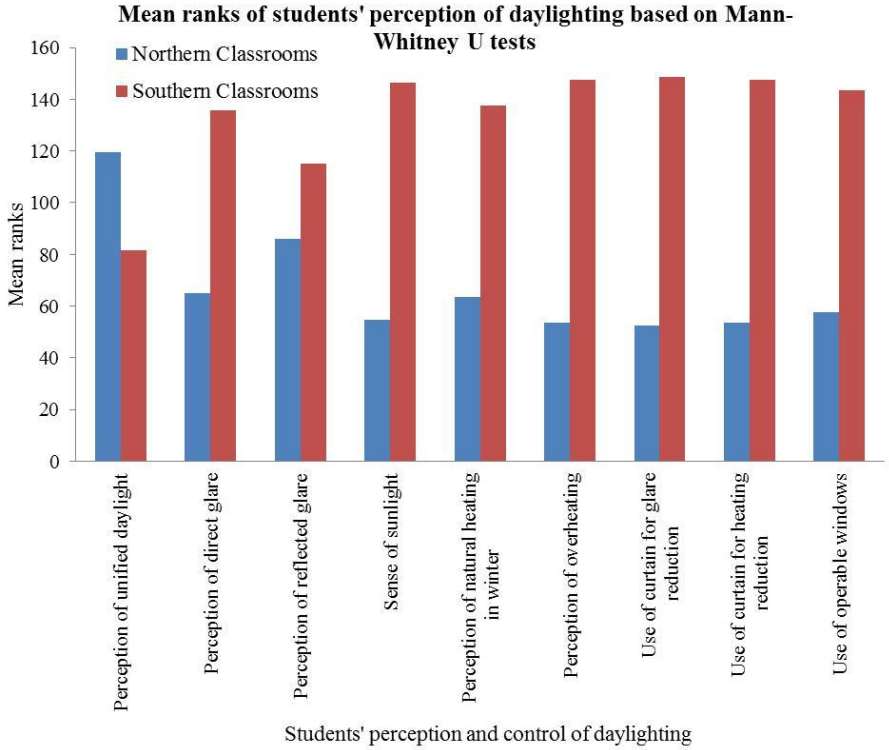


Fig. 7 Comparison of the mean ranks of perception of daylight features in southern and northern classrooms

The results of Spearman test indicate that unified daylight and the use of operable windows have strong and significantly positive correlation (P<0.01) with satisfaction with daylighting in northern classrooms (Table 3). Overheating has a correlation coefficient with P-value lower than 0.05. The other factors have poor P-values and lower correlation coefficients indicating that they do not have significant correlation with satisfaction with daylighting.

In southern classrooms, perceptions of reflected and direct glares have strong correlation (P<0.01) with satisfaction with daylighting. These correlations are significantly negative and positive for reflective and direct glares, respectively (Table 3).

Table 3 Spearman rank correlation coefficients of satisfaction with daylighting in northern and southern classrooms

	Orientation	Perception of unified daylight	Perception of direct glare	Perception of Reflected Glare	Sense of sunlight	Perception of natural heating	Perception of overheating	Use of curtain for glare reduction	Use of curtain for heating reduction	Use of operable windows
Satisfaction with daylighting	North	.322[a]	.049	.034	.179	-.063	.229[b]	.010	-.159	.270[a]
	South	.065	.310[a]	-.320[a]	-.071	-.058	.103	.006	.085	.005

[a]Correlation is significant at the 0.01 level (2-tailed).[b]Correlation is significant at the 0.05 level (2-tailed).

5.3. Friedman Test

This test is applied for determination of the rank obtained from ordinal data. Ordinal data are not independent measures. The results of Friedman test consists of hierarchy of ranks given for each daylight factors of the classrooms in accordance with the students' votes. The highest mean rank is represented as the most influential daylight factor and vice versa.

Friedman test was done for both orientations. P-Values are 0.000<0.05 for two groups. Chi- squares are 224.725 and 390.625 for south- and north-oriented classrooms, respectively. The results of Friedman test for southern classrooms show that the use of curtain for direct glare reduction, sense of sunlight, the use of curtain for sunlight heating reduction and the use of operable windows for overheating prevention have 1-4th positions in the mean ranks (Fig. 8).

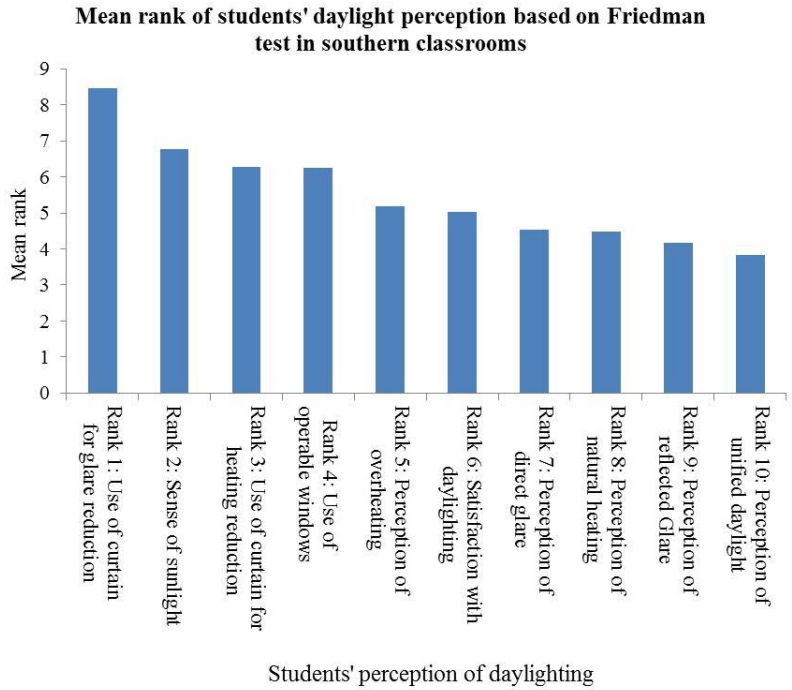


Fig. 8 The mean ranks of the students' perceptions of daylighting based on Friedman Test for southern classrooms

In northern classrooms, Friedman test indicated perception of unified daylight, satisfaction with daylighting, perception of reflected glare and sense of sunlight as top-ranked variables. In other words, daylight control and sense of sunlight have high mean rank values for the students of southern classrooms. In northern classrooms, quality of daylighting and sense of daylighting achieved high mean ranks (Fig. 9).

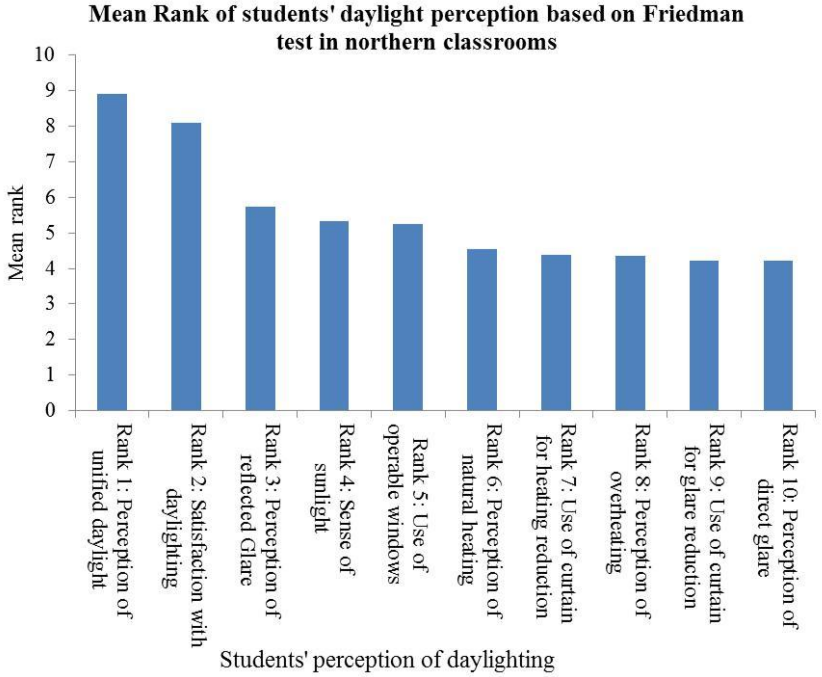


Fig. 9 The mean ranks of the students' perceptions of daylighting based on Friedman Test for northern classrooms

Southern classrooms have lower difference level in rankings (chi-square=224.725) than northern classrooms (chi-square=390.625). It indicates that ranks between daylight features in southern classrooms represent closer degree of difference than ranks in northern classrooms.

5.4. Seating Locations Factor

The results of a Kruskal Wallis tests revealed significant differences between the students' seating locations and satisfaction with daylighting and perception of direct glare in southern classrooms ($p<0.05$). While, the results showed that perception of reflected glare could have significant difference related to the students' seating locations in northern classrooms ($p<0.05$) (Table 4).

Table 4 Kruskal Wallis tests regarding students' seating locations

	P-values for students' sitting locations	
	Southern Classrooms	Northern Classrooms
Satisfaction with daylighting	.002*	.329
Perception of unified daylighting	.358	.566
Perception of direct glare	.009*	.106
Perception of reflected glare	.317	.031*
Sense of sunlight	.699	.062
Perception of natural heating in winter	.424	.717
Perception of overheating	.851	.117
Use of curtain for glare reduction	.428	.831
Use of curtain for heating reduction	.359	.778
Use of operable windows	.846	.079

In north-oriented classrooms, the students located in the front row and near the interior wall had the highest mean rank of perception of reflected glare. While, the students with seating location in the back row and near the window had the lowest mean rank of perception of reflected glare in comparison to other students (Fig. 10).

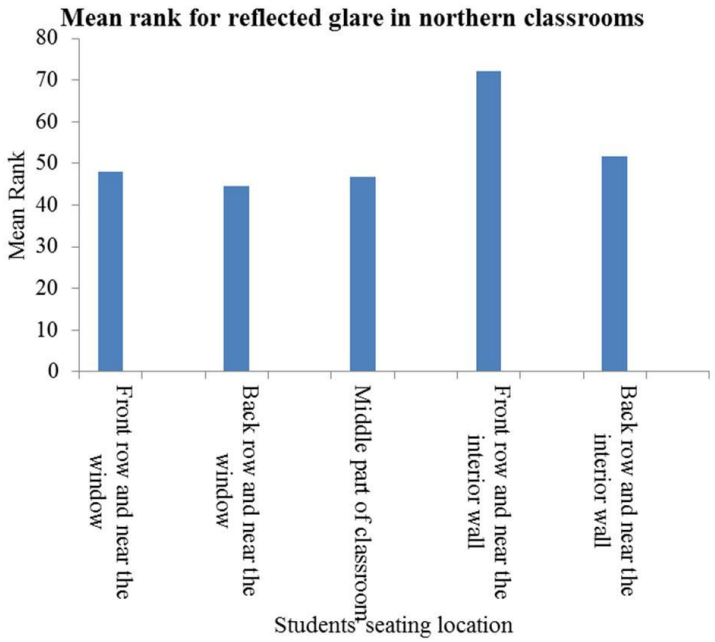


Fig. 10 Kruskal Wallis test for the mean rank of perception of reflected glare in northern classrooms

In south-oriented classrooms, the students with seating location in the front row and near the window had the highest mean rank of daylight satisfaction. While, the students were located in the back row and near the interior wall had the lowest mean rank of daylight satisfaction (Fig. 11).

In southern classrooms, the students seated in the front row and near the window had the highest mean rank of perception of direct glare. While, the students seated in the front row and near the interior wall had the lowest mean rank of perception of direct glare (Fig. 11).

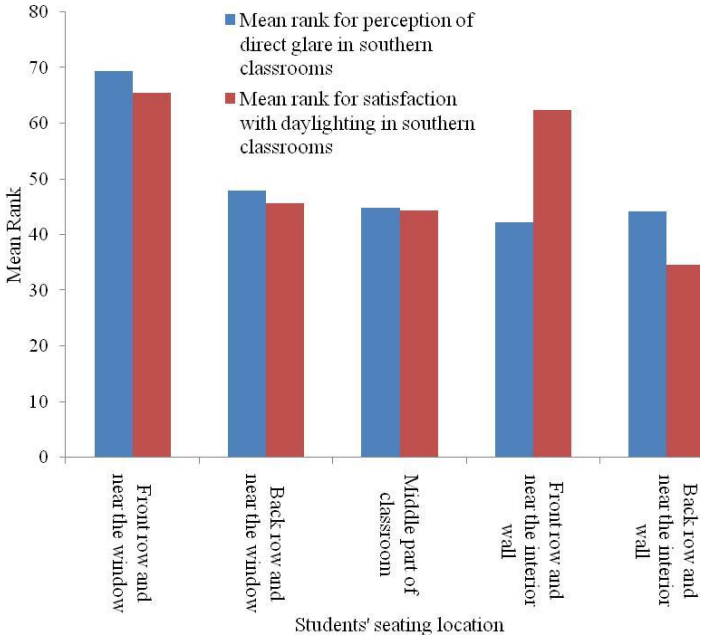


Fig. 11 Kruskal Wallis test for mean rank of satisfaction with daylighting and direct glare in southern classrooms

6. DISCUSSION

The 200 valid responses to the questionnaires were collected about the students' feelings of daylighting in their classrooms. The results showed that students have different feelings and priorities of daylighting in south-and north- oriented classrooms. The whole study concentrated on comparing students' feelings of daylight quality, thermal effects, daylight control behaviors and satisfaction with daylighting in south- and north-oriented classrooms. It should be mentioned in this case study, the role of other daylight control equipments like awnings and external blinds have not been explored regarding architectural properties of the selected school.

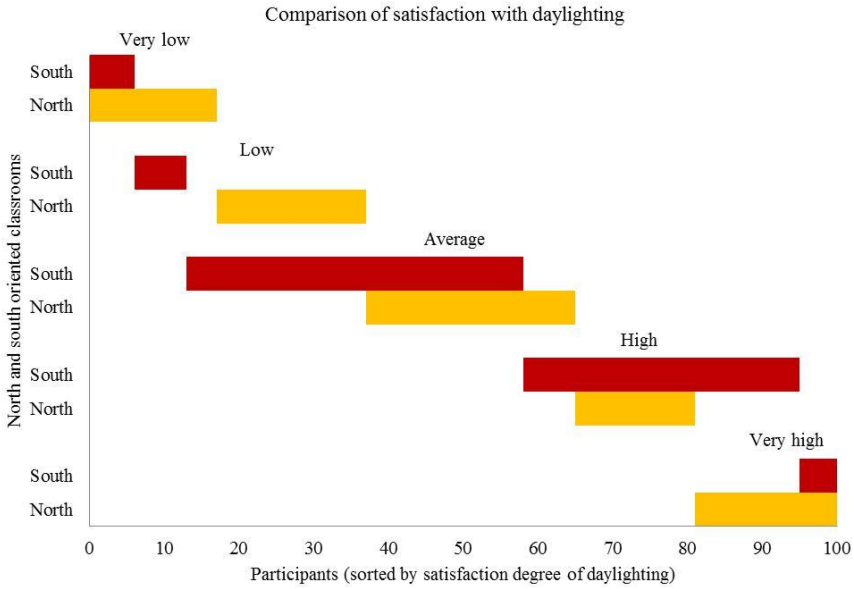


Fig. 12 Comparison of students' satisfaction degree with daylighting for southern and northern classrooms

Fig. 12 shows that in southern classrooms, majority of the students' satisfaction votes were concentrated on average and high range. While, in northern classrooms, the students' satisfaction votes were distributed in steady rhythm. The results show that 24% of the students feel less dissatisfied with daylighting in south-oriented classrooms rather than the north-oriented classrooms. These results are in congruence with a previous research by Jovanovc et al. [9]. They indicated that students prefer southern rooms in their dorm rooms regardless of the fact that they are more frequently overexposed to direct sun [9]. In northern classrooms, daylighting quality including perception of unified daylight, direct and reflected glare seems more acceptable than southern classrooms. While, in southern classrooms, the students feel thermal effects of daylighting more than northern classrooms and consequently, the use of daylight control strategies is more than northern classrooms. Perception of high level of glare and low level of unified distribution of daylighting do not cause less satisfaction of students in southern classrooms in comparison with northern classrooms. According to the results, perception of reflected glare had the strongest and negative correlation with satisfaction with daylighting and perception of direct glare had positive correlation with satisfaction with daylighting in southern classrooms. It seems in the southern classrooms, satisfaction with daylighting is not diminished with perception of high level of direct glare. Xue et al. indicated that the glare problem had a low correlation with satisfaction with daylighting in their residential survey [4]. But, in educational aims, it seems acceptable that high level of reflected glare can decrease satisfaction with daylighting. The results also indicated that the use of curtain for direct glare reduction and sense of sunlight have the highest mean rank in southern classrooms, respectively. In fact, daylight control and sense of sunlight have gained high ranks in the students' votes in southern classrooms. It confirms the importance of sense of sunlight conducted in other studies [4, 10].

In northern classrooms, perception of unified daylight had strongest positive correlation with satisfaction with daylighting.

Opening of windows and perception of overheating also had next positive and strong correlation with daylight satisfaction in northern classrooms. In other words, the students' satisfaction could have direct correlation with thermal effects of daylighting and its control in northern classrooms. It indicates that more feeling of natural heating of sunlight in northern classrooms can promote the students' satisfaction.

In southern classrooms, the students' seating location had significant influence on their satisfaction with daylighting and direct glare perception. The students seated in the front row, near the window felt the most satisfaction with daylighting and direct glare. It may be due to cold winters of Tabriz, the city with cold and arid climate, and existence of glare control with internal curtains. The lowest mean ranks of daylight satisfaction and perception of direct glare feeling were specified for the back row, near the interior wall and the front row, near the interior wall, respectively. In northern classrooms, the students' seating location has significant influence on perception of reflected glare. The students seated in the front row, near the interior wall had highest mean rank of perception of reflected glare. It can be related to near distance of seating location and reflected sunlight from black/whiteboard of the classrooms. While, the students seated in the back row, near the window is not influenced considerably with reflected glare.

7. CONCLUSION

A questionnaire survey was conducted to study and compare the effects of daylighting in south- and north-oriented classrooms of a high school in Tabriz, Iran. Based on the analysis of data, the following conclusions about daylighting in southern and northern classrooms can be drawn:

1) According to Mann- Whitney U tests, there is no significant difference between satisfactions with daylighting in north- and south-oriented classrooms. But, the students' mean votes of satisfaction with daylighting for southern classrooms were higher than northern classrooms.
2) According to Mann- Whitney U tests, there are significant differences between daylight factors in southern and northern classrooms. The students felt more unified daylight in northern classrooms, while they felt more glare and sunlight in southern classrooms. They also used more daylight control strategies in southern classrooms.
3) Spearman rank correlations showed that satisfaction with daylighting had negative and positive correlation with perception of reflected and direct glare in southern classrooms, respectively. In northern classrooms, perception of unified daylight and use of operable windows had positive and strong correlation with satisfaction with daylighting, respectively. Perception of overheating had P-value<0.05 and significant correlation with satisfaction with daylighting in northern classrooms. It indicates that increasing of thermal effects of daylighting and its control could promote daylighting satisfaction in northern classrooms.
4) Friedman test revealed that the use of curtain for direct glare prevention, sense of sunlight and the use of curtain for overheating reduction have the highest mean ranks in southern classrooms, while in northern classrooms, perception of unified daylight, satisfaction with daylighting and perception of reflected glare have the highest mean ranks.
5) According to Kruskal Wallis tests, the students' perception was influenced by their seating location in classrooms. Satisfaction with daylighting and perception of direct glare differed significantly by the students' seating locations in southern classrooms. While, in northern classrooms, perception of reflected glare only differed significantly with the students' seating location.
6) In southern classrooms, the students with seating location in the front row and near the window voted the highest mean rank for satisfaction with daylighting regardless their highest mean rank of perception of direct glare. It could be related to cold winter of Tabriz and desirable sense of sunlight in this orientation. In northern classrooms, the students with seating location in the front row and near the interior wall have the highest mean vote of perception of reflected glare.

The results of this study may help to concentrate on daylight features in architectural design. The study revealed that students' senses can be other than prospect estimation. Although, southern classrooms gained high mean vote of perceptions of direct and reflected glare and low mean vote of perception of unified daylight in comparison with northern classrooms, southern classrooms achieved more satisfaction mean votes than northern classrooms. This issue emphasizes on importance of human feelings like desirable sense of sunlight and its psychological and physical health effects. In northern classrooms, satisfaction with daylighting had positive strong correlation with perception of unified daylight, overheating caused by sunlight and its control by operable windows. In southern classrooms, perception of glare had strong correlation with daylight satisfaction. Perception of reflected and direct glare had negative and positive correlations with satisfaction with daylighting, respectively. The use of curtains for glare prevention had the highest mean rank of the students' votes in southern classrooms. This study emphasizes on importance of different daylight control strategies. The students' satisfactions with daylighting were related to the use of curtain and operable windows in southern and northern classrooms, respectively. In other words, the use of different sunlight control strategies can affect the results of the survey. In future studies, it is suggested to explore influences of different daylight control systems and their impact on students' satisfaction and performance.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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