

Junior High School Students' Perception of Physical Factors in the Classroom Based on the Online Q Method

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Students spend a lot of time in the classroom, and the physical environment in the classroom plays an important role in the development of students. It is necessary to scientifically investigate students' views and opinions on the physical factors in the classroom. Due to the COVID-19 pandemic, this study used the Q method online and allowed 40 junior high school students to rank 32 physical factors in the classrooms according to their own perspectives. The results can provide a reference for the reconstruction and construction of classrooms in middle schools and contribute to the design of learner-oriented humanized classrooms.

Introduction

Many researchers have found that the relationship between the classroom and learning environment is very important and that the environment can influence students' behavior [1]. Experts in pedagogy and educational psychology believe that effective education depends on the suitability of the physical and social environment of the classroom [2]. As one of the important elements in the education and learning process, the physical environment in the classroom plays an important role in the development of students [3]. A large number of studies have shown that physical factors in the classroom such as noise [4,5,6], illumination [5,7,8], and spatial layout [9,10] influence students' academic performance [11,12], attention [5,13], emotion [14,15], and physical and mental health [16,17]. Taylor and Vlastos have discovered the relationship between the physical environment and design from a theoretical point of view. They have found that the physical environment of the classroom is like a "silent course" [18], which means that the environmental design can facilitate and improve the learning process as well as the curriculum. In addition, in Reggio Emilia project, the physical environment is referred to as a "third educator" [19]. This shows the importance of the physical environment.

However, the current research on physical environment mostly focuses on the measurement of objective data such as temperature and illumination, and pays little attention to the opinions of students. Moreover, most of the research participants were college students and elementary students, with middle school students being paid the least amount of attention. Students are the main users of classrooms, so it is necessary to plan and design classrooms that meet students' needs and preferences from the "user-centered" perspective. In a subjective survey of students' perception of the classroom environment, interviews or scales are generally used to carry out the survey. For example, Barrett et al. used an open questionnaire to interview primary school students and explore their preference for the school environment [20]. It was found that students' answers were not in the preset range, and the open questionnaire could not reflect students' preference for basic environmental factors in the literature. Vicente and Lorenzo et al surveyed on college and primary school students about their perceptions of the physical environment in the classroom [21,22]. Survey scales are usually predesigned by researchers or experts [23,24,25], and this method has obvious limitations. First, subjects were less deeply researched through the scale. Second, subjects may misunderstand the concepts used in the scale, thus affecting the survey data. Third, subjects mostly choose the neutral option when given a Likert scale.

The Q method is a research method to explain the views, beliefs, motivations, and attitudes of a group of people in a specific background by asking participants to show their operational subjectivity in an ordered form in a prescribed table [26]. Therefore, this study adopted the Q method to investigate the perception of physical factors in the

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classroom of middle school students, externalizing students' internal views into observable and meaningful views [27], and analyzing the importance of physical factors in the classroom from the perspective of students to provide inspiration and suggestions for the improvement of middle school classrooms. The following research questions are proposed: 1) How do junior high school students prefer physical factors in the classroom? 2) what is the reason behind their ranking? Due to the COVID-19 pandemic, the online Q method was adopted in this study, which also avoided personnel and external interference in offline operations.

Study Design

Methods

The Q method was proposed and developed by the British psychologist and physicist William Stephenson in 1935. The Q method was first applied in psychology and economics [28] and applied later in education, mainly concentrated in the last decade. The themes of inquiry in the field of pedagogy mainly include improving students' writing [29], developing students' participation skills [30], exploring conceptual understanding, participation and motivation [31], cognition of foreign language mobile learning [32], and differences in teachers' attitudes toward "electronic schoolbag" [33], which does not involve learning space. In this study, the characteristics of "measurement subjectivity" of the Q method were used to explore junior high school students' perception of physical factors in the classroom. The implementation steps of the Q method include selecting P sets (selecting subjects), collecting Q samples, Q-sorting, interviewing, analyzing data, and factor interpretation.

The purpose of the Q method is to explain the main viewpoints of specific groups and explore patterns within and between individuals based on individuals' views on topics [34]. Therefore, it is not to explore participants' reactions to a single sample but to allow participants to consider the relationship between samples as a whole and make comparisons. Any given sample is meaningful only if it is treated as a whole [35]. The Q method has the following characteristics. First, it combines the advantages of quantitative research and qualitative research, which not only meets the needs of in-depth mining of participants' views and attitudes in qualitative research but also provides statistical data processing in quantitative research. It is a scientific method that objectively measures individual subjectivity [27]. Second, the Q method is self-referential, requiring participants to participate in the collection of samples, and participants' opinions are independent of researchers' opinions. Third, participants are "forced" to order the Q samples according to their subjectivity in the

table of normal distribution, and there will not be an option for all of the answers to the questions to be neutral.

Subjects

In the Q method, the participants are considered variables, called P sets. The Q method does not require a large number of P sets and the researcher only needs to select a small number of participants for the research topic [36]. Some studies indicate that the number of P sets should be 40-60 [37]. There are also studies showing that the quantity ratio of the P set and Q sample should be 1:3 - 1:2 [38]. In this study, 40 junior high students in an urban middle school in Shandong Province, China volunteered to participate in the experiment and were randomly selected as the P sets. P sets included 20 boys and 20 girls with an average age of 14. Prior to the experiment, students and their parents were informed of the purpose and procedure of the experiment, and each student received an email. Only the students who got their parents' permission participated in this survey.

Study environment design and preparation

Collecting Q samples

The Q sample is what the participants rank. In this study, Q samples were collected in the form of an online questionnaire, and each student was asked to list 8-10 physical factors in the classroom. Researchers integrated the factors in the relevant literature. A total of 108 physical factors were collected. Second, a review panel consisting of two experts and three graduate students in the field of learning space conducted two rounds of screening. In the first round, 58 factors were screened. These factors were organized into the form of a Likert scale. Five people were asked to choose the importance level and the researcher chose the factors that scored highest. Cronbach's alpha was 0.962. In the second round, the factors with inclusion relationships were deleted and reduced to 32, and these 32 physical factors were finally determined as Q samples of this study.

Develop online Q sorting website

Through iH5 software design and development of a web page, students fill in online, web background for data collection. Students filled out data forms that were created through iH5 software design.

Interview preparation

A semi-structured interview was conducted with 15 minutes for each student. The interview explored the reason for Q ranking, focusing on "extreme" positions, i.e., the most important (+4), the least important (-4), and the interviewer asked for additional clarification of other important factors.

1. intensity of natural light	5. distance between students and blackboard	9. ventilation opening	13. air conditioning	17. first-aid kit	21. the size of the classroom	25. fire extinguisher	29. the size of the space occupied by individuals
2. controllability of light	6. safe passage	10. the light intensity	14. table and chair comfort	18. the board size	22. reducing noise inside and outside the classroom	26. clock	30. activity area
3. sunshade equipment	7. table and chair neatly placed	11. seat arrangement	15. the window size	19. smell	23. table and chair mobility	27. table reconfigurable	31. floor cleanliness
4. screen sharpness	8. the height of table and chair	12. the number of students	16. sound equipment	20. ventilation number	24. display cabinet	28. green plants	32. the platform location

Degree of importance	most important	←————→					ordinary important	←————→			least important
level	+4	+3	+2	+1	0	-1	-2	-3	-4		
Item number	1	3	4	5	6	5	4	3	1		

Q samples	importance
screen sharpness	+4
distance between students and blackboard	+3
seat arrangement	+3
the size of the space occupied by individuals	+2
fire extinguisher	-3
the number of students	-4

Q samples	importance
intensity of natural light	+4
controllability of light	+3
sunshade equipment	+3
smell	+3
table reconfigurable	-3
table and chair mobility	-3
the platform location	-3
clock	-4

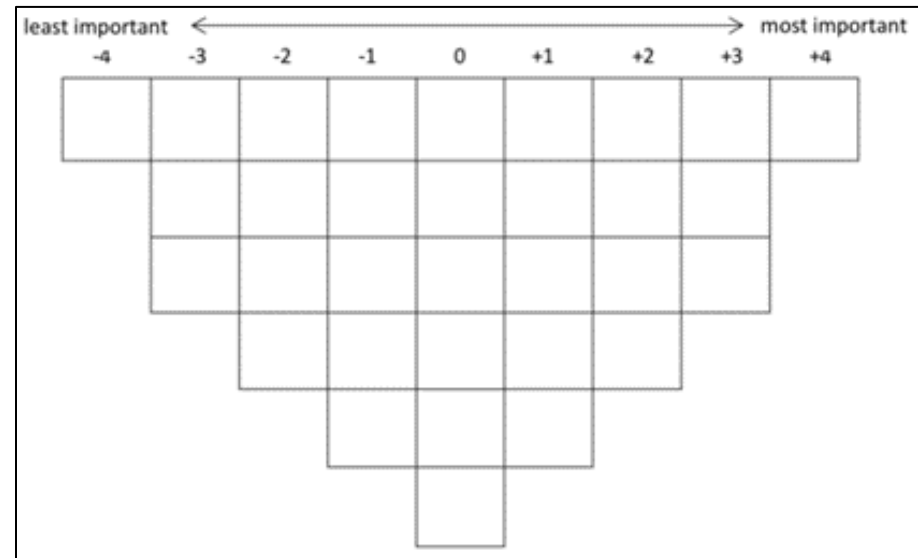


Figure 1. Interface of Q method online (a) Normal distribution table of Q method (b)

Research process

The research process was divided into three parts. Before the experiments, P sets were selected and Q samples were collected. During the experiments, students were asked to carry out Q-sorting and interview online. After the experiments, the data were sorted out and analyzed.

Implementation of online Q method

Q-sorting

Before Q-sorting, 32 Q samples were sent to students by email to ensure that students understood all factors. Then, the online website (as shown in Figure 1(a)) and the demonstration video of the Q method were sent to inform the filling method, steps and matters needing attention. Students carry out Q-sorting according to their own ideas, Q samples cannot be repeated. The number of grades in the normal distribution table of the Q method is generally odd, 9-level or 11-level grades are the most common, and the normal distribution or approximate normal distribution is the most ideal (see Figure 1(b)). The table specifies the order of samples, with the middle having the most cells and going down equally at both ends (see Table 2). In this study, a 9-level normal distribution form was adopted, ranging from the most important (+4) to the least important (-4). Students filled in the sample serial number, which could not be changed after submission.

Disposal data

After the students finished the Q-sorting, 38 data cases were collected (2 students did not fill in the table). Through screening, 8 invalid submissions with "repeated" and "omitted" factors were deleted, and 30 valid data cases were finally sorted out.

Interview

One-on-one online interviews with 30 students were conducted so that researchers could further understand participants' views. The interview time for each student was approximately 15 minutes, and the total interview duration was 8 hours.

Data analysis

The data in the sorted table were input into *PQ Method 2.35 software*. Principal component analysis was used for factor analysis, and the correlation matrix and eigenvalue of the sample were calculated. According to Kaiser's rule, factors with eigenvalues greater than 1 were considered to be meaningful [36]. Four factors with eigenvalues greater than 1 (as shown in Figure 3) were selected for maximum variance

rotation, which cumulatively accounted for 53% of the sample size. After rotation, the factor loadings of each factor were obtained. Then, the formula $2.58/\sqrt{N}$ (N = Number of Q samples) was used to test the significant loadings [39]. In this study, the number of Q samples $N=32$. Therefore, a factor loading greater than 0.456 (significant load) was taken as the factor classification standard, and the significant loading of each factor should not be less than two [38]. One factor in this study has only one significant load, so this factor was removed. Participants with two or more significant load were deleted. Therefore, two participants were removed (S2; S19). In the end, there were 28 participants and 3 factors. The ranking scores of each participant in these three factors were weighted and summarized into three representative Q rankings (see Figure 4).

Explanation of factors

Factor 1

According to Table 3, these students pay more attention to issues related to screen distance, such as "screen sharpness," "distance between students and blackboard," and "seat arrangement." S1 proposed that "the semicircular seating arrangement would be more effective than the current transplanting classroom". Many international active learning classrooms (TEALs, ALCs) are equipped with display screens on all four walls [40,41]. However, in the interview, participants did not agree with the solution of a four-sided screen, and S21 believed that "this design will distract my attention;" S10 said that "Setting the screen in multiple directions will affect my attention to the teacher's body movements. I do not want to miss the teacher's movements during the teaching, which will lose the conveyed information." Therefore, it may have something to do with the way students of different ages interact with the medium. Second, such students think that "personal space" is more important, while "number of students" is not, which may be because students are more accepting of the current class sizes. The "fire extinguishers" in the classrooms are not so important because the school is well equipped with fire prevention facilities and there are already fire extinguishers in the corridors.

Factor 2

According to Table 4, such students pay more attention to factors such as "intensity of natural light" and "smell". They believe that too much or too little light can cause visual discomfort and affect education quality. Some students put forward problems such as reflection of blackboard and glare of light. S14 said, "The adjustment of light is very important, because the lights in the classroom cannot be controlled separately. When the lights are turned off, the classroom will be dark and students in the back row cannot see, but when

Figure 2. Research process

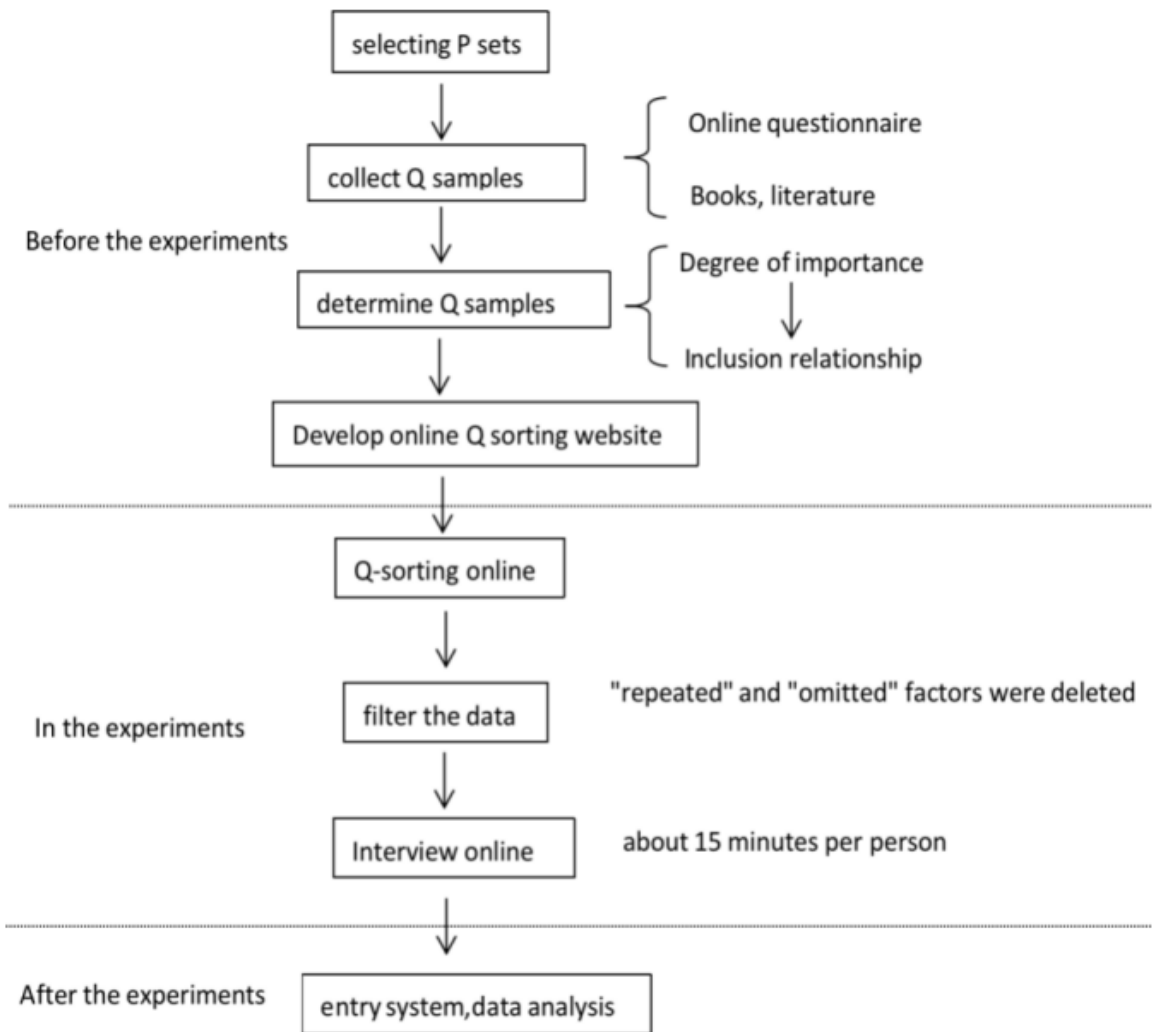
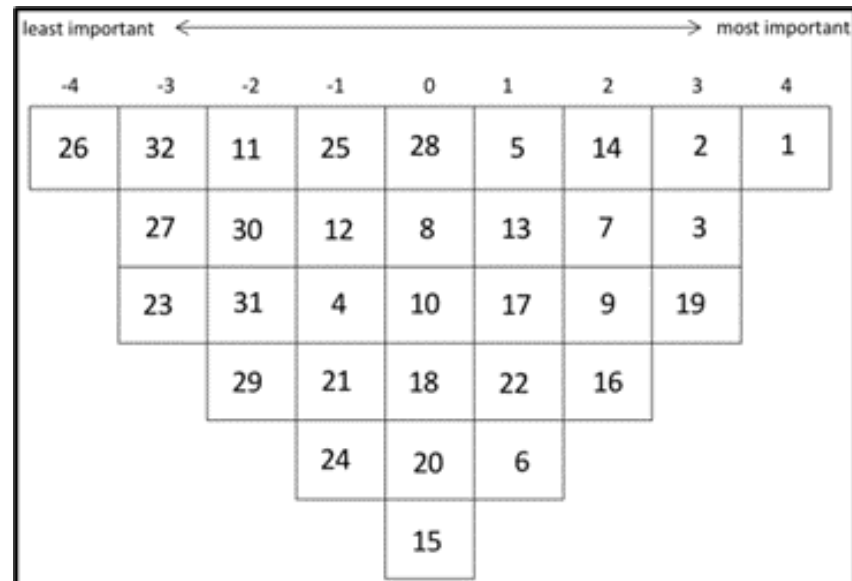
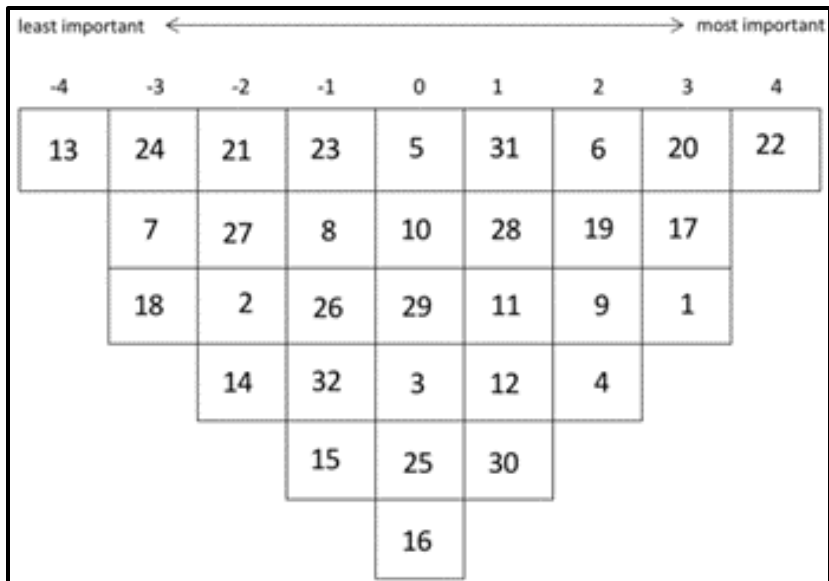
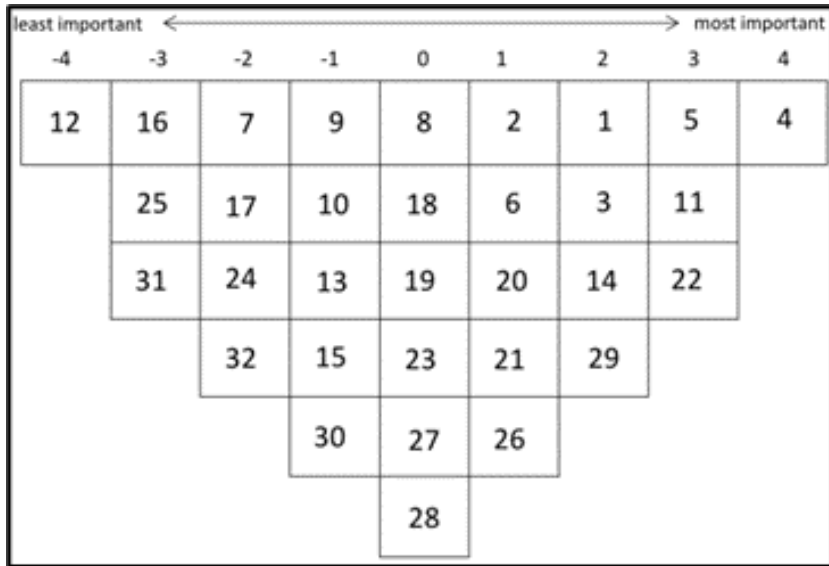


Figure 3. Eigenvalues of factors

Eigenvalues	As Percentages	Cumul. Percentages
1 4.6643	21.2013	21.2013
2 2.7477	12.4894	33.6907
3 2.2636	10.2889	43.9796
4 1.9453	8.8421	52.8217

Figure 4. Arrangement of idealized factors



the lights are on, the lights in the front row will cause reflection of the blackboard". Having a curtain can solve the problem better. The students also said that smell in the room can affect mood, such as when someone eats something with a pungent smell in the classroom. In addition, these students believed that moving tables and chairs was not desirable, mainly because when the students move tables and chairs, the movement will create noise and thus, have an effect on teaching and learning, which causes more harm than good. In class, students' eyes follow the teacher, so the position of the platform is not important. However, it was also suggested that the effect of the teacher walking around occasionally is better than standing on the platform all the time. The clock in the classroom will affect the efficiency of class and distract attention. S27 said that "I will frequently look at the clock in class to predict whether it is going to be the end of class." S5 thought that "we have a bell to remind us, and we do not need a clock in the classroom except for exams."

Factor 3

According to Table 5, these students consider "reducing noise inside and outside the classroom" to be the most important factor. They mention indoor noise caused by air conditioning and multimedia, as well as outdoor noises, such as reading in the next classroom and honking of vehicles on the road to be disruptive. They also say that soundproof walls, especially sound-absorbing blankets, are necessary and that a quiet environment is important for learning. The "air conditioning" factor was also placed at the "least important" position due to noise generated during operation and some unpleasant smells generated in enclosed spaces. These students also think that the setting of a "display cabinet" is unnecessary. S6 said that the "display cabinet is the least important and has nothing to do with learning," and S24 thought that "we do not often make handcrafts, so there is no work to show." S11 also expressed that "I think there is no need to show works."

Q samples	importance
reducing noise inside and outside the classroom	+4
ventilation number	+3
the board size	-3
display cabinet	-3
air conditioning	-4

Analysis of common points

In Figure 5, the ordinate indicates importance: greater than 0 indicates importance and less than 0 indicates unimportance. The abscissa is the Q sample. Students have a relatively consistent opinions with the 13 Q samples. They attach the highest importance to "intensity of natural light" and "reduction of internal and external noise," which is consistent with the large number of research results mentioned above that light and noise can significantly affect students' learning efficiency and attention. At the same time, "sunshade equipment" is also important. Students also generally believe that "the distance between students and the blackboard" will have a greater impact on learning. "Safe passage" is very important. In their understanding, the "safe passage" in the classroom mainly includes the row and column spacing of desks and chairs in the classroom, and enough "corridor space" should be set aside. The front and back doors of the classroom should always be open, and even if the back door is closed, it should not pile up sundries. Students believe that "smell" and "ventilation times" are more important. S25 believed that "ventilation can give off bad smells in the classroom, regular window ventilation is conducive to air circulation, the classroom will not be too stuffy," which, together with the study of smell and CO₂ in the classroom, will affect students' performance. This is consistent with the research result found by Dong [42] which demonstrated the impact of air quality on students. Students expressed a "neutral" attitude toward "green plants". S15 believed that "plants are not important, even if they can make me happy, they are also dangerous and [we] may accidentally break the flowerpot." However, studies have shown that green plants can purify air, bring people a sense of pleasure and comfort, and relax their mood [43]. In the end, most students said that plants do not matter, and more ventilation in the classroom is enough. Students generally think that the "display cabinet," "table and chair mobility," "platform position," and "fire extinguisher" are of low importance.

Analysis of disparate points

In Figure 6, the ordinate indicates importance, with values greater than 0 indicating importance and values less than 0 indicating unimportance. The abscissa is the Q sample. Students' identification degree to the 6 samples is relatively scattered. For "table and chair comfort" factors, the students have different points of view; some students think that "comfort" is more important: S18 said "uncomfortable seats will distract my attention, I would often go to adjust it." S23 said "Too comfortable a table and chair makes me sleepy, especially in summer." Some students think that desks and chairs should be designed to be adjustable because sitting in

Figure 5. Common point bar graph

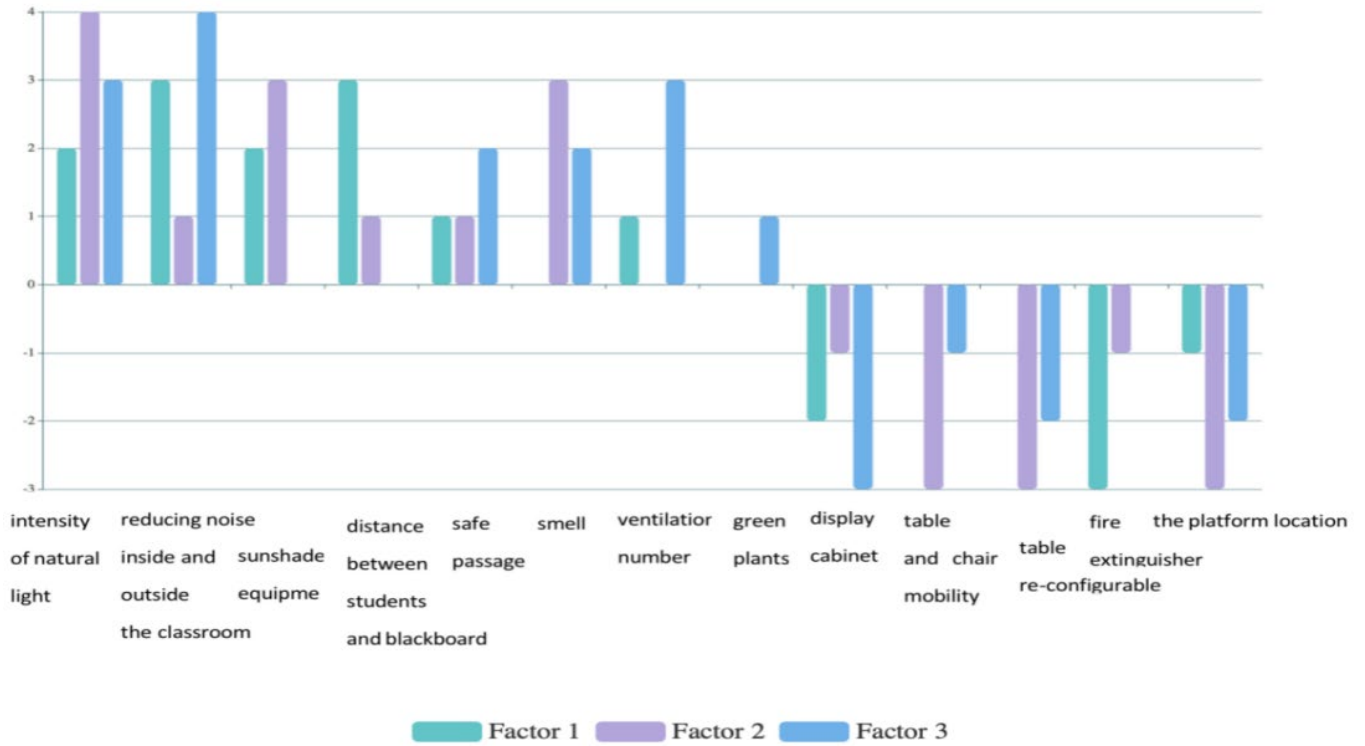
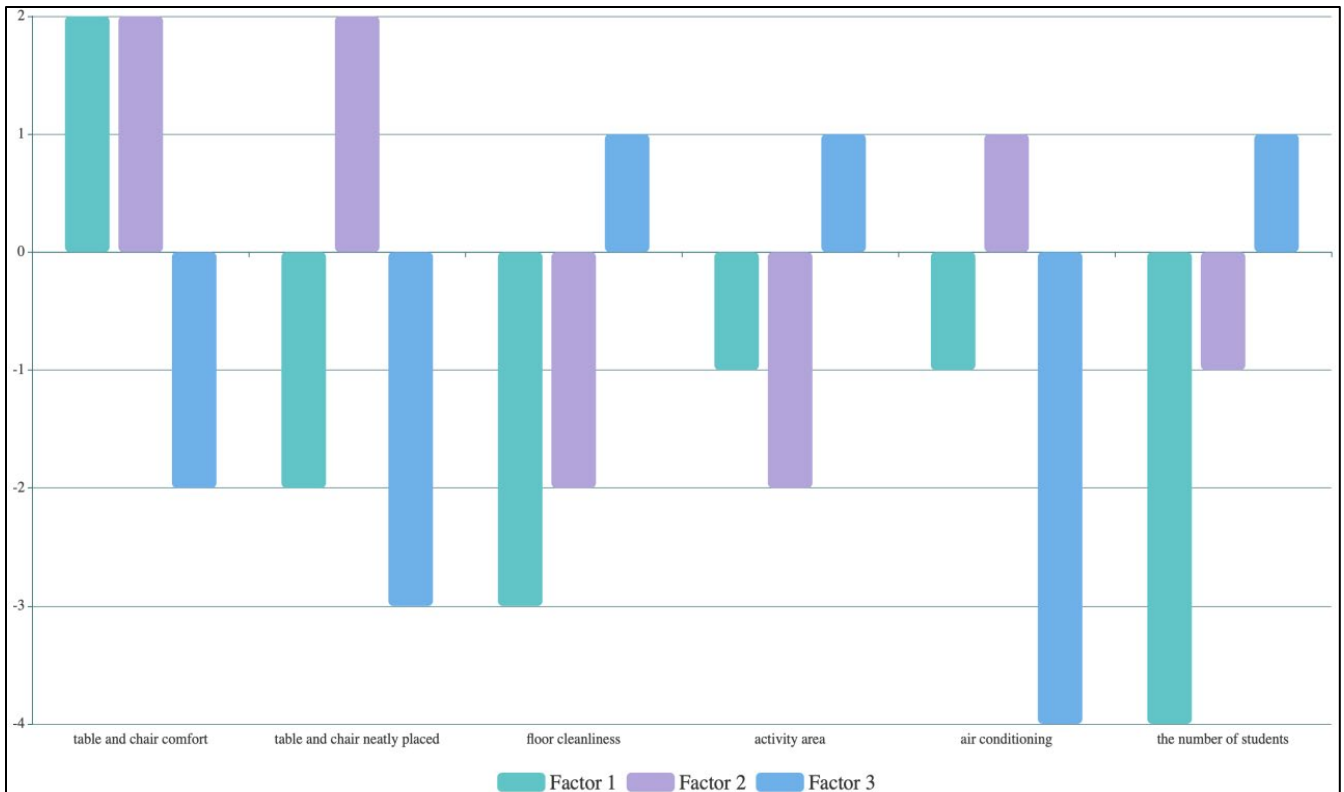


Figure 6. Disparate points bar graph



the seat for a long time will be unpleasant, and desks and chairs should be designed according to the height of students. In terms of "table and chair neatly placed" and "floor cleanliness," a small number of students prefer a neat environment, while most of them think that tidiness is not related to learning. S24 even said, "I like a messy environment, I cannot learn if it is too neat." Regarding the "activity area," some of the students thought the activity area was necessary and gave students activity space. S4 advised that the "activity area was more important" and that the "teacher should have an activity area, and we have an activity area. The activity area of the teacher is used to look at what we wrote, and our activity area is easy to communicate with the teacher." However, some students think that the activity area has nothing to do with learning. S20 thought that "we do not have many extracurricular activities, so we do not need the activity area," while S8 said that "our classroom is not large, so if the activity area is small, it will bump." Most of the students think that air conditioning and the number of students is not important. In addition to 32 Q samples, S26 added the importance of "ownership." The student said that some of the equipment or teaching tools in his classroom were damaged by other students accidentally, emphasizing the "openness" of the items. He also mentioned that the books in the book corner would get dusty and no one would clean them, so he was unwilling to borrow them.

Conclusion and discussion

By studying the Q rankings of 32 physical factors (Q samples) in a classroom of junior high school students, we can clearly understand about what factors students are concerned. This study found that junior high school students are most concerned about "screen sharpness," "intensity of natural light," and auditory factors, which is consistent with Haghghi's research conclusion that learners prefer visual and auditory factors compared with other architectural elements, and designers and researchers should pay more attention to these factors [44]. At the same time, the issue of "reflection of blackboard" was mentioned very frequently in the interview, and related factors such as "light intensity," "sunshine intensity," "controllability of light," "sunshade equipment," and so on were all mentioned. This issue should be focused on in classroom design. Students think it is very important to "reduce noise." They want not only to reduce outdoor noise, but also to avoid indoor electronic equipment, such as air conditioning and other sounds. In addition, the "seating arrangement" affects students' ability to see the blackboard clearly. Some students mentioned that a "semicircular" seating arrangement would make it easier to see the blackboard clearly and shorten the distance between teachers and students. Many domestic and overseas

researchers have also shown that curved seat arrangements are better than rows [45,46]. Marx points out that students are more active and answer more questions in classrooms with "semicircular" seating arrangements [46]. Studies show that teachers design ideal classrooms without abandoning traditional seating, but they generally prefer "U" or "V" seating in the classroom [47]. Therefore, teachers should be encouraged to experiment with innovative and flexible seating arrangements.

Most students said that "table and chair mobility" is not desirable, and the main reasons were that it is "unsafe," "causes confusion," and is "noisy". A few students, however, think that the flexibility of chairs can increase communication among students and facilitate group work. Saban mentioned that teachers adopt flexible seating arrangements in their ideal classrooms [47], and Tanahashi also believes that flexibility of seating is very important to adapt to changes in teaching styles [48]. For the "display cabinet" factor, students from the investigated school had a negative opinion. The results are different from those of foreign studies [49]. Killian proposed that there is a significant connection between display works and students' sense of belonging. Students like their works to be exhibited permanently, which will enhance their sense of belonging [49]. In this study, the junior high school students had a negative attitude toward "display cases" and disliked this form of "display." This may be related to the cultural differences between the East and the West and the age differences of students surveyed. Students' attitude toward "display cabinet" might even be different from different cities and provinces within the same country. This may need to be confirmed by further research. Students think that the "number of students" in the classroom is not important, while Saban's study found that the physical variables that teachers pay most attention to are "the number of students" and the "cleanliness of the classroom." Teachers believe that reducing the number of students is more conducive to teaching quality [47], which may be due to the cognitive difference between students and adults. Therefore, a balance of viewpoints should be carried out in the design of the classroom environment.

In this study, the Q method was applied to scientifically explore the real views of junior high school students on physical factors in the classroom with students at the center, providing new ideas for improving middle school classrooms. The results show that junior high school students attach more importance to screen sharpness, intensity of natural light and auditory factors and have a lower identity to flexibility. For some factors, there is a large difference from related studies in other countries, which may be caused by the differences between eastern and western education systems and mechanisms. It is suggested

that the needs and opinions of local students should be given special attention when building active classrooms in middle schools. According to the research results, suggestions on middle school classroom design are put forward from four aspects, including vision, sound, equipment and furniture, as follows:

(1) Visual: Attention should be given to the visibility and clarity of the blackboard and projection screen in the classroom. It is suggested to set up special blackboard lamps to avoid reflections and other problems and install lamps that can control the switch and light intensity individually to improve indoor lighting quality;

(2) Sound: Sound-absorbing blankets, acoustic barriers and other facilities could be installed to reduce noise interference inside and outside the classroom;

(3) Equipment: Regularly maintain and clean the equipment in the classroom to ensure the normal operation and cleanliness of the equipment;

(4) Furniture: It is suggested that teachers try to change the arrangement and layout of seats, strengthen the interaction between teachers and students, consider the distance between students and the blackboard, and ensure that the distance between desks and chairs is not too small. If flexible and movable desks and chairs are used, measures should be taken in advance to avoid the noise and confusion caused by students' curious movements.

The shortcoming of this study is that the implementation of the Q method is time-consuming: it takes approximately half an hour for each participant in the whole process. In addition, the purpose is to explore the preferences of junior middle school students regarding physical factors in the classroom, but students subconsciously will rank these factors according to their influences on learning, for example, a student said "first-aid kit" and "fire extinguisher" in security is important, but "they do not have much to do with learning." Future studies should further determine the criteria for screening factors. The number of participants selected by the Q method is small, the results can only represent a particular group, and the views of students and teachers of different ages on physical factors in the classroom are different [50]. This study should further expand the sample scope to different regions, different cultural backgrounds, and different groups. Through comparative analysis of the comprehensive conclusions, it provides more comprehensive constructive suggestions and guidance for classroom reconstruction in the future.

This study did not take into account online learning or classrooms, such as active learning classrooms or smart classrooms, and it only focused on studies in the traditional face-to-face classroom. Future studies on digital classrooms are possible.

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