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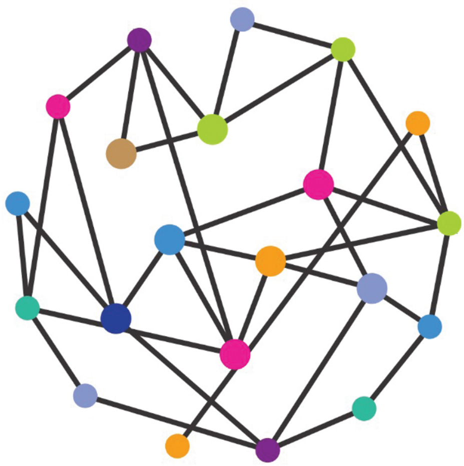

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PREFACE

This book explores the impact of various environmental factors on the learning process in technology-enhanced smart class design at the higher education level, employing a multidisciplinary approach. The present study benefited from the collaborative efforts of experts in engineering, health, and education science, who provided invaluable contributions to the research.

Our research has demonstrated that the learning process is enhanced by in-class interactions among instructors, students, content, and environment, as outlined by Moore's theory of transactional distance. It has been observed that the efficacy of the learning-teaching process is enhanced when a technologically advanced learning environment is integrated with the values inherent within the environment. It is regarded as a pivotal element in the design of learning-teaching environments assisted by smart systems in a learner-centered approach for economical and meaningful learning. The findings suggested that the effective integration of technology and the provision of equitable access to technology are pivotal in fostering equal opportunities in classroom learning, thereby initiating a positive and supportive learning process. Furthermore, an analysis of the classroom environment revealed that specific conditions, including indoor air temperature, relative humidity, pressure, light intensity, CO_2 levels, and sound intensity, exerted a discernible influence on the observed phenomena. The conclusion of this study indicates that the incorporation of smart learning systems, which take into account environmental factors and employ a learner-centered design approach, enhances students' learning outcomes. This smart system has been shown to enhance both the physical comfort of students and teachers and to facilitate modern technology for more effective learning practices in higher education. The research recommends that instructional designers and policymakers direct their attention to both environmental and pedagogical variables. Doing so would allow for the integration of educational technology with learner-centered methods, which would result in more efficient learning in higher education.

Acknowledgement

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1. INTRODUCTION

Technology-enriched learning environments are educational settings where information technologies are employed to stimulate individuals' motivation to learn, enhance learning resources through technology, support the implementation of teaching strategies, and utilize technology for the assessment of learning outcomes (Jurāne-Brēmane, 2023; Wang & Kinuthia, 2004). In technology-enriched learning environments, teachers and students benefit from digital tools and related methods and techniques to achieve learning-teaching goals (Healey, 2018; Kim, 2020). The aim of the present project was to investigate the influence of several environmental characteristics on learning in technology-supported learning settings in higher education. The research collected and analyzed quantitative and qualitative data in a technology-enriched smart classroom environment. The research study group comprises twenty-five undergraduate and graduate students attending Ege University during the spring and fall semesters of the years 2021-2022. Data flow and communication mechanisms between an intelligent board, student tablets, and a research application are established in technical design. In addition, quantitative and qualitative data collection instruments were used to examine indoor conditions (temperature, relative humidity, pressure, light intensity, CO_2, and sound intensity) and their effects on learning: course evaluation questionnaire, student opinion questionnaire, course video recordings, academician interview form, and course observation form. In the study, the first semester of the fall semester, during which courses were given, lasted eight weeks; the second round of the application process lasted eight weeks during the spring semester. The data were analyzed through qualitative analytic approaches and content analysis. Descriptive and descriptive statistical analyses were conducted on the quantitative data. The research findings show that the technology-enriched classroom supports student achievement. According to student perspectives, a technology-enriched classroom setting and its accompanying instructional materials have a good impact on the cognitive and affective aspects of the learning process. From an academic standpoint, this course significantly affects the learning process. Observations based on quantitative data indicate that indoor environmental factors influence learning in technology-enrich classrooms. In the context of existing literature, the research findings and recommendations for learning environments are discussed. In this context, the research focuses on the smart classroom as a technology-enriched learning environment and the effects of the curriculum applied in this classroom on the learning process.

1.1. SMART CLASSROOM

When the concept of a smart classroom emerged, it was used to differentiate it from the concept of a "computer classroom" (Li et al., 2015). The smart classroom is defined as a classroom equipped with an interactive whiteboard to support real-time interaction between teachers and students and to carry out learning activities (Zhao, 2008; Li et al., 2015). In another definition, the smart classroom refers to a technology-rich classroom (Li et al., 2015). With one of the most recent definitions, a smart classroom refers to a physical classroom created by integrating advanced educational technology types (Lu et al., 2021).

Smart classrooms are made up of smart environments equipped with various software and hardware devices and applications. A smart classroom integrates advanced instructional technologies into the classroom environment beyond the traditional classroom environment to contribute to developing the student's learning ability and participation in the lesson. Although the technological products and equipment used varies, cameras, interactive smart boards, touchscreen televisions, tablets, smartphones, projectors, wireless internet, administrative software of educational technologies, face recognition systems, and sensors are the most common types (MacLeoda et al., 2018). With such technological opportunities, teachers can monitor, guide, evaluate, and facilitate students' understanding more efficiently. At the same time, intervening when necessary is among the things that the teacher can do. The student is expected to engage more actively with technology, which can lead to feeling safer in the learning environment.

The smart classroom concept is a physical environment that emerged due to a pedagogical approach that aims to develop the student's learning ability through socially interactive ways by assuming more innovative roles and responsibilities than traditional methods. It differs from teacher-centered didactic teaching techniques by shifting towards student-centeredness.

Research on the classroom environment shows that physical environment plays a vital role in learning among the other variables (Hanaysha et al.,2023; Suleman & Hussain, 2014). The situations related to the physical environment dimension of classroom management are the classroom size, light, temperature, noise regulations, cleaning, colors, educational tools, grouping of students and seating arrangement (Rusticus et al., 2023; Sarı & Dilmaç, 2011). For the activities to be carried out effectively and appropriately in the classroom environment, enough light should be used in the environment, and features such as the color of this light source, reflection, and direction of light should be taken into consideration (Kaya, 2002); cited in (Otrar et al., 2011). Considering the seasonal conditions, indoor air temperature required for an individual with clothing insulation should be approximately 20°C (Başar, 1998), cited in (Otrar et al., 2011). Pastel or light colors should be used in the classroom environment (Otrar et al., 2011). The seating arrangement in the classroom is also stated as a factor that significantly affects the interactions in the classroom (Sarıçoban & Sakızlı, 2006). Variables affecting the quality of the indoor environment in the classroom environment are critical for productivity, health, comfort, efficiency and satisfaction.

1.2. DIGITAL MATERIALS USED IN CLASSROOM ENVIRONMENT

According to the forms of digital materials published in Learning Resources - Material Types. (2014), the following digital materials can be used in the classroom environment.

- Animations
- Assessment tools
- Events
- Case studies
- Design tools
- Exercises
- E-Portfolio
- Visuals
- Learning objects/learning object repositories
- Online courses and course content
- Open-source journals and articles
- Open books
- Instructional photos
- Presentations
- Quizzes and tests
- Sample materials/sample objects
- Simulations

- Social networking tools
- Lesson plan
- Tutorial Software
- Instructional videos
- Workshop and training materials, etc.

Today, technologies such as mobile devices, applications, interactive projections, and interactive boards are used in classroom environments (Quetti, 2019). Information and communication technologies can maintain communication by interacting with students in a two-way approach through instant feedback (Eastman et al., 2009; Yeung et al.,2023). The following technologies can be given as examples of information and communication technologies that provide interaction that can be used in this context (ICT Tools, 2021).

- Quizzes, tests and games: Kahoot, Flipgrid, Classkick, etc.
- Presentations include Google Slides, Mentimeter, Nearpod, etc.
- Videos and cartoons: Animaker, Edpuzzle, DoInk, etc.
- Ready-made lesson series: BookWidgets, Gooru, ReadWriteThink, etc.
- Brainstorming and organisation applications: Miro, Mural, Padlet etc.
- Creative content creation environments: Canva, Pixton, Wordle, etc.
- Study applications: CoboCards, Vocabulary, Learningpod etc.
- Online collaboration applications: Edmodo, Google Docs, Talky, etc.
- Other apps: Evernote, Classdojo, HP Reveal, etc.

Many studies have been conducted in this context. Paliç and Keleş (2011) aimed to examine teachers' views on classroom management in their study. Forty-two teachers working at primary and secondary education levels participated in the study. According to the results of this qualitative study, personal characteristics, professional characteristics, and approaches to students are essential to effective classroom management. In addition, teachers frequently encounter problems in classroom management due to individual differences between students, a reflection of students' family structure in the classroom and students' attitudes towards the lesson. However, teachers generally adopt preventive, developmental and reactive approaches in classroom management. In another study, Bozan and Ekinci (2020) aimed to examine the difficulties experienced by teachers in classroom management and the opinions of new teachers. According to the study's results, the participants responded to the difficulties encountered in classroom management due to the teacher attracting attention, maintaining attention, and the teacher's inadequacy in the field. Participants frequently stated the answers to questions of lack of preliminary preparation for the lesson, student readiness, violation of classroom rules, and difficulties caused by the students. When the difficulties arising from the parents are analyzed, social differences and attitudes of the parents come to the fore. Regarding the difficulties encountered regarding space, the participants stated physical inadequacy and crowded class size. New teachers were advised to develop professional competencies, create and organize a suitable classroom climate, apply different methods and techniques, and organize the space.

Can and Arslan (2018) aimed to determine the classroom management competencies of teachers by referring to students' opinions in their study. In this context, 1016 students participated in this mixed-design study. According to the study results, students stated that teachers were moderately competent regarding teacher-student relations and compliance with instructional principles. In addition, the students stated that teachers were moderately competent in complying with the principles of classroom management. In addition, students stated that they wanted the lessons to progress more entertainingly. According to the other study results, students want rewards in the form of achievement points and punishments in the form of warnings. In addition, students also want games to be included in the lesson processes.

Yılmazsoy, Özdinç, and Kahraman (2018) aimed to examine students' views in a virtual classroom environment on classroom management. In this study, which was designed with a descriptive survey model, 56 graduate students participated. According to the results of the study, it was stated by the students that the communication process is accessible in the virtual classroom environment, success increases with communication, a well-made lesson plan increases motivation, and an effective process is realized if time management is planned successfully.

Wannapiroon and Pimdee (2022) developed and examined a digital virtual classroom learning environment for undergraduate students pursuing STEAM disciplines. The model was subjected to a rigorous review by experts and subsequently employed in a classroom setting. The findings indicated that students who utilized the virtual model demonstrated higher levels of creativity and innovation compared to those engaged in traditional, face-to-face instruction.

1.3. TEACHING METHODS IN TECHNOLOGY-ENRICHED SMART CLASSROOMS

Technology-enriched classroom environments are characterized by the integration of course content, interaction styles, and learning objectives that are supported by technological tools. These environments foster active engagement in collaborative work, both individually and collectively, among learners (Li et al., 2015). In technologically-rich classroom settings, active learning methodologies are employed that are centered on the learner (Chiu, 2016). The following methods can be regarded as exemplars of student-centered teaching methods employed in this context (TeachThought Staff, 2020):

- Cooperative learning
- Presentation
- Brainstorming
- Creating an environment
- Discussion
- Small group
- Case study
- Experiment
- Drama
- Simulation
- Workshop
- Example citation
- Project preparation
- Problem-solving
- Exploring activities
- Social media
- Games, etc.

1.4. ASSESSMENT METHODS IN TECHNOLOGY-ENRICHED SMART CLASSROOMS

Assessment is one of the essential parts of the learning process (Stödberg, 2012). Information and communication technologies are used in technology-enriched classroom environments and assessment processes (Li et al., 2015; Wang & Kinuthia, 2004). Since information and communication technologies have become widespread in technology-enriched classroom environments, new methods for learning and assessment are emerging (Stödberg, 2012; Welsh & Mastrup, 2025). One of these assessment methods is e-assessment. E-assessment is an assessment process that is carried out by recording the process and answers to the assessment activities carried out during the learning process using information and communication technologies (Joint Information Systems Committee, 2007). E-assessment is a form of assessment that can be used for both formative and summative purposes (Stödberg, 2012). The methods used in the e-assessment process are open-ended questions, multiple choice questions, e-portfolio, product and discussion (Stödberg, 2012).

1.5. RESEARCH ON TECHNOLOGY ENRICHED CLASSROOM ENVIRONMENTS

In his study, Page (2002) compared the achievement, self-esteem and classroom interaction of primary school students in terms of students' achievement, self-esteem and classroom interaction after the procedures carried out in the technology-enriched classroom and traditional classroom environment. It is stated that 211 primary school students participated in the study. It is stated that the existing classes were randomly assigned to the experimental and control groups. At the end of the study, based on the analyses between the experimental and control groups, it was emphasized that there was a significant differentiation in favor of the experimental group regarding achievement and self-esteem.

Chiu (2016), studied with the students regarding active learning activities and environment by designing a technology-enriched active learning environment. It is stated that there is an area where furniture can be arranged according to the needs of different active learners and technologies, such as a three-dimensional printer, electron microscope, and Echo360 presentation tracking system. When the results of the studies are analyzed, it is seen that the students stated that the environment contributed to conducting active learning activities and providing a physical environment.

Christensen et al. (2019) emphasized in their study that to improve students' knowledge and dispositions towards space science, they carried out studies to enrich learning environments with innovative technologies to positively affect students' perceptions towards space science. In this context, it is stated that the innovative technologies included in the learning environment include augmented reality, virtual reality, robotics, drones, two-dimensional printing and three-dimensional printing. This 2019 study was conducted in the Saturday Space Science Camp, which lasted four hours and involved 24 sixth-grade students (10 boys and 14 girls). The study applied pre-tests and post-tests to determine the change in students' content, tendency and interest in space science. The data obtained in the study were analyzed using a t-test. The study revealed that students' tendencies towards space science increased significantly, but content knowledge did not significantly increase. The observations of both the teachers accompanying the students and the space camp staff also generally showed positive results.

In their study, Erkek and Işıksal Bostan (2019) aimed to examine the argument justifications that are claimed to develop individuals' higher-order thinking, critical thinking and metacognitive skills. They emphasized that the study focused on the argument justifications of pre-service teachers. They stated that the study was conducted to determine the reasons for the arguments put forward by pre-service teachers in the GeoGebra environment. In this context, a case study, one of the qualitative research methods, was utilized. It is stated that eight prospective elementary mathematics teachers studying at a state university participated in the study. As a result of the analysis of the data obtained in the study, the researchers showed that many justification types put forward in the technology-enriched environment were visual argumentation. Depending on this situation, it is stated that using GeoGebra in the study supports visual argumentation.

Liu et al. (2020) aimed to examine the implementation process of a program designed using problem-based learning enriched with technology for secondary school teachers. In this context, they aimed to determine the factors affecting teachers' motivation regarding the process, the difficulties they encountered, and the strategies to combat these difficulties. The participants of the study were science teachers working in 18 different schools. It was stated that a problem-based learning program enriched with multimedia technologies was implemented during the study process. The results of the study emphasized that teachers who benefited from problem-based learning processes enriched with technology observed that students' learning was positively affected as a result of their collaborative work. It is stated that teachers who observe that students' learning is positively affected are motivated to benefit from problem-based learning processes. In addition to this situation, in the study, the difficulties encountered by the teachers in the problem-based learning process are related to pedagogy and the fact that students who are at a lower level than the general class have different teaching processes. In this context, it is stated in the study that the difficulties teachers encounter in problem-based learning processes enriched with technology are not experienced in terms of technology but in terms of pedagogy. In addition, when the literature was examined, it was found that the related studies were limited in the studies conducted on higher education students and instructors.

1.5.1. STUDIES ON THE ATTITUDES OF STUDENTS AND INSTRUCTORS TOWARDS THE SMART CLASSROOM ENVIRONMENT AND ITS EFFECT ON STUDENT ACHIEVEMENT

Hopson, Simms, and Knezek (2001) examined the effect of a technology-enriched classroom on students' higher-order thinking skills and attitudes towards computers. They studied with 80 sixth grade and 86 fifth-grade students by using the "Ross higher order thinking skills test" and "computer attitude questionnaire". As a result of the study, it was stated that the creation of a technology-enriched classroom environment positively affected students' acquisition of higher-order thinking skills. In addition, it was emphasized that the technology-enriched classroom environment significantly affected fifth-grade students' attitudes towards the importance of computers and perceived value.

Like the above study, Giunta (2017) reported that in technology-enriched classrooms, students' attitudes towards computers were positive, students were successful in using technology, and they thought using technology was beneficial. In addition to this situation, Giunta (2017) also stated that students will continue to use computer technologies as a learning tool. Like Hopson, Simms, and Knezek's (2001) study, Simi and Bindu (2021) stated that the technology-enriched classroom environment positively affects students' higher-order thinking skills. In this context, students' scientific reasoning skills should be developed with competent, professional teachers aware of modern literacy concepts.

The study by Chiu (2016) underscores the crucial role of the physical environment in supporting students' interactive learning tasks in a technology-enriched setting. It also highlights the positive impact of this environment on students' attitudes, a finding that has been internationally recognized.

Christensen et al. (2019) found that while there was no significant difference in the content knowledge of students in a technology-enriched environment, there was a positive trend towards increased subject content. This finding has important implications for the design and management of educational facilities.

1.6. INDOOR ENVIRONMENTAL CONDITIONS

1.6.1.LITERATURE REVIEW

Variables affecting indoor environmental quality in the classroom are critical for productivity, health, comfort, efficiency and satisfaction. A study conducted in university classrooms in Hong Kong (Yang & Ming Mak, 2020) revealed that indoor air quality and thermal comfort are the most important variables determining user satisfaction among all factors, followed by lighting and acoustic values. A study conducted in South Korea compared thermal, acoustic and visual comfort factors. It was determined that acoustic value had the most importance among the variables affecting indoor comfort. In a study conducted in Italy (Ricciardi & Buratti, 2018) in 7 university classes, it was concluded that among thermal, acoustic and lighting variables, lighting was the most effective one on overall user satisfaction in indoor environments. In a joint study conducted in Canada, Australia, Finland, and the USA, noise and sound levels were the most effective variables. The studies show that these results may vary according to the climate in the region where the study was conducted and during the study period. Therefore, it is not possible to generalize user satisfaction in indoor environments. For example, in Hong Kong, where people from different nationalities are concentrated, the variation of subjective user satisfaction also increases. In a study conducted at the University of Belgrade (Uzelac et al., 2015) with 197 participants, 14 lectures with a student count ranging from 15 to 21 were observed in classes for a duration of 90 minutes. Indoor environmental conditions including CO2, relative humidity, indoor air temperature, pressure and noise level measurements were monitored with sensors installed in the classroom. The study evaluated indoor air temperature and relative humidity together as a single index. The teacher's voice and speech characteristics were recorded with the help of Bluetooth-connected headphones and a microphone. The research is one of the first studies to consider the teacher's voice as a variable. In particular, the study aimed to identify the leading variables on which students' focus depends on and to correlate them with students' focus. It was aimed to reveal the effect of changes in both the physical conditions of the classroom and changes in 22 different features of the teacher's voice and classroom noise level (such as speech frequency, sound spectrum irregularities, average of peak values, average of energy values, variations of irregularities, energy averages and peak value averages, average speech length, short speech lengths and excessive speech lengths) on student focus. Students' focus on the lesson was measured through immediate feedback. As a result of the study, it was found that increasing carbon dioxide, relative humidity and indoor air temperature negatively affected students' focus, and among the calculated values of noise, the mean of the standard deviations of the noise levels, the mean of the formant frequency values calculated from the teacher's voice values and the standard deviations of the autocorrelation upper values were found to be the determining variables. Although indoor pressure is also among the measured variables, it was confirmed in this study, as in previous studies, that it is not an effective variable and that indoor pressure values do not vary much. The data sets tested with ten different machine learning algorithms provided the best results with a precision of 86.78%. These findings contribute to our understanding of the variables influencing students' focus and provide a roadmap for future research in this area.

There are two different approaches for estimating the thermal comfort index (Yank & Ming Mak, 2020). 1) Heat-balance Approach 2) Adaptive Approach. The most well-known heat-balance approach is determined by six variables, 4 of which are physical and 2 of which depend on the person. Variables related to the physical environment are indoor air temperature, relative humidity, air flow rate, average radiant temperature, and personal variables, such as clothing insulation and the person's metabolic rate. The Adaptive Approach presents an index considering climate, social, cultural, psychological, and behavioral adaptations. In a study conducted at the University of Pavia (Ricciardi & Buratti, 2018), the characteristics of 7 engineering classrooms (dimensions, furniture, coating and glass surfaces, window areas, crowding characteristics, etc.) were determined and acoustic, thermal, lighting measurements were recorded by sensors. During the research, in addition to the insulation of the students' clothes, their thermal preferences, whether they use devices that they can control to change the classroom temperature and whether they are satisfied with the indoor environment, indoor air temperature they perceive were obtained through a questionnaire. In addition, students' perceptions on acoustic and lighting such as speech intelligibility, noise sources, sound quality, as well as natural and artificial light sources were obtained through questionnaires. As a result of the research, it was observed that the background sound level was 40 dB in three classrooms, exceeded 40 dB in 4 classrooms and exceeded the recommended 35 dB in all classrooms. In all classrooms, the sound reverberation time was found to be higher than the standards recommending 0.6s regardless of the classroom volume; according to the Hodgson formula, which calculates the optimum reverberation time by considering the volume of the classroom. The illuminance values varied considerably according to the presence of windows, with the lowest average value of 49 lux measured in two classrooms and the highest of 564 lux in one classroom due to the high number of fluorescent lamps per square meter. As a result, it was measured that the average illumination value was above 300 lux in 2 classrooms, the average illumination value was around 250 lux in 2 classrooms, and the average illumination value was around 200 lux in 3 classrooms, which is below the value required to perform visual activities. The survey results revealed that students felt more comfortable as the illumination value increased, but the disturbing reflections increased at the same rate as the illumination level increased. The acoustic values for the classrooms used in this study were further away from the comfort zone than the illumination values. The perceived indoor air temperature was slightly warmer than the measured temperature in the other classrooms except for one classroom and the thermal dissatisfaction level of students varied between 6.7% and 16%, and 80%. Another study result show that as the background noise level increases, such as traffic noise, the students' discomfort with the average ambient noise level decreases if the teacher's voice is heard. However, continuous or prolonged ambient noise, e.g., the sound of a projector in the classroom, was perceived to disturb for a longer period as the background noise level increased, as did the traffic noise level. The correlation coefficient between intelligibility and the speech transfer index was smaller than the proportional index, which is the ratio of the sound energy level determined within 50 ms to the total energy at the initial output. In other words, the intelligibility and clarity of the teacher's voice are more related and directly proportional to the energy absorption value of the environment.

Acoustic comfort varies depending on the noise level in the environment, the noise level in the background, the sound's reverberation time, and the acoustic isolation conditions of the classroom. Although it affects the quality of verbal communication, it is a more effective variable in younger students. In Finland (Sala & Rantala, 2016), activity and background noise levels were measured in 40 primary school classrooms, and the sound and speech transmission rate reverberation time were considered. Another study was also carried out by considering the background noise level. In this study, the background noise level is caused by the electrical appliances, installation, traffic, etc. whereas the activity noise level is considered as the sounds that occur during learning, teamwork, speech, and sounds caused by shifting desks and desks, etc. Acoustic comfort is associated with two basic parameters: reverberation time and speech transmission index. The reverberation time is the time until the sound loses 60 dB and is related to the volume of the room, its shape and its ability to absorb sound. The speech transmission index is a parameter that varies between 0 and 1 and shows how intelligible the speech reaches. As a result of the study, it was seen that the classrooms were acoustically poor, 1/3 of the classrooms met the Finnish requirements when the reverberation time was taken as a criterion, and only one of the classrooms met the standards when the speech transfer index was taken as a criterion. The reverberation time was recorded as short in classrooms with an average area of 63 m2, and it is possible to say that this situation is advantageous in such relatively small classrooms. Although there is a theoretical correlation between reverberation time and classroom volume, there is no correlation between reverberation time and room volume, room area and speech transmission rate. The classrooms were, on average, 3.2 m high and ranged from 56 to 68 m2. It was observed that the activity noise level exceeded the recommended level in 50% of the measured periods, with an average activity noise level of 69 dB in the range of 40-57 dB, which does not pose a risk for the teacher voice in the range of 66 to 72 dB. This situation was again considered a result of the work carried out in classrooms with poor acoustic values, and it was concluded that more attention should be given to acoustic ergonomics and sound ergonomics during the construction phase.

Indoor air quality can be determined depending on the concentration of CO_2, organic compounds, dust particles, NO_2, and ammonia. Studies show that the concentration of CO_2 is the most important variable and there is a relationship between academic achievement and classroom ventilation. Suppose we accept the carbon dioxide ratio as a measure of classroom ventilation. In that case, the excessive amount of carbon dioxide causes a decrease in speed, an increase in the error rate and a decrease in performance in language and numerical-based assignments. Students have more positive perception opportunities in a sufficiently ventilated classroom. In a recent study, carbon dioxide, formaldehyde, fine and medium-sized particles, ozone, carbon monoxide nitrogen dioxide and volatile organic compounds were monitored in 220 mechanically ventilated classrooms in a total of 39 schools at the primary, secondary and high school levels (Kabirikopaei et al., 2021), in three seasons except summer when the classrooms are empty. The effects of these variables on student performance were analyzed. In addition, ventilation was estimated according to the carbon dioxide rate measured in classrooms where indoor air temperature and relative humidity were also measured. Furthermore, student performance was analyzed by observing how the values measured throughout the year affect the students' grades. Seasonal parameters assumed to be linearly correlated were determined, and statistical analyses were performed after the measured values were included in the model as seasonal variables. As a result, it was concluded that the type of mechanical ventilation, the number of fine particles in the autumn season and the carbon dioxide concentration are the determining variables for mathematics grades; in the evaluation of the grades of the courses related to reading, the ventilation rate in the autumn and spring periods, the amount of ozone and the fine particles in the winter season are the determining variables. As a result of the research, mechanical ventilation units were noisier, less able to ventilate and more related to forming medium-sized particles than mechanical ventilation systems ventilating multiple zones. Mechanical ventilation systems ventilating multiple zones were found to be more effective and efficient in terms of improving the quality of indoor air more advanced filtering properties and more effective in performance than single zone systems due to their higher capacity to provide clean air. The high ventilation rate in the autumn season resulted in high achievement in reading assignments. For math achievement, the ventilation rate did not significantly affect all three seasons. While previous studies examined the effect of ventilation levels on learning and test achievement, this study made a seasonal distinction. It was found that the effect of ventilation rate in winter on student performance was significantly less than in autumn and spring. The study also revealed that the students' different demographic and socio-economic structures affect the ventilation rate and, consequently, the student performance due to the different responses to indoor air quality. About the particles, it was found that medium and coarse particles were ineffective in success, while fine particles had a positive effect in the autumn period when considered seasonally.

1.6.2.RELEVANT STANDARDS

There are several standards regulating the conditions of indoor environments. In Türkiye, the Ministry of Labour and Social Security regulates indoor air quality short-term and long-term exposure values following Occupational Health and Safety Law No. 6331.

The most common thermal comfort standards are ISO 7730 (2005) and ASHRAE Standard 55 (2017). In ASHRAE 55, the indoor environment's operative temperature value is considered. This value is calculated using the following formula, depending on indoor air temperature, air flow rate, and average radiant temperature (American Society of Heating).

$T_o = A \times T_a + (1\text{-}A) \times T_r$

In the equation, T_o: Operative Temperature

T_a: Indoor Air Temperature

T_r: Average Radiation Temperature

A: Weight Factor

In ASHRAE 55 (2010), A values depending on the air flow rate are as follows.

V_r	Vr <0.2m/s (Vr <40 fpm)	0.2< Vr <0.6m/s (40< Vr 120fpm)	0.6< Vr < 1.0 m/s (120< Vr <200fpm)
A	0.5	0.6	0.7

Table 1. Air Flow Rate Values in ASHRAE 55

According to ASHRAE 55, the recommended values for indoor operative temperatures according to the users' clothing insulation and metabolic rates are determined by the graph in Figure 1. For the metabolic rates of the users, the required values are given in the annex of the standard for activities such as sleeping, resting, writing, reading, sitting in line, and standing (Çalış et al., 2017). Similarly, clothing insulation is also presented in the annex. It should be noted that obtaining the operative indoor temperature both with the graph or the formula above is possible.

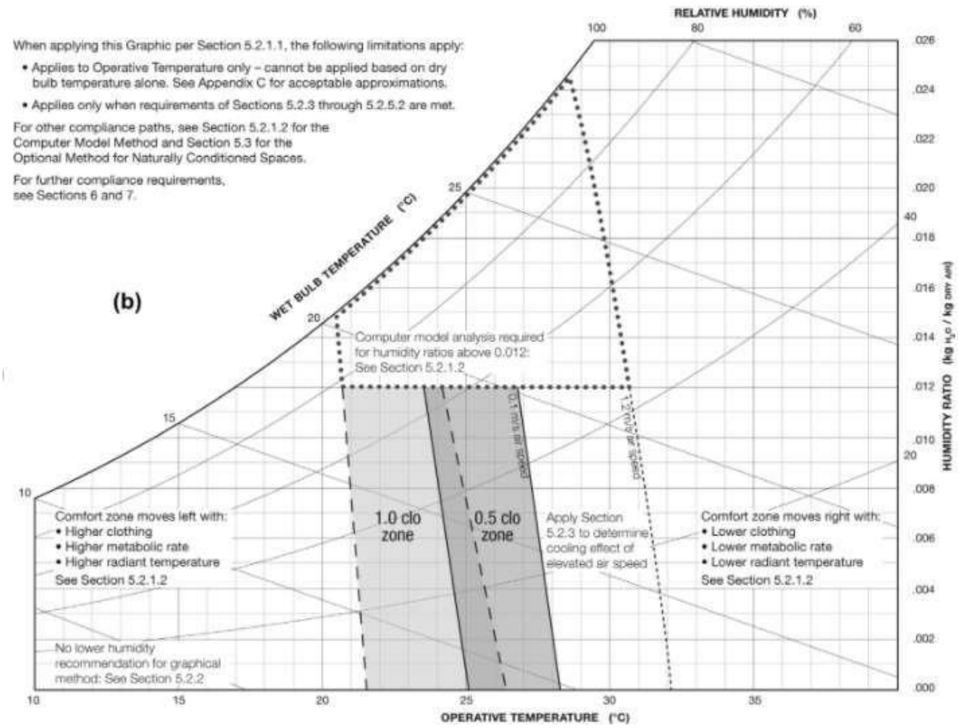

Figure 1. Thermal Comfort Area Method with Graphic

TS EN 12464-1 (2013) is used for lighting levels in Türkiye. Lighting level is measured as luminous flux per unit surface. According to TS EN12464-1 (2013), the minimum illumination levels required according to the usage areas of educational buildings are shown in *Figure 2* in lux units (TS EN 12464-1, 2013). In the standard, apart from the illuminance level, reflection ratio, glare, direct illumination, indirect illumination, color temperature of light, color rendering, daylight criteria and illumination are explained. In the standard, the sections of educational buildings according to their intended use are also presented with the minimum values required for these criteria, such as health buildings, closed work areas, and production areas. In *Figure 2*, only the minimum values of the illumination level criterion are given. *Table 2* shows the relative humidity values, airflow velocity and operative indoor temperatures recommended by ISO7730, the standard used in Türkiye, and ASHRAE 55, the American standard, for heating and cooling seasons.

Table 2. Recommended Values for Heating and Cooling Seasons

Field-Task - Activity Types	lx
Classroom and Practice Rooms	300
Classes for Evening Lessons	500
Auditorium and Lecture hall	500
Black, Green or White Boards	500
Demo Desk	500
Art Workshops	500
Art Workshops in Art Schools	750
Technical Drawing Rooms	750
Laboratory and Practice Rooms	500
Ability Rooms	500
Teaching Workshops	500
Music Practice Rooms	300
Computer Rooms	300
Foreign Language Classrooms	300
Fitting Rooms	500
Entrance Halls, Looby	200
Gallery and Corridors	100
Stairs	150
Student Canteens, Halls	200
Teacher Rooms	300
Bookcase: Shelves	200
Library: Reading Zones	500
Teaching Material Room	100
Gymnasiums and Sports Halls, Swimming pools	300
Canteens	200
Kitchen	500

For Heating Season

Parameter	Reference value
Indoor air temperature (°C)	-
Relative humidity (%)	30-60[a]/30-70[b]
Air velocity (m/s)	max 0.16[b]
Mean radiant temperature (°C)	NA
Operative temperature (°C)	22.0±2.0[b]

a: ASHRAE Standard 55;
b: ISO 7730

For Cooling Season

Parameter	Reference value
Indoor air temperature (°C)	-
Relative humidity (%)	30-60[a]/30-70[b]
Air velocity (m/s)	max 0.19[b]
Mean radiant temperature (°C)	NA
Operative temperature (°C)	24.5±1.5[b]

Figure 2. Minimum Lighting Level Required in Circulation Zones of Educational Buildings

1.7. PURPOSE AND IMPORTANCE OF THE RESEARCH

The objective of this project is to investigate the various variables that affect learning performance in technology-enriched learning environments at the higher education level. In this study, the impact of indoor environmental conditions and instructional designs in the enriched classroom on the learning performance of 15 university students is examined. In this context the variables are as follows:

- Thermal comfort conditions of the classroom,
- CO2,
- Noise level,
- Illumination level,
- Classroom design,
- Technologies to interact with,
- Learning processes,
- Student-digital material interaction,
- Digital materials

Research has demonstrated that such variables in the classroom environment can impact attention and learning performance. Consequently, an interdisciplinary study was undertaken to address this research gap, focusing on the examination of physical and pedagogical variables in conjunction with indoor environmental conditions that promote student productivity and the impact of diverse environmental factors on student performance. The research findings are expected to facilitate the creation of an ideal learning environment in higher education in terms of physical conditions and instructional design and technology. The findings are anticipated to inform the design of technology-enriched classrooms at the higher education level and the pedagogical practices employed in these settings.

1.8. RESEARCH QUESTIONS

The present research encompasses the following domains:

- The conceptualization of a technologically-augmented learning environment in physical space
- The development of a curriculum design
- The production of a sample smart classroom application
- The collection and analysis of data from multiple sources The primary objective of the research is to examine the variables affecting perceived learning performance in technology-enriched learning environments at the higher education level and to determine their impact levels. In this context, the research questions are determined as follows:

1. Does the classroom indoor environment enriched with technology affect student achievement?
2. What are the students' opinions about the technology-enriched smart classroom environment?
3. What are the opinions of instructors about the technology-enriched classroom environment?
4. What are the students' opinions about the digital materials used in the technology-enriched classroom environment?
5. What are the instructors' opinions about the digital materials used in the technology-enriched classroom environment?
6. What are the instructors' views towards management of the technology-enriched classroom?
7. Which variables regarding indoor environment conditions in the technology-enriched classroom affect learning performance?
8. What are the optimum values of indoor environmental variables affecting learning in a technology-enriched classroom?
9. Do indoor environmental conditions in the technology-enriched classroom affect university students' perceived learning performance?

2. METHOD

This section includes research methods, research model, research group, data collection tools, data collection process, data analysis, and validity and reliability studies.

2.1. RESEARCH MODEL

The present study employs a mixed research method, incorporating a design model. The objective is to employ a dual approach, integrating qualitative and quantitative methodologies, to address the research inquiries. Mixed models can be explained as the integration of qualitative and quantitative approaches to examine and understand research questions in greater depth (Creswell, 2006). In their 2004 study, Johnson and Onwuegbuzie underscored the potential benefits of integrating qualitative and quantitative methodologies, while simultaneously cautioning against their uncritical amalgamation.

2.2. RESEARCH GROUP

The research study group consists of students pursuing undergraduate and postgraduate degrees, as well as instructors who are responsible for teaching the relevant courses. One lecturer and 13 students participated in the first round, and one lecturer and 12 students participated in the second round.

Table 3. Student Profiles in the Second Round of Implementation

Student	Age	Gender	Education Level	Location/City
1	18-24	Female	Graduate	Izmir
2	18-24	Female	Graduate	Izmir
3	18-24	Female	Graduate	Izmir
4	25-34	Female	Graduate	Izmir
5	18-24	Female	Graduate	Izmir
6	25-34	Male	Graduate	Izmir
7	18-24	Male	Graduate	Izmir
8	18-24	Female	Graduate	Izmir
9	25-34	Female	Graduate	Izmir
10	25-34	Male	Graduate	Izmir
11	35-44	Female	Graduate	Izmir
12	25-34	Male	Graduate	Izmir
13	25-34	Male	Graduate	Manisa
Descriptive Statistics	**18-24 age** *f*=6 46,15% **25-34 age** *f*=6 46,15% **35-44 age** *f*=1 7,7%	**Female** *f*=8 61,5% **Male** *f*=5 38,5%	**Graduate** *f*=13 100%	**Izmir** *f*=12 92,3% **Manisa** *f*=1 7,7%

The demographic variables such as gender, age, city of residence and higher education level of the students who took part in the *first* pilot study are described in *Table 3*.

Table 4. Student Profiles in the Second Round of Implementation

Student	Age	Gender	Education Level	Location/City
1	18-24	Female	Undergraduate	Izmir
2	18-24	Female	Undergraduate	Izmir
3	18-24	Female	Undergraduate	Izmir
4	18-24	Female	Undergraduate	Izmir
5	18-24	Female	Undergraduate	Izmir
6	25-34	Male	Undergraduate	Izmir
7	18-24	Male	Undergraduate	Izmir
8	18-24	Female	Undergraduate	Izmir
9	18-24	Female	Undergraduate	Izmir
10	25-34	Male	Undergraduate	Izmir
11	18-24	Female	Undergraduate	Izmir
12	18-24	Male	Undergraduate	Izmir
Descriptive Statistics	**18-24 age** *f*=10 83,3%	**Female** *f*=8 66.6%	**Graduate** *f*=12 100%	**Izmir** *f*=12 100%
	25-34 age *f*=2 16,6%	**Male** *f*=4 33,4%		

The demographic variables such as gender, age, city of residence, higher education level, smoking status and frequency of doing sports of the students who took part in the *second* pilot study are described in Table 4.

2.3. DATA COLLECTION TOOLS

In the design of the enriched classroom environment, the technologies to be used and the variables, such as heat, light, etc., created by these technologies are expected to provide data regularly. The interactive board is intended for utilization within the confines of the classroom environment. The number of tablets (15) is to be equivalent to the number of students enrolled in the course. The organization of wireless internet connection technologies will be implemented for the classroom, and these tools will be made available for communication purposes. In this section, both qualitative and quantitative data were collected. To illustrate, while room temperature provides quantitative data as a variable, learner opinions against this situation constitute the qualitative data source. In order to evaluate the variables related to the internal environment and the effectiveness of the course, feedback was received from the relevant sample profile. The application of data collection tools was employed to ascertain the opinions of faculty members and students within the research group. The objective of these data collection instruments is to solicit the opinions of participants regarding the technology-enriched classroom environment.

2.3.1. COURSE EVALUATION QUESTIONNAIRE

After the courses were conducted by the researchers within the research scope, a course evaluation questionnaire was applied to the students in the hybrid or classroom. The course evaluation questionnaire was developed to obtain the participants' evaluations of the courses conducted. The course evaluation questionnaire has five questions to determine the descriptive statistics of the participants, such as age, gender, and undergraduate department, and five Likert-type questions to determine their evaluations of the course process. In addition, six open-ended questions about the course process were included in the course evaluation questionnaire to determine the students' opinions. The related course evaluation questionnaire is given in *Appendix1.*

2.3.2. STUDENT OPINION SURVEY

The researchers developed a student opinion questionnaire consisting of 42 closed- and open-ended questions to be used after the courses conducted within the research to determine the students' opinions about the learning environment and the course process. The student opinion questionnaire was used in each lesson. The questionnaire was used to collect the students' opinions at the end of the course. The related opinion questionnaire is given in *Appendix 2.*

2.3.3. LECTURE VIDEO RECORDINGS

In the lessons conducted within the scope of the research, the learning environment and students were recorded using a camera. During the data analysis process, the researchers examined the course recordings to confirm the observations made during the lessons and to elaborate the analysis process. The video recordings of the lessons are kept confidential within the scope of the relevant ethical permissions. There were 1200 minutes of video recordings during the first and second rounds of implementation, each eight weeks in total 16 weeks of lessons. While there were approximately 655 minutes of recording time in the first pilot implementation, 545 minutes were recorded in the second pilot implementation.

2.3.4. ACADEMICIAN INTERVIEW FORM

The researchers prepared a semi-structured interview form to collect the interview data, which is one of the qualitative data of the research. In addition to fixed-choice answers, in-depth answers are obtained in the relevant field with the semi-structured interview technique. While preparing the semi-structured interview form, a literature review was conducted first, and then draft interview questions were created in line with the information obtained. The interview form development process was continued by assessing the researchers' opinions. According to the feedback received from the researchers, necessary corrections were made, and the final version of the interview form was created. "Academician Interview Form" was applied in face-to-face individual interviews with academicians who are the instructors of the courses carried out within the research scope. The academic interview form consists of 18 questions in total. Eight of the 18 questions in the interview form are related to the technology-enriched classroom environment, five are within the scope of teaching materials, and five focus on the classroom management process. The "Academic Interview Form" applied within the scope of the research is given in Appendix 3.

2.3.5. COURSE OBSERVATION FORM

The researchers developed an observation form to provide course observation data in the first and second- pilot study within the research scope. The lesson observation form was applied during 16 lessons, eight of which were first-round and eight of which were second-pilot study. In addition, the observation form was used to confirm the data and to deepen the analysis. The lesson observation form was applied while the records were being monitored. It consists of four dimensions: "Activism during the lesson," "Effective Communication," "Motivation," and "Interest and Attitude." Time and behavior repetition were prioritized in the lesson observation, and detailed data were obtained. The lesson observation form is given in Appendix 4.

2.4. DATA COLLECTION PROCESS

Indoor environmental conditions were recorded simultaneously with the lessons in which instructional design-oriented tests were carried out in the smart classroom. At the end of each test, the quality and suitability of the recorded data for analysis were evaluated, and the tests were repeated when necessary.

There are 15 tables and 15 chairs in the smart classroom. These are arranged in 3 columns, five from front to back. The entrance to the classroom is through the door at the front (See Figure 4). The smart board has a webcam that transfers the classroom image to the digital environment. The teacher's desk and computer are on the left side of the smart board. On the right side of the smart board, there is a camera observing the classroom. Two devices measure the classroom environment values on the right wall of the classroom, close to the smart board, and on the back wall opposite the smart board. These devices display the values of observed indoor environmental conditions and record them. There is an air conditioner in the upper part close to the device on the back wall. There are windows on the left wall of the classroom. It should be noted that the same classroom setting was used both the pilot and testing phases.

The opinions of the lecturer and students who will use the environment jointly within the scope of a sample course were taken at the end of each course, and the students' behaviors in the recorded lessons were examined during the course period. The opinions received in the design model research process continued to eliminate deficiencies. The following stages carry out the data collection process.

Stage 1: Creating a Technology-Enriched Learning Environment: At this stage, the variables related to the indoor environmental conditions affecting learning performance were identified through the literature survey. The sensor network required for measuring and recording the relevant variables was defined. In this context,

- At least 18,000 BTU air conditioner, to be determined by feasibility (capable of recording data such as when the set points change, when they are switched on and off)
- Ambient air humidifier (adjustable according to ambient relative humidity)
- Adjustable lighting system
- Camera
- Indoor environmental conditions' measurement set content: indoor air temperature, relative humidity meter, CO2 / air quality, light intensity measuring sensors (luxmeter), and sound measurement sensors are installed.

Technical specifications for the sensors selected for measuring indoor environmental conditions are given in *Table 5.*

Table 5 Technical Specifications for Indoor Environmental Conditions' Data Measurement

Sensor	Measurement Range	Sensibility	Resolution
Indoor air temperature	-20....+50 °C	±0,3 °C	0,1 °C
Relative humidity	0.....100%	±3% (between 5-85%)	%1
CO2/Air quality	0....10.000 ppm	±(75 ppm ±3% mv) (0 ... 5000 ppm) ±(150 ppm ±5% mv) (5001... 10000 ppm)	-
Light intensity	0....99.999 Lux	±3 Lux or ±3%	1 Lux
Sound measurement	30....130 dB	±1.4 dB (under reference conditions: 94 dB, 1 kHz)	0,1 dB

Stage 2: Design of sample lesson(s) for the smart classroom: The interactive whiteboards and mobile devices planned for the lessons and the interactive course programs were designed in technical and content dimensions. This work package provided for the selection of the sample course, the lecturer's delivery of the sample course, the adaptation of the course content for the enriched classroom environment, and the integration of the course materials into the smart classroom.

Some variables of technology-enriched classroom environment,

- Indoor air temperature
- Relative humidity
- Lighting intensity optimization.

However, to optimize this situation, (i) the stakeholders' views using the environment and (ii) the design of the learning environment are important factors.

(i) In this context, the opinions of the lecturer and students who will use the environment jointly within the scope of a sample course were taken at the end of each course, and the students' behaviors in the recorded lessons were examined during the course period.

(ii) In the design of the enriched classroom environment, the technologies to be used in the environment and the system that will regularly provide data from the variables such as indoor air temperature, light, etc., have been designed. The interactive board in the classroom environment, as many tablets (15) as the number of students who will take the course, wireless internet connection technologies were organized for the classroom, and these tools were enabled to talk to each other. In this process, the effects of the data in (i) on this classroom environment were measured. The data collected in this section are both qualitative and quantitative. For example, while room temperature provides quantitative data as a variable, learner opinions against this situation constitute the qualitative data source.

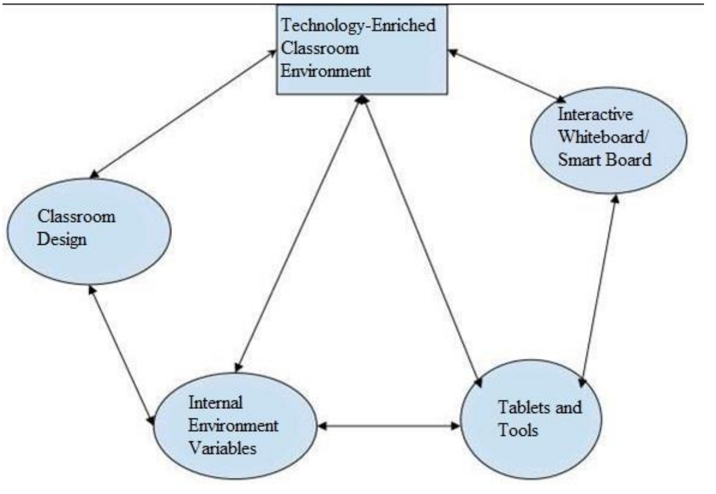

Figure 3 Interaction Area for Smart Classroom Data

The smart classroom provides an in-class and out-of-class interaction environment via the Internet of Things. Given the factors affecting the classroom learning environment, the aim is to create a classroom model with high efficiency and effectiveness by analyzing the data used to ensure the optimum level of communication between the technologies used.

Stage 3: Collection and evaluation of data on indoor environmental conditions and student feedback during sample lessons: Firstly, data collection strategies (measurement interval and frequency, etc.) for the indoor environmental variable were determined to observe the physical conditions. While analyzing the teaching process in the smart classroom established in line with the determined strategies, the ambient conditions were recorded simultaneously with the lessons. At the end of each test, the quality and suitability of the recorded data for analysis were evaluated.

2.4.1. DATA ACQUISITION OF INDOOR ENVIRONMENTAL VARIABLES

Student placement in the smart classroom was predetermined by considering the sensor and camera positions since people are a source of CO_2, heat and sound, which might cause bias in the measurements. Thus, in order to minimize the sudden changes in the CO_2, indoor air temperature, sound level, air pressure, relative humidity and light intensity values, students were asked not to sit in the first and last rows, which are close to the sensors. In addition, the same method was used on the students not to close the camera angle.

The sketch of the smart classroom is shown in *Figure 4*. As seen in *Figure 4*, the sensors are placed far away from the students and the teacher in the smart classroom to obtain the raw data of the environment, as described above. Two sensors at each end of the classroom are set so that they are not directly affected by ambient variables. Air conditioner, doors, windows, radiators, and light sources were considered while positioning the sensors. Moreover, the sudden changes in the ambient variables and the instantaneous measurement errors that may occur are also considered; the sensors are positioned to be less affected.

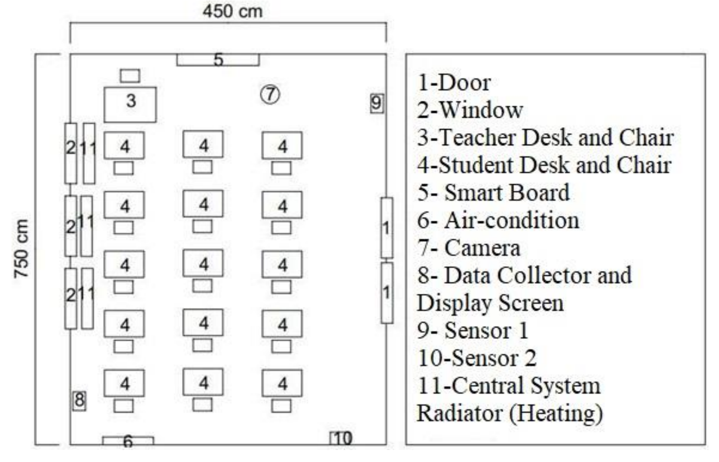

Figure 4 Technology Enriched Smart Classroom Sketch

The sensors were soldered to the Raspberry Pi minicomputer by designing a mini card. The communication between the sensors and Raspberry Pi was established physically using an Arduino circuit board, and a program in Python running on Raspberry Pi was created to receive and record the data. To provide remote access to the recorded sensor data, Raspberry Pi was connected to the school internet; a special proxy was set in the school internet system that allows remote management of the sensor system. The sensor system was set to record the data every 10 seconds. The schematic of the sensor and recording system is shown in *Figure 5*.

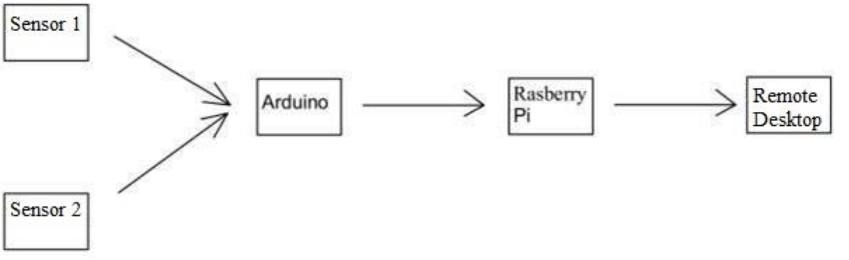

Figure 5 Schematic Representation of Sensor and Recording System

The sensor data consists of indoor air temperature, relative humidity, pressure, light intensity, CO_2, and sound intensity values of the environment. The pressure values of the environment are shown on the graphs as additional data since they are indirectly related to the comfort levels of students. The sensors are divided into two main groups: Sensor 1 group and Sensor 2 group. The placement of the sensor groups is shown in the sketch in *Figure 5*. Temperature, relative humidity, pressure, light intensity, CO_2, and sound sensors are in both groups. The reason for taking ambient data from two different ends of the classroom is that the ambient comfort variables are not homogeneously distributed throughout the classroom due to the variables mentioned in the literature section. The sensor layout plan aims to obtain average values in the smart classroom environment.

2.4.2. PILOT STUDY - I

The first pilot study was conducted for eight weeks. In this context, the Scientific Research Methods course was taught in a smart classroom environment, and an online environment was utilized. The data was collected during the fall semester of the 2020-2021 academic year. All students had tablet computers with internet connections in the classroom, including the program that connects to the smart board. Students were able to follow the lesson on the tablet computers they were provided with. The data obtained was used to improve the software on the smartboard. Access structure to some of the Web 2.0 tools through the program was developed. In addition, the sensor layout was confirmed to be appropriate whereas some bugs regarding the recording of ambient data were improved.

2.4.3. PILOT STUDY - II

The second pilot study was conducted for eight weeks. The Scientific Research Methods course was conducted with the second-year students of the Faculty of Education, Turkish and Computer Education and Instructional Technology Education undergraduate program using the smart classroom and online environment. Data was collected during the spring semester of 2021-2022 academic year. The software was installed on the tablets and ready to be used by the students. The measurement of the environment variables was monitored simultaneously.

2.5. DATA ANALYSIS

The procedure to analyze the data related to indoor environmental conditions consists of two stages. First, the compliance of indoor environmental conditions with the relevant standards and regulations were determined. The standards considered are as follows:

- ASHRAE 55 and ISO 7730 Standards (indoor air temperature and relative humidity)
- World Health Organization (CO2/air quality)
- World Labor Organization (light intensity)
- World Health Organization (sound level)

In the second stage, descriptive statistics of the data were calculated to determine the effects of indoor environmental conditions on learning performance. First, scatter diagrams were created and the suitability of the data to normal distribution was determined by drawing histograms. In the next stage, the data distribution was determined by conducting the Anderson-Darling tests. In addition, uncertainties in the data were calculated. Statistical tests determined the homogeneity or heterogeneity of the distribution of the data. Whether each independent variable (e.g. indoor air temperature, illumination) significantly affected the dependent variable (e.g. learning performance) was determined and the reliability was checked via statistical tests. The strengths of the obtained significances, in other words, the degree of the effect of each variable relative to the effect of another variable, were calculated using post-hoc tests. Linear and non-linear correlation coefficients were calculated. At this stage, the variables' effects on the output variables were calculated and evaluated, and the results obtained were compared parametrically.

Table 6 Demonstration of research questions and data analysis methods

Research Questions	Data Analysis
1. What is the effect of technology-enriched classroom environment on perceived learning of students?	Descriptive statistics
2. What are the students' opinions about the contributions of the technology-enriched course to their learning?	Content analysis
3. What are the opinions of the instructors on their teaching experiences in the technology-enriched classroom?	Content analysis
4. What are the students' opinions on the effectiveness of the digital materials used in the technology-enriched classroom?	Content analysis
5. What are the instructors' opinions on the effectiveness of the digital materials used in the technology-enriched classroom?	Content analysis
6. What are the instructors' experiences on managing the technology-enriched classroom?	Content analysis
7. How do the indoor environmental conditions in the technology-enriched classroom affect the learning and teaching process?	Content analysis
8. How do the indoor environmental parameters vary affecting the perceived learning and learner comfort in a technology-enriched classroom?	Descriptive statistics

The research questions and data analysis methods are shown in Table 6, and the answers to the same questions were sought in the first and second applications. In the process, the research questions "Do the indoor environmental conditions in the technology-enriched classroom affect the learning performances of university students?" and "Which variables in the indoor environmental conditions in the technology-enriched classroom affect learning?" were combined as a result of the analyses and described under the analyses of the question "Which variables in the indoor environmental conditions in the technology-enriched classroom affect learning?".

2.6. RESEARCHER ROLE AND VALIDITY AND RELIABILITY MEASURES IN QUALITATIVE DATA ANALYSIS

While analyzing the qualitative data for the credibility and transferability of the findings, two separate researchers, faculty members of the faculty of education, coded the data in separate periods. While creating the codes, the terms in literature and similar studies were utilized. These two researchers analyzed the documents related to the study, examined the smart classroom and watched the course videos. Thus, they obtained detailed information about the environment, identified situations that could cause distortions, and made their interpretations with professional judgements. Then, the researchers came together and created a common coding structure. They shared this common coding system with another researcher in the study. Miles and Huberman's (1994) internal consistency formula was applied to measure coder reliability. This rate was calculated as 84%. A consensus between 80% and above coders indicates reliability (Miles & Huberman, 1994).

Data collection tools were diversified to serve the research's purpose and help analyze the situation from multiple perspectives. Survey, interview and observation data and individual experiences were verified from different sources. The process was analyzed from different perspectives with diverse participants (engineering and education faculty students). Participants were told that they could leave the study at any time. Thus, their free will and sincere opinions were obtained. The same questionnaire was applied to the participants at different periods, and contradictions were tried to be determined. The data were recorded meticulously. The study's implementation and data analysis processes were detailed and transparently reported. The researchers interpreted the data reflectively, reflecting on their perspectives from educational and engineering sciences.

2.7. ABBREVIATIONS USED IN CODING

Some abbreviations were used to express the units from whom and where the texts were presented as evidence in the findings section; the codes and themes were obtained. Table 7 shows the abbreviations expressing the time and method of data collection.

Table 7 Display of abbreviations

Time and method of data collection	Abbreviation
Second Pilot Study Student Survey	ITUO
Second Pilot Study Academician Interview	ITUA
Second Pilot Study Observer Observation Note or Video	ITUG
First-Pilot Study Student Survey	BTUO
First-Pilot Study Academician Interview	BTUA
First-Pilot Study Observer Observation Note or Video	BTUG

Numbers were added to the abbreviations to distinguish the individuals. For example, if a text in the questionnaire applied to the students in the first pilot study was used and the fifth person said it, it was expressed as "ITUO5".

3. FINDINGS

The findings of the project were presented inductively and holistically to answer the research questions. The first and second pilot study data were handled together. The views of students and instructors on the technology-enriched environment were analyzed in terms of environment, materials, and classroom management components. The qualitative findings for the 1st, 2nd, 3rd, fourth and fifth questions were answered. Research questions number 6-9 were analyzed using descriptive statistics over the sensor data, which were provided with continuous data flow within the scope of the research. The themes, sub-themes and codes obtained from the content analysis are given in *Figure 6.*

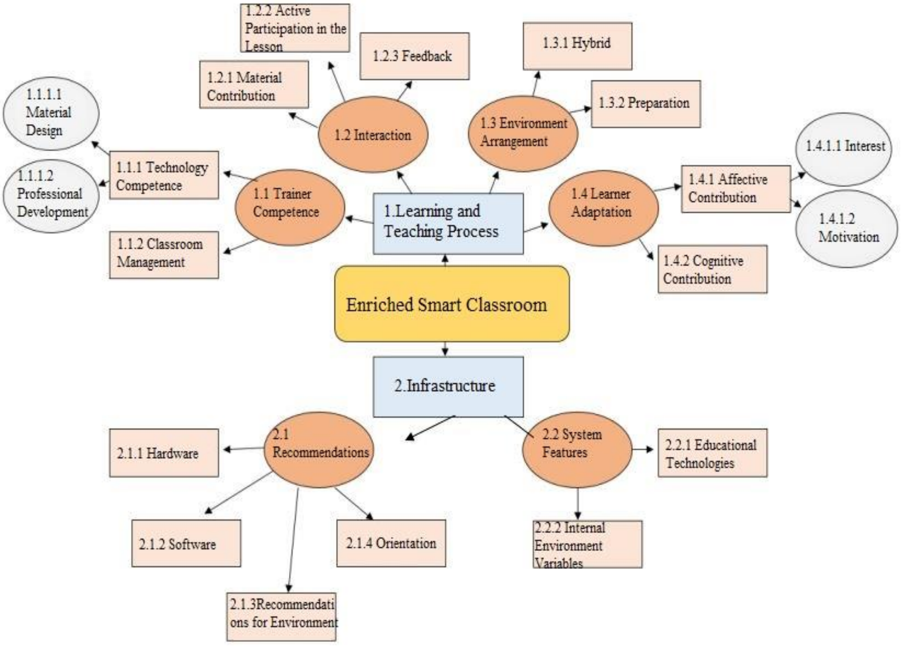

Figure 6 Theme, Sub-theme and Code Scheme for Qualitative Findings

As seen in *Figure 6,* there are two main themes: Learning and teaching (a) and Infrastructure (b).

3.1. THE EFFECT OF TECHNOLOGY-ENRICHED CLASSROOM ENVIRONMENT ON PERCEIVED LEARNING OF STUDENTS

The findings obtained from the data collection tools show a relationship between the technology-enriched classroom environment and the student in terms of interaction, harmony and order. When the student factor is considered holistically, it is not considered independent from achievement. Therefore, in *Figure 7*, the relationship between student achievement and technology-enriched classroom environment is visualized based on the codes and themes obtained from qualitative data collection tools.

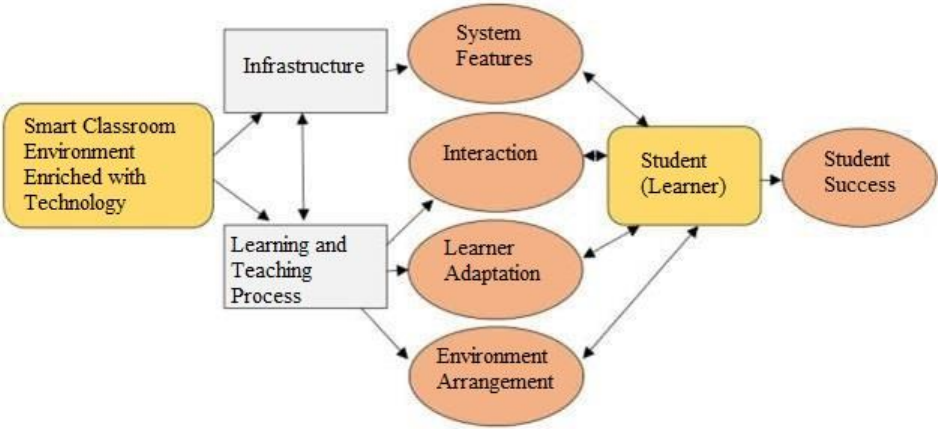

Figure 7 Qualitative Relationship Between Technology-Enriched Classroom Environment and Perceived Learning of the Students

Based on the opinions of students and academicians who took part in the first and second pilot studies, it is reported that the learning process carried out in the technology-enriched classroom environment positively affects student achievement. According to the participants, teaching in a technology-enriched classroom environment and the teaching materials used in the teaching process positively affect the learning-teaching process of the students and, thus, the success. The participants' views on teaching in a technology-enriched classroom environment are positive regarding the theme of interaction and active participation in the lesson (*f*=5) within the framework of student achievement, which is favorable. In addition, based on the participants' opinions, the possibilities of using technology (*f*=3) and the environmental conditions (*f*=5) are positive regarding the classroom environment's systemic characteristics. Based on the opinions of students and academicians, the factors that positively affect the cognitive and affective learning process and student success are emphasized. According to the participants, the classroom environment enriched with technology in terms of focusing (*f*=13), efficiency (*f*=8), retention (*f*=1) and increasing interest (*f*=5) positively affects student achievement. The related opinions of the participants are expressed as follows:

"It was an active and productive process." [BTU22, survey, learner cohesion]

"...I think it is a healthy, successful and efficient choice." [BTUO12, survey, educational technologies]

"I think that the ease of course follow-up increases the benefit from the course." [BTUO7, survey, learner adaptation]

"It helped me understand the lesson better. Since the environmental conditions are ideal, I can pay better attention to the lesson." [ITUO7, survey, learner adaptation]

"...I think the lesson was more productive." [BTUO4, survey, learner adaptation]

"...I think it increases the student's motivation, which reflects positively on me..." [BTUA1, interview]

"The parallelism of the course content and materials facilitated my comprehension and focusing process..." [BTUO7, survey, material contribution] "I understood better..." [BTUO6, survey, material contribution]

"I understand better..." [BTUO6, survey, material contribution]

"Visually, it increases the permanence in me..." [ITUO1, survey, material contribution] "Easier adaptation and focusing..." [ITUO2, survey, material contribution]

"Intriguing..." [ITUO9, survey, material contribution]

"I think it helps students to be more motivated..." [BTUA1, interview, effective contribution]

"I have seen that students' interest in this direction has also increased..." [ITUA1, interview, affective contribution

"...I think it contributes positively to learning..." [BTUA1, interview, cognitive contribution - active participation in the lesson]

3.2. THE STUDENTS' OPINIONS ABOUT THE CONTRIBUTIONS OF THE TECHNOLOGY-ENRICHED COURSE ON THEIR LEARNING

When the students were asked to evaluate the contributions of the technology-enriched course on their learning on a 5- points scale in the first pilot study, an average of 4.48 points was reached. The students gave five points (*f*=16, 55,17%), four points *(f*=11, 37,93%) and three points *(f*=2, 6,90%). When the students were asked to evaluate the course over 5 points in terms of the teaching process, an average of 4.55 points was reached. 65,52% of the students gave five points (f=19), 27.59% four points (f=8), 3.45% three points (f=1) and 3,45% two points (f=1). BTUO17, one of the students who participated in the hybrid classroom application, stated, "*It was a different experience to connect online with those in the smart classroom and to follow the whole process live...*" while the participants also expressed different opinions about the process. Some of the participant opinions are as follows:

> *"It was very nice to include technology with the smart classroom in the lesson process..." [BTUO27, survey, educational technologies]*
>
> *"It was an active and productive process." [BTU22, survey, learner cohesion]*
>
> *"I think switching to online course systems is a healthy, successful and efficient choice considering today's COVID conditions and the conveniences brought by the 21st century." [BTUO12, survey, educational technologies]*

When the participants in the first-pilot implementation period were asked about their attitudes towards teaching with this method, which includes smart classroom applications, 89,66% of the students stated that they would prefer such a design (*f*=26), while 10,34% of the participants stated that they do not (*f*=3).

When asked to evaluate the hybrid applications and the course process carried out during the first pilot of the implementation period in terms of technical aspects, it was seen that the participant opinions reached an average of 4.62 points out of 5 points. In the technical evaluation of the course process, 65,52% of the participants graded five points (*f*=19), 61,03% four points (*f*=9), and 3,45% three points (*f*=1). In addition, 24 participants (82.76%) stated that they did not experience any technical problems during the course, while the participants stated that they experienced some technical problems during the course (17.24%). The technical problems experienced by the students during the course are as follows: Personal internet connection problems (*f*=2, 6,90%), audio transmission problems (*f*=2, 6,90%), and not being able to access the course recording (*f*=1, 3,45%).

The participants' views of the first pilot study were positive (*f*=11) about learning in a technology-enriched smart classroom. All the participants find the lesson process positive. The following opinion of BTUO1, one of the students; *"...Entering the classroom environment in a technology-enriched environment for the first time after the pandemic period helped me adapt more easily. Although I sat at the back, I had no difficulty, thanks to the tablet. In the normal process, I could miss the lesson when I sat at the back..."* emphasizes the positive features of the technology-enriched smart classroom. In addition to this, the following opinion of BTUO3 is also positive: *"...I think it will be useful in increasing the focus on the lesson after the transition to the application of optimum values with measurements in the classroom environment..."* In parallel with these views, the opinions of the participants are diversified as follows:

> *"I think all the university classrooms should be converted into such smart classrooms if possible; it is very good for teaching; it provides convenience for both students and teachers." [BTUO5, survey]*
>
> *"It was positive for me as trying to improve our facilities in the classroom and as a different lesson experience. I think that not seeing names in the applications in the classroom encouraged the students to give more comfortable answers. I think that the ease of following the course increased the benefit from the course." [BTUO7, survey, learner adaptation]*

The findings obtained from the data collection tools show that the participants in the second pilot of the implementation process had positive feelings about teaching in a smart classroom environment. The participants' opinions are on the learner adaptation sub-themes affective and cognitive contribution codes. Learners stated that teaching in a technology-enriched smart classroom was a different experience (*f*=8); they enjoyed (*f*=3), had fun (*f*=1), felt happy (*f*=2) and excited (*f*=3). The opinions of the participants are as follows:

> *"It was a different experience for me; I had never been in such a smart classroom environment before; it was efficient to teach in this environment" [ITUO5, survey, learner adaptation]*
>
> *"It is good because it is a class that keeps up with the new age" [ITUO2, survey, learner adaptation]*

"There was a happy excitement of being intertwined with technology." [ITUO12, survey, learner adaptation]

Participants also reported the positive features of the technology-enriched smart classroom. Participants emphasized some positive features of the smart classroom, including the first-pilot study (f=12) and the second-pilot study (f=21). From this point of view, the features that the participants find positive are as follows: tablet (f=12), smart board (f=6), environment values (f=10) and interactive lesson environment (f=5) and emphasize the sub-themes of system features, interaction and learner adaptation. The opinions of some of the participants who stated positive features of the technology-enriched smart classroom are as follows:

"The fact that we can manage the heat and light conditions of the classroom with the smart board." [ITUO6, survey, system features]

"Tablet use was good because it was difficult to see the board. Keeping the ambient air and temperature at appropriate values increased the focus on the lesson." [ITUO7, survey, system features]

"Monitoring the physical comfort of students in the classroom environment and working on this issue was a positive experience for me. As someone affected by physical conditions, I can say that the smart classroom environment is better than other classrooms." [BTUO7, survey, system features]

"It is an interactive lesson environment. We are more interested in the lesson with instant question and answer and surveys." [BTUO11, survey, interaction]

"Simultaneous teaching is more beneficial for student-centered education." [ITUO1, survey, interaction]

"Post-added temperature and lighting adjustment, tablet feature, interactive environment." [BTUO1, survey, system features]

When the participants were asked to indicate the negative features of the technology-enriched smart classroom, all participants expressed their opinions, including the first-pilot study (*f*=12) and the second-pilot study (*f*=22). Accordingly, the features that the participants found negative about the technology-enriched smart classroom are as follows: ventilation (*f*=4), lighting (*f*=6) and temperature (*f*=4). In addition, some participants (*f*=2) stated that there were some problems regarding control and individualization on the tablet. On the other hand, 41.17% of the participants stated no negative features (*f*=14) for the technology-enriched smart classroom. The opinions of some of the participants who stated negative features of the technology-enriched smart classroom are as follows:

"The lighting in the classroom was insufficient. It would be more spacious if it had daylight." [ITUO7, survey] "I think the ventilation was insufficient." [BTUO3, survey]

"It can cause headaches because there are too many technological devices." [ITUO2, survey]

"The lack of personalization and note-taking was a negative aspect for me..." [BTUO7, survey]

"There is no feature that I find negative." [ITUO4, survey]

"It would be good if students could control the tablets more, not negatively. For example, the back-forward button of the presentations can be added because sometimes there is information that is missed, but there is no possibility of returning." [BTUO5, survey]

When the participant's views on teaching in a technology-enriched smart classroom environment are examined, the sub-themes of system features, learner adaptation and interaction come to the fore. Participants expressed opinions about the contributions of teaching in the smart classroom, including the first-pilot study (n=11) and second-pilot study (n=12). The participants explained the contributions of teaching in a smart classroom environment enriched with technology as active participation in the lesson (*f*=5), focusing (*f*=13), efficiency (*f*=8), ease of following the lesson-tablet (*f*=4), memorable (*f*=1), ease of access to technology (*f*=3), positive environmental conditions (*f*=5) and increased interest in the lesson (*f*=3). The opinions of the participants are as follows:

"It helped me understand the lesson better. Since the environmental conditions are ideal, I can pay better attention to the lesson." [ITUO7, survey, learner adaptation]

"I think that being able to reach technology immediately when needed and getting help from technology increases the efficiency of teaching in this environment" [ITUO5, questionnaire, system features]

"...Having a tablet is very good; it is easier to follow and understand the lesson. After that, one needs to be comfortable to focus on the lesson. This smart classroom provides this condition because we can choose the appropriate environment (brightness and temperature) ..." [BTUO5, survey, system specifications]

"It was the first experience for me. I enjoyed teaching in this environment. I think the lesson was more productive." [BTUO4, survey, learner adaptation]

"Providing a fluent and active lesson environment" [ITUO10, survey, interaction]

"It was good; it can provide optimum efficiency for students to focus on the lesson." [ITUO11, survey, learner adaptation]

The participants' opinions also include negative contributions to teaching in a technology-enriched smart classroom environment. Participants stated that ventilation (*f*=3), temperature (*f*=1), distraction (*f*=1), and illumination (*f*=2) contributed negatively to the process of teaching in the smart classroom environment. In addition, 52.17% of the participants stated that there is no negative contribution to teaching in a smart classroom enriched with technology (*f*=12).

One of the participants' opinions regarding the smart classroom environment enriched with technology is the design thoughts of the participants regarding the smart classroom environment and their suggestions for changes in the smart classroom. In this regard, the participants' views on the smart classroom environment and their classroom environment designs were reached. According to the findings obtained from the data collection tools, the participants emphasized the elements of a large classroom (*f*=3), an airy environment (*f*=3), a classroom with daylight (*f*=1), software changes (*f*=3), hardware changes (*f*=2) and light reductions (*f*=3) in the design of a smart classroom enriched with technology. In addition, some participants (*f*=9) stated that they found the current design of the smart classroom environment appropriate and did not want to change it. Participants expressed their views as follows:

"I would prefer a more spacious classroom." [ITUO7, survey, suggestions] "I would use less light" [ITUO1, survey, suggestions]

"I would pay more attention to the ventilation of the classroom..." [BTUO1, survey, recommendations]

"I would make sure that the classroom environment is bigger. I would like to have automatic lighting and temperature systems. I would like to have a smart note system that will ensure that there are slides and my notes on the tablets simultaneously every week, and that reminds me." [BTUO7, survey, suggestions]

"It could have been as if we were all working together with our online friends reflected on the side." [BTUO11, survey, suggestions]

"I would upload a digital pen." [BTUO6, survey, suggestions] "I designed a similar environment." [BTUO6, survey]

"I would have done it just like that, nothing to change..." [BTUO5, survey]

"As stated later in the classroom changes, it was created in such a way that it can be applied if 70% of the requests are made, but I think that after a student's request, a questionnaire can be sent to the other tablets to see if they approve and changes can be made faster as a result of the questionnaire..." [BTUO9, survey, recommendations]

3.3. THE OPINIONS OF THE INSTRUCTORS ON THEIR TEACHING EXPERIENCES IN THE TECHNOLOGY-ENRICHED CLASSROOM

In line with the findings obtained from the data collection tools, it is seen that the opinions of the instructors involved in the first pilot study and the second pilot implementation process are positive towards the technology-enriched classroom environment. It is seen that the opinions of the instructors about the technology-enriched classroom environment are concentrated in the sub-themes of "system features", "interaction", and "instructor competence". In addition to this, the sub-themes of "learner adaptation", "suggestions", and "environment layout" are reached in the opinions. The density of the sub-themes and codes obtained from the instructors' opinions is visualized in *Figure8*.

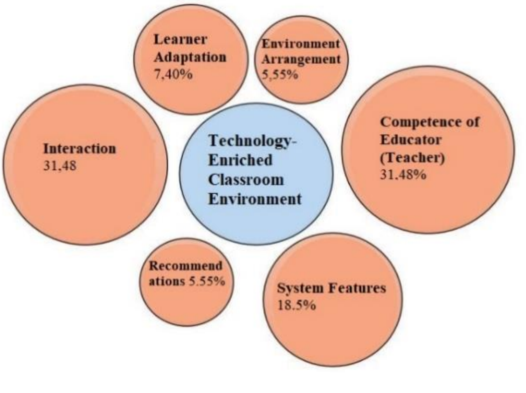

Figure 8 Sub-theme and Code Density of Instructor Opinions on Technology-Enriched Classroom Environment

The instructors' opinions posit that teaching in a technology-enriched classroom environment is a different experience (*f*=2). Some of the instructors expressed feelings of excitement (*f*=1), anxiety (*f*=1) and happiness (*f*=1). While BTUA1 expressed his feelings about teaching in a technology-enriched classroom environment as *"I can say that it is a different experience..."*, ITUA1 expressed his feelings about teaching in this classroom environment as follows:

> *"Giving a lesson in such an environment excited me a little. I had such an experience for the first time. I liked it, I liked it... It was an experience that I was happy... Although my field is close to technology, I feared what I would do if I had problems. However, I realized this fear was unfounded when I used the classroom..." [ITUA1, interview, learning teaching process]*

Teaching in a technology-enriched classroom environment is found to be positive based on the opinions of the instructors. ICTUA1 stated that lecturing in the classroom environment is *"a much more interactive environment than lecturing in the classroom..."*. In addition, BTUA1 states that *"the experience of lecturing on the smart board is positive, and being able to access the board from my tablet made the experience even easier... In addition, the fact that students can interact with it is one of the positive features."* ITUA1 expresses his views on teaching in the classroom environment as follows:

> *"From an instructional point of view, with the application on the smart board, the teacher could transfer his/her presentation, make markings on it and offer his/her students the opportunity to use the whiteboard... Thus, an interactive lesson could be taught, and students in the online environment could see what was written on the board... There were links to some web 2.0 applications that worked in integration with the program. All students could access that application by starting it from there..." [ITUA1, interview, system characteristics, interaction]*

The system features of the infrastructure in the technology-enriched classroom environment are emphasized in the instructors' opinions. ITUA1 expresses that the system features reflect positively on the process with the following views:

> *"Each student had a tablet. The same application was used on the tablet as on the smart board. Thus, the students having difficulty seeing the board could follow the lesson on his/her tablet..." [ITUA1, interview, system characteristics, interaction]*

In parallel, ITUA1 stated that the layout of the classroom environment has positive effects: "*I find it positive to have individual tables and chairs in the smart classroom. Thus, working areas can be created with students in different layouts. Even if the students are not facing the board, they can follow the presentation on the board thanks to the tablets...*". The student feedback system for the internal environment variables in the classroom environment is also positive based on the instructors' opinions. ITUA1's views on this subject are as follows:

> *"It is a good system for students to send notifications about the classroom environment, such as light, temperature, and lack of air. Thus, the instructor can notice the distraction caused by the physical environment." [ITUA1, interview, interaction; system features]*

ITUA1 adds the following regarding the student feedback system for indoor environment variables:

> *"...There were small devices mounted on the walls that measured the environment. With the help of these devices, the amount of carbon dioxide, light, relative humidity, and temperature in the classroom can be recorded. At the end of one lesson, the students said that the environment was too hot; for example, in the next lesson, we started the lesson with the air conditioner switched on beforehand..." [ITUA1, interview, system characteristics; interaction]*

The fact that the classroom environment is enriched with technology allows the current environment to be taught using the hybrid method, which is emphasized in the instructors' opinions. The teaching of the courses with the hybrid method is considered positive based on the instructors' opinions. BTUA1: *"It is also important for me to have the necessary infrastructure to teach the course hybrid..."*; ITUA1, "...*I presented all these activities to the students using smart board technology and internet infrastructure. Students in the virtual environment could easily follow the lesson. There was also a camera image where they could see us...*".

In addition to this, ITUA1 and BTUA1 emphasize that they find the effect of the technology-enriched classroom environment on the lessons taught with the hybrid method positive with the following opinions:

> *"...When using interactive materials, it was nice that both the students in the classroom and the students at the computer could give answers together." [BTUA1, interview, environment layout]*

"...I think that connecting from the environment for the classroom also strengthens the distance education experience..." [BTUA1, interview, system specifications, media layout]

Based on the instructors' opinions, the infrastructure, i.e., system features in the classroom environment enriched with technology, are found to increase interaction in the learning-teaching process.

When the opinions of the instructors about the technology-enriched classroom environment are examined, it is seen that there are negative features. The negative features of the classroom environment are expressed in the opinions of the instructors as internet connection (*f*=2) and technological competence of the instructor (*f*=1). The opinions of the instructors are as follows:

"My students sometimes have connection errors..." [BTUA1, interview, system specifications]

"...There were limitations such as me needing time to get used to the technology..." [BTUA1, interview, trainer competence]

"...Sometimes having slow internet or connection problems could affect the lesson's teaching badly..." [ITUA1, interview, system specifications]

The contribution of teaching in a technology-enriched classroom environment to the instructors is one of the findings obtained from the instructors' opinions. In the opinions of the instructors, the positive contributions of teaching in a technology-enriched classroom environment to the instructors are expressed as student feedback (*f*=2), technology competence (*f*=2), course efficiency (*f*=1), classroom management (*f*=2), instructor motivation (*f*=2), material design (*f*=2), teaching techniques (*f*=1), pre-lesson preparation (*f*=2), problem-solving skills (*f*=1), material diversity (*f*=1) and technology integration (*f*=2).

As one of the positive contributions of teaching in a technology-enriched classroom environment, student feedback (*f*=2) was expressed by the instructors as follows:

"It contributed to a process in which I could get more feedback from my students..." [BTUA1, interview, interaction/feedback]

"...Especially being able to get instant feedback from the students brings a lot for the lecturer..." [BTUA1, interview, interaction/feedback]

According to the instructors, technology competence (*f*=2) is among the contributions of teaching in a technology-enriched classroom environment. Instructors express the contribution of technology competence as follows:

"...improved my technology skills..." [ITUA1, interview, trainer competence]

"...I had the opportunity to improve my field knowledge about technology..." [ITUA1, interview, trainer competence]

Based on the opinions of the instructors, the contributions of teaching in the classroom environment to the instructors include improving classroom management skills (*f*=2) and course efficiency (*f*=1). The opinions of the instructors are as follows:

"When I look at it as professional development, managing both the physical classroom environment and the online environment together... It also had an impact on my classroom management skills." [BTUA1, interview, trainer competence/classroom management]

"I have experienced more productive lessons when students participate actively..." [BTUA1, interview, interaction/ active participation in the lesson]

Based on the instructors' opinions, instructor motivation (f=2) and material design (f=2) are among the contributions of teaching in the classroom environment to the instructors. The opinions of the instructors are as follows:

"...As an instructor, I was coming to class more motivated..." [ITUA1, interview]

"...I think it increases the student's motivation, which reflects positively on me..." [BTUA1, interview]

"...some lessons in their materials change by making interactive one Classroom that I could provide the environment..." [BTUA1, interview, trainer competence/technology competence]

Some of the prominent contributions of the instructors are teaching techniques (*f*=1), preparation before the lesson (*f*=2), and problem-solving skills (*f*=1). The related opinions of the instructors are as follows:

"...I can say that I increased my preparations before the lesson..." [ITUA1, interview]

"The materials I used for teaching purposes supported me in repeating the subject and coming prepared for the lesson..." [ITUA1, interview]

"I gained experience in finding solutions to problems that arise..." [ITUA1, interview]

"In terms of teaching techniques, I realized the importance of providing diversity in the lesson..." [ITUA1, interview]

According to the instructors' opinions, material diversity (*f*=1) and technology integration (*f*=2) are among the contributions of teaching in a technology-enriched classroom environment. Instructors express their views as follows:

"It made me think about increasing the variety of teaching materials..." [ITUA1, interview, trainer competence/technology competence]

"...I saw that using tablets in the classroom had positive effects. I observed that the students followed the lesson with the tablet in front of them. This strengthened my positive thoughts that technology should occur in the classroom environment..." [ITUA1, interview]

"...It contributed to integrating technology into the classroom as a whole..." [ITUA1, interview]

The instructors' opinions also include the negative contributions of teaching in a technology-enriched classroom environment to the instructors. According to this, BTUA1 stated: "*In this experience, I did not have much difficulty because I was supported in terms of technology, but if I were alone, it would be quite challenging to have to deal with more than one subject (classroom environment, technological tools, etc.) ...*". ITUA1 said: "*I cannot think of anything as a negative effect. No... I can say that there is no negative effect...*". In addition, ITUA1 continues his views on the harms or negative contributions of this process as follows:

"I do not think there is any negative effect..." [BTUA1, interview]

Another point in the instructors' opinions is whether they recommend the experience of teaching in a technology-enriched classroom environment to their colleagues and the reasons for this recommendation. Based on the opinions of the instructors, it is seen that they recommend the experience of teaching in a technology-enriched classroom environment to their colleagues. The instructors' opinions about this experience are positive at the point of recommendation to their colleagues. The opinions of the instructors are as follows:

"I recommend it. It is an environment that develops the lecturer... First, the lecturer needs to get used to the environment and feel comfortable in the environment... After getting used to it, I can say that it makes the lecturer's job easier. Because students can participate in the

lesson through their tablets and participate without hesitation..." [ITUA1, interview, professional development]

"I would recommend it, especially since getting instant student feedback brings a lot to the faculty members..." [BTUA1, interview, interaction]

One of the instructors' opinions about the technology-enriched classroom environment is their design ideas about the classroom environment and their suggestions for changes in the smart classroom. In this regard, opinions on instructors and their classroom environment designs were obtained. According to the findings obtained from the data collection tools, instructors emphasize the software (*f*=3), lesson preparation (*f*=1) and orientation (*f*=2) elements in technology-enriched classroom design. The opinions of the instructors are as follows:

"...I would like students to be able to monitor ambient values such as temperature, etc., with a small software on the tablet. It would be nice to have values renewed every 10 minutes, even every minute..." [ITUA1, interview, suggestions/software]

"First, I would like to make my course content more compatible with this classroom environment..." [BTUA1, interview, professional development]

"...It would also be nice to create an environment where they can do group work with their friends in the virtual classroom..." [ITUA1, interview, recommendations]

"An environment that gives feedback when it senses a decrease in the student's interest in the classroom environment would be useful..." [BTUA1, interview, suggestions/software]

"To facilitate the process, a 1–2-page pdf user manual can be prepared for students and teachers. Thus, for the first time, someone in a smart classroom can learn what to do and start the lesson..." [BTUA1, interview, suggestions/orientation]

"It would be nice to give training to instructors and students beforehand. It would be nice to inform the students how to use the tablets and the software and the instructors about using educational and media components in the classroom. A certificate program for instructors can be organized." [ITUA1, interview, suggestions/orientation]

3.4. THE STUDENTS' OPINIONS ABOUT THE DIGITAL MATERIALS USED IN THE TECHNOLOGY-ENRICHED CLASSROOM ENVIRONMENT

When the participants who took part in the lessons carried out with the hybrid method in the first pilot study process were asked to evaluate the teaching materials used in the technology-enriched classroom environment, it was seen that the average score of the students (n=29) reached 4.62 points out of 5 points. Students rated the teaching materials used in the course process students expressed positive opinions about the teaching materials used in the technology-enriched classroom environment. *Figure 9* visualizes the students' ratings of the teaching materials used in the technology-enriched classroom environment.

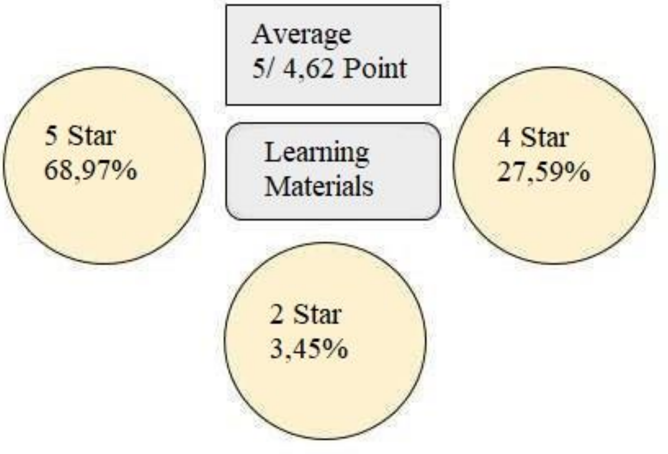

Figure 9 Student Evaluation of Instructional Materials Used in the Course

As visualized in *Figure* 9, 68.97% of the students gave five points (*f*=20), 27.59% of the students gave four points (*f*=8), and 3.45% (*f*=1) of the students gave two points when they expressed positive opinions about the teaching materials used in the technology-enriched classroom environment. It is seen that students did not prefer three-star and 1-star options in their evaluations. When the students' opinions about the teaching materials are analyzed, it is seen that five students (17,24%) expressed their opinions on different subjects, and one student (3,45%) expressed that he/she wanted more detailed materials. Twenty-three students (79,31%) found the materials sufficient and positive. Students express their views as follows:

"The materials are detailed and clear..." [BTUO2, survey, interaction/material contribution] "Very nice..." [BTUO7, survey, interaction/material contribution]

"It was enjoyable to have interactive applications such as surveys, question and answer..." [BTUO18, survey, interaction/material contribution]

"It is adapted to the developing technology." [BTUO24, survey, interaction/material contribution] "It was very explanatory and informative..." [BTUO25, survey, interaction/material contribution] "I think it did not contribute to the process." [BTUO10, survey]

Based on the opinions of the students in the first pilot study (n=12) and the second pilot study (n=12), findings related to the instructional materials used by the instructors in the technology-enriched classroom environment were obtained. While 95,84% (*f*=23) of the students reported positive opinions about the teaching materials used in the course, 4,16% (*f*=1) reported negative opinions. The students reported that the teaching materials used in the technology-enriched classroom environment were useful (*f*=3), useful (*f*=5), understandable (*f*=5), integrated with technology (*f*=5), facilitating follow-up (*f*=2), appropriate to the content (*f*=3), saving time (*f*=2), quality (*f*=3) and successful (*f*=1). Some of the students' opinions about the teaching materials being useful (*f*=3) and beneficial (*f*=5) are as follows:

"I find it very useful..." [BTUO9, survey, interaction/material contribution] "Good quality and suitable for the course..." [ITUO8, survey, interaction/material contribution] "Tablets are very useful..." [ITUO9, survey, interaction/material contribution]

"The presentation projected on the smart board was a useful element in terms of field education..." [ITUO12, survey, interaction/material contribution]

Their opinions on the teaching materials being integrated with technology (*f*=5), understandable (*f*=5) and facilitating follow-up (*f*=2) are as follows:

"I adapted to technology education with the smart classroom environment..." [ITUO3, survey, material contribution]

"A simple and understandable material was prepared for us to understand" [ITUO4, survey, material contribution]

"I think that the materials used by my teacher are quite sufficient, and the smart board-tablet follow-up is carried out in an integrated manner..." [ITUO1, survey, material contribution]

"I think the course content uses the materials and provides understandable active use..." [BTUO7, survey, material contribution]

"Good, understandable..." [ITUO4, survey, material contribution]

"I could follow better regardless of the distance to the board. It was a good contribution." [BTUO3, survey, material contribution]

The student opinions that the teaching materials are appropriate to the content (*f*=3), timesaving (*f*=2), quality (*f*=3), and success (*f*=1) are expressed as follows:

"The parallelism of the course content and materials facilitated my comprehension and focusing process..." [BTUO7, survey, material contribution]

"The materials were sufficient. They were suitable for the content of the course." [ITUO7, survey, material contribution]

"Thanks to the tablets, there was no loss of time as there was faster access" [ITUO2, survey, material contribution]

"It was sufficient and of good quality." [ITUO7, questionnaire, material contribution] "It provided an accelerating effect..." [ITUO12, survey, material contribution]

"I could follow better regardless of the distance to the board. It was a good contribution." [BTUO3, survey, material contribution]

Another finding from student opinions is the contribution of instructional materials instructors use in the technology-enriched classroom environment to learning. While 91,67% (*f*=22) of the students (n=24) who took part in the first pilot study and the second pilot study stated that the instructional materials used in the course process contributed positively to the learning process, 8,33% (*f*=2) of the students thought that the instructional materials did not contribute to learning. The students stated that the contributions of instructional materials used by the instructors in the technology-enriched classroom environment to learning were active participation in the lesson (*f*=6), efficiency (*f*=4), facilitating learning (*f*=10), focusing (*f*=5), retention (*f*=2) and increasing interest (*f*=4). In *Figure 10, the* students' opinions regarding the contribution of teaching materials to learning are visualized.

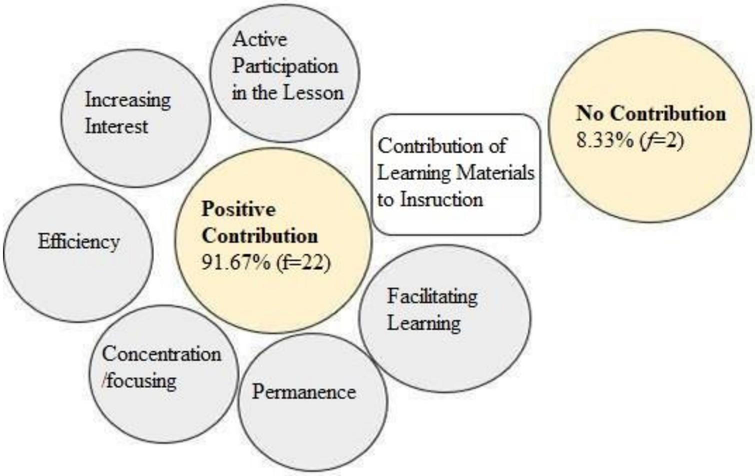

Figure 10 Contribution of Teaching Materials to Learning

The instructors' contribution of the instructional materials in the technology-enriched classroom environment to learning is expressed from the students' opinions, as shown in *Figure 10*. Active participation in the lesson (*f*=6), permanence (*f*=2) and efficiency (*f*=4), which are the contributions of teaching materials to learning, are expressed as follows in student opinions:

"Visually, it increases the permanence for me..." [ITUO1, survey, material contribution]

"...In class, we used survey Question Implementation, and the lesson was active. "He supported the processing..." [BTUO5, survey, material

contribution]

"He made me active in class..." [ITUO1, questionnaire, material contribution] "I understood better..." [BTUO6, survey, material contribution]

"It helped me to be positive and effective." [ITUO7, questionnaire, material contribution] "I understood better..." [BTUO6, survey, material contribution]

"It was enough to learn about the course. Reinforcing with extra reviews increased efficiency..." [ITUO7, survey, material contribution]

Among the contributions of instructional materials to learning, increasing interest (f=4), facilitating learning (f=10) and focusing (f=5) are expressed as follows in student opinions:

"Easier adaptation and focusing..."[BTUO2, survey, material contribution]

"During the learning process, I did not lose attention due to writing, and it became easier for me to listen..." [BTUO8, survey, material contribution]

"The parallelism of the course content and materials facilitated my comprehension and focusing process..." [BTUO7, survey, material contribution]

"It facilitates visual and auditory learning..." [ITUO1, survey, material contribution] "Intriguing..." [ITUO9, survey, material contribution]

"...It increased my learning and interest process..." [BTUO10, survey, material contribution]

In addition, some students stated that teaching materials contributed to their affective aspects and considered them important for their future. The students emphasized making them happy (*f*=1) and benefiting from them in the future (*f*=2). Related opinions are as follows:

"The materials made me happy. They were compatible in terms of visual and information." [ITUO7, survey, material contribution]

"I do not know for now, but I think it may contribute to the future" [ITUO4, questionnaire, material contribution]

"I have seen the smart classroom environment. If I need to use it in the future, it will be an environment I know." [ITUO7, survey, material contribution]

The data collection tools were used to determine whether the students had difficulties using the teaching materials. Accordingly, 29.16% of the students who participated in the first pilot of implementation (n=12) and the second pilot of implementation (n=12) stated that they had various difficulties (*f*=7) while using the teaching materials. In comparison, 70.83% of the students stated they had no difficulties (*f*=17). Students' views on the use of teaching materials are expressed as I had no difficulty (*f*=17), connection problem (*f*=4), tablet use (*f*=3), keyboard use in the application (*f*=1) and the need for a tablet stand (*f*=1). Students express their opinions as follows:

"I did not have any difficulties..." [ITUO12, survey] "I did not experience any difficulties..." [BTUO5, survey] "I had no difficulty..." [BTUO1, survey]

"Connection with the Internet." [BTUO3, survey] "Connecting..." [BTUO6, survey]

"Keyboard not working in the application..."[BTUO7, survey] "I had difficulty using the tablet..."[BTUO9, survey]

"I think the physical features of the tablets could have made it easier to use if there were inclined apparatus for placing the tablets..." [BTUO7, survey]

"I had difficulty typing on the tablet..." [BTUO1, survey]

"I had difficulty getting used to the tablet at first..." [ITUO5, questionnaire] "It was just a little difficult to discover the tablet..." [ITUO11, survey]

The students expressed opinions about using the materials used in the technology-enriched classroom environment in other lessons. While 91,66% (f=22) of the students (n=24) who participated in the first-pilot study and second-pilot study process expressed positive opinions about the use of the materials in the technology-enriched classroom environment in other lessons, 4,16% (f=1) stated that it was not necessary, and 4,16% (f=1) did not express an opinion. Students express their opinions as follows:

"It can ensure that other courses are taught more effectively and efficiently..." [ITUO5, survey] "It may be necessary for a healthy classroom environment and a good atmosphere." [ITUO10, survey] "It would be more useful, especially in crowded classes..." [BTUO10, survey]

"I think it will be very good; it will increase the level of education..." [BTUO9, survey] "I think it would be better and more efficient..." [BTUO6, survey]

"For more formulaic mathematical lessons, I think it would be easy to follow the text or solution written by the teacher on the tablets, speed up the comprehension process and provide time to ask questions." [BTUO7, survey]

"I think that using this system in all courses will greatly contribute to the learning process. [BTUO1, survey]

In addition, one student expressed a suggestion for the use of teaching materials in other courses:

"I think it can be developed more and applied more efficiently after giving seminars to the instructors." [BTUO2, survey, suggestions/orientation]

In addition, one student stated that preparing and using the teaching materials used in the technology-enriched classroom environment in other courses is unnecessary. ITUO8 expresses his opinion as follows: *"If it is a cost-effective solution, it can be applied, but I think it is not very necessary."*

3.5. THE INSTRUCTORS' OPINIONS ON THE EFFECTIVENESS OF THE DIGITAL MATERIALS USED IN THE TECHNOLOGY-ENRICHED CLASSROOM

In line with the findings obtained from the data collection tools, it is seen that the opinions of the instructors involved in the first pilot implementation and the second pilot implementation process are positive towards the teaching materials used in the technology-enriched classroom environment. It is seen that the opinions of the instructors about the technology-enriched classroom environment are concentrated in the sub-themes of "environment order", "learner harmony", "interaction", and "instructor competence". The opinions of the instructors about the teaching materials used in the technology-enriched classroom environment are emphasized in the sub-themes of "material contribution", "material design", "professional development", "preparation", and "cognitive contribution" codes. The density of the codes obtained from the instructors' opinions is visualized in *Figure 11*.

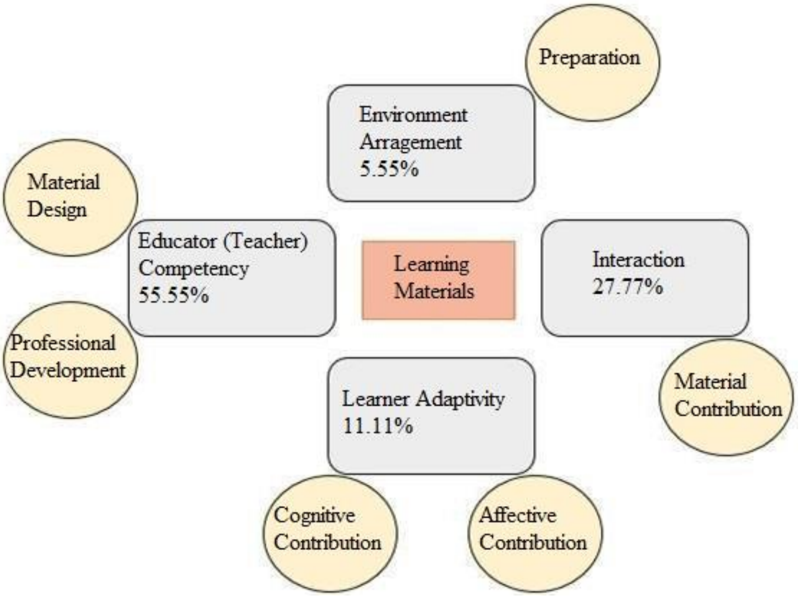

Figure 11 Code Density of Instructor Opinions on Instructional Materials

It is seen that the instructors' opinions about the teaching materials used in the technology-enriched classroom environment are positive. BTUA1 expressed their views on instructional materials: *"The materials used are for* *measurement and evaluation purposes... I think that especially in-class measurement and evaluation in an interactive environment contributes positively to learning..."*. ITUA1 expresses his views as follows:

> *"I tried to choose my materials in a way that would interact with the students and strengthen communication..." [ITUA1, interview, material design]*
>
> *"Students both in the classroom and in the virtual environment participated. I tried to attract the students' attention by marking on the presentations..." [ITUA1, interview, interaction]*
>
> *"I am satisfied with the materials I use. I think they appeal to both the lecturer and the students..." [ITUA1, interview, material contribution]*

The instructors' opinions also include the effects of instructional materials used in the technology-enriched classroom environment on students. In the opinions of the instructors, it is seen that the teaching materials used in the classroom environment positively affect the students in terms of learning (f=3), active participation in the lesson (f=2), interest (f=1) and motivation (f=1). Instructors express their opinions as follows:

> *"I think it helps students to be more motivated..." [BTUA1, interview, affective contribution]*
>
> *"The activities I prepared using Web 2.0 tools were useful in assimilating the information and getting an idea about the lesson's teaching..." [ITUA1, interview, cognitive contribution]*
>
> *"I have seen that students' interest in this direction has also increased..." [ITUA1, interview, affective contribution]*
>
> *"I believe that applications such as word clouds especially increase their learning visually." [BTUA1, interview, cognitive contribution]*
>
> *"I think that especially in-class measurement and evaluation in an interactive environment contributes positively to learning..." [BTUA1, interview, cognitive contribution - active participation in the lesson]*
>
> *"Students can participate in the lesson through their tablets without hesitation... Since it is an environment where students feel comfortable, we had productive lessons. [ITUA1, interview, active participation in the lesson - cognitive contribution]*

Instructors expressed opinions about preparing instructional materials used in a technology-enriched classroom environment. From this point of view, material design, preparation and professional development codes come to the fore. While BTUA1 of the instructors stated that they needed support to prepare teaching materials, ITUA1 stated that they did not feel the need for support. The instructors express their views as follows:

> *"I received support for the new applications I met, but I cannot say that we completely changed the course materials; interactive materials for assessment and evaluation were added..." [BTUA1, interview, material design]*

> *"I did not need any support as I have been working in this field, and material preparation is within my area of expertise..." [ITUA1, interview, material design]*

> *The instructors' opinions about the process of preparing the teaching materials used in the technology-enriched classroom environment are that they do not have difficulty designing and preparing the materials (f=2). Related opinions are as follows:*

> *"I did not experience any significant strain..." [BTUA1, interview, material design]*

> *"I did not need any support because I have been working in this field, and material preparation is within my area of expertise... I was comfortable because I trusted my technological skills and material design knowledge..." [ITUA1, interview, material design]*

In addition, ITUA1 stated that he received support for the preparation of the technology-enriched classroom environment with the following views: *"But at the stage of preparing the classroom in advance, for example, uploading the materials to the lesson environment, transferring the web addresses to the tablets, answering the questionnaires... I received help.*" In addition to this, ICTUA1 expresses that he needs professional development in material design (f=1) with the following opinions:

> *"...I think I need to work on it more... My course materials are unsuitable for the smart classroom environment; I think they need to change a lot and become more interactive..." [BTUA1, interview, professional development]*

ITUA1 stated that preparing and using the teaching materials used in the technology-enriched classroom environment contributed to professional development. Related opinions are as follows:

"While presenting the materials, I had the opportunity to improve my field knowledge about technology. It contributed in this field..." [ITUA1, interview, professional development]

While ITUA1 stated that he would volunteer in the preparation of teaching materials used in the technology-enriched classroom environment and teaching lessons in the classroom environment, he stated that he recommended the use of materials to his colleagues with the following views:

"I would volunteer to be a guide in material preparation. I would also volunteer to teach in a smart classroom environment. Because it was a process, I enjoyed..." [ITUA1, interview, material design]

"...I recommend the use of materials to my colleagues. It is useful to evaluate students' participation or achievement and increase classroom interaction..." [ITUA1, interview, material contribution]

3.6. THE INSTRUCTORS' EXPERIENCES ON MANAGING THE TECHNOLOGY-ENRICHED CLASSROOM

Instructor opinions on managing the technology-enriched classroom environment are concentrated in the sub-themes of "instructor competence" and "interaction." The codes of "active participation in the lesson," "technology competence," "feedback," and "classroom management" belonging to these sub-themes come to the fore in the opinions.

Adaptation (f=1), teacher control (f=1), technology competence (f=1) and individual learning (f=1) are considered important for classroom management in a technology-enriched classroom environment. ITUA1 expresses the views of instructors and students on technology competence in the classroom management process as follows:

"Managing the smart classroom is actually the same as managing the physical classroom. The teacher does not need to have a high level of technology knowledge. It is enough to know how to use the program on the smart board. It is enough that the students' technological competences are at a basic level" [ITUA1, interview, educator competence/technology competence].

"When they have problems, they can ask and help each other. Thus, the teacher does not have to deal with technical support in the classroom environment. Since there is a tablet in front of the students, the

student feels individuality and can do the necessary applications (such as note-taking, repetition, follow-up) ..." [ITUA1, interview, classroom management]

BTUA1 evaluates classroom management in a technology-enriched classroom environment: "*At first glance, it seems difficult to manage alone, but when both students and teachers get used to it, a more comfortable environment is created..."* Moreover, BTUA1 adds the following comment about teacher control in classroom management:

> *"My experience was with 15 people, but it can be applied in larger classes without too much confusion, especially due to the permissions under the teacher's control..." [BTUA1, interview, classroom management]*

ITUA1 stated that the classroom environment enriched with technology contributed to classroom management and professional development. Their views are as follows:

> *"...It is a good system for students to send notifications about the classroom environment, such as light, temperature, and lack of air. Thus, the instructor can recognize the distraction caused by the physical environment..." [ITUA1, interview, classroom management - system features]*

> *"It helped me to be more flexible in classroom management... It also had an impact on my classroom management skills..." [ITUA1, interview, professional development]*

The differences between technology-enriched classroom management and classroom management in the traditional classroom environment also come to the forefront in the instructors' opinions. Instructors state that there is a difference between technology-enriched classroom management and traditional classroom management in terms of "interaction" and "system features". Instructors emphasize that there are differences in terms of active participation (f=2), feedback (f=1) and educational technologies (f=2). ITUA1 states that there is a similarity between technology-enriched classroom management and traditional classroom management: *"The instructor could move easily as in the traditional classroom environment..."* while the instructors express the differences in classroom management as follows:

> *"Unlike the traditional classroom environment, the student can be more active in asking for the floor, especially in environments where they can participate anonymously (such as word clouds), they can be more*

courageous and express their opinions..." [BTUA1, interview, active participation in the lesson]

"In the traditional classroom environment, when students say things like opening the window or switching on the air conditioner, the course can be disrupted, but in the smart classroom environment, these can be handled quietly..." [ITUA1, interview, feedback]

"Students can be more comfortable in the lesson and do not hesitate to ask questions..." [ITUA1, interview, active participation in the lesson]

"...It is more motivating for students who do not dare to raise their hands and speak, as it allows them to communicate in writing..." [BTUA1, interview, active participation in the lesson - educational technologies]

"...In the traditional classroom environment, it can sometimes be difficult for students sitting at the back to see the board, especially on slides with figures. Since everyone has a tablet in the smart classroom environment, this problem is eliminated, so there is no need to explain the situations that are not understood repeatedly." [ITUA1, interview, educational technologies]

Based on the instructors' opinions, instructors should have some skills for technology-enriched classroom management. According to the instructors, they should have material design (*f*=1), classroom management (*f*=2), technology competence *(f*=2) and problem-solving (*f*=2) skills for technology-enriched classroom management. The opinions of the instructors are as follows:

"First of all, I guess that there may be people who may have difficulty with technology; a good knowledge of technology is required..." [BTUA1, interview, technology competence]

"It is necessary to create an environment where the teacher takes part as a leader... Another feature is interactive teaching..." [ITUA1, interview, classroom management]

"Firstly, I think the ability to design materials using web tools is very important.

Then there may be the ability to use technology..." [ITUA1, interview, material design]

"...Must have developed skills in problem-solving..." [BTUA1, interview, classroom management]

"Knowing technology integration can support these said skills..." [ITUA1, interview, technology competence]

According to the instructors, the words in *Figure 12* express a technology-enriched classroom management experience. Instructors included words and word groups that reflect this experience in their opinions.

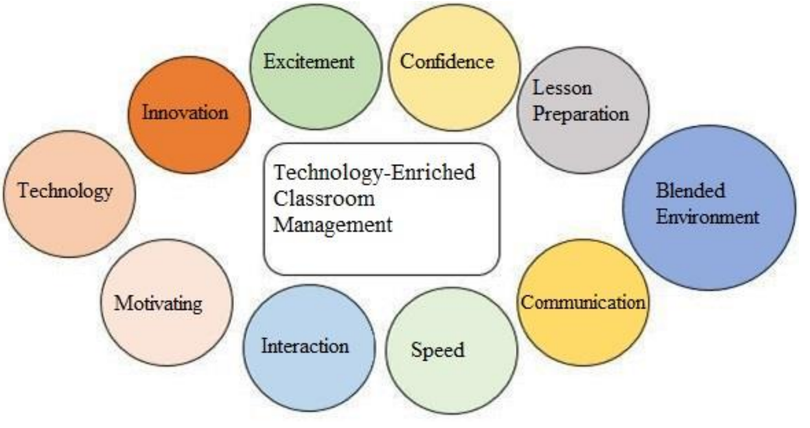

Figure 12 Technology Enriched Classroom Management Experience Concept Diagram

ITUA1 further elaborates on the five words that express technology-enriched classroom management experience. According to ITUA1, classroom management experience is expressed by the words and phrases innovation, excitement, self-confidence, lesson preparation and blended environment. ITUA1 explains these concepts associated with classroom management experience as follows:

"Teaching with a different system represents innovation and excitement..." [ITUA1, interview, classroom management]

"...Self-confidence means being competent in technology integration. Web Preparing materials using 2.0 tools can be considered preparation for the lesson..." [ITUA1, interview, classroom management]

" Combining the physical and virtual classroom environment represents the blended environment..." [ITUA1, interview, classroom management]

In their opinions, instructors also make suggestions regarding technology-enriched classroom environments and classroom *management. Suggestions in terms of orientation (f=2) by the instructors are expressed as follows:*

"To facilitate the process, a 1–2-page pdf user manual can be prepared for students and teachers. Thus, for the first time, someone in a smart classroom can learn what to do and start the lesson..." [BTUA1, interview, suggestions/orientation]

"It would be nice to give training to instructors and students beforehand. It would be good to inform the students about how to use the tablets and the software and the instructors about using educational and media components in the classroom. A certificate program can be organized for instructors." [ITUA1, interview, suggestions/orientation]

3.7. THE EFFECTS OF INDOOR ENVIRONMENTAL CONDITIONS ON THE LEARNING AND TEACHING PROCESS IN THE TECHNOLOGY-ENRICHED CLASSROOM

Table 8 shows the average values of the indoor measurements based on variables, and Table 9 evaluates the indoor environment regarding the comfort variables. The measurement results show that the average thermal comfort during the lessons in the smart classroom environment is 2.69 in the autumn semester and 2.34 in the spring semester. Accordingly, it is seen that the indoor conditions in the autumn semester are closer to a satisfactory level with respect to thermal comfort. However, it can be said that this result is due to the measurement recorded on 15.12.2021, which was 3.83 corresponding to good thermal conditions. When the time-dependent distribution of indoor air temperature in the courses held in the autumn term is examined, it is seen that the standard deviation is 0.20625, 0.51948 and 0.36615 in the courses dated 08.12.2021, 15.12.2022 and 29.12.2021, respectively, that is, indoor air temperature fluctuation is not high. On the other hand, it was determined that the standard deviation of the time-dependent temperature change in the course dated 22.12.2022 was the highest at 2,51085. In the spring term, it can be said that, in general, the ambient conditions remained within acceptable limits at 2.50, but during the lesson held on 20.05.2022, the ambient conditions were classified as bad at 1.67. It should be noted that similar fluctuations were observed in relative humidity measurements, and this played a role in the poor thermal comfort conditions in general. The fluctuations observed in the thermal environmental conditions may be attributed to the fact that the lectures were held back-to-back, the environment was ventilated during breaks, the differences in the set- point of the air conditioner and the number of people in the classroom. When the time-dependent distribution of the temperature in the courses held in the spring semester is examined, neutral temperature was observed in the courses dated 22.04.2022, 13.05.2022 and 20.05.2022.It is seen that the deviation is 0.25, 0.46 and 0.52, respectively; that is, indoor air temperature fluctuation is not high. On the other hand, it was observed in the lesson dated 03.06.2022 that the trend of relative humidity measurements is also compatible with indoor air temperature fluctuation. In general, it can be said that the increase in the standard deviation in the thermal environment measurements on 27.05.2022 can be attributed to the fact that the air conditioner started to be operated in part-time cooling and natural ventilation was preferred before that.

The measurements show that the average visual comfort during the lectures in the smart classroom environment is 1.00, i.e. very bad, in both the autumn and spring semesters. It was determined that the average standard deviation of the measurements in the spring semester was lower compared to the autumn semester. The reasons for the poor assessment of visual comfort, in general, include the fact that the windows that will provide natural lighting in the classroom are insufficient in terms of area and are at the back, according to the classroom layout plan. In addition, the fact that the LED lamps used for artificial lighting were sometimes switched off due to the reflection effect on seeing the board may also be among the reasons affecting visual comfort. The measurement results show that the average air quality in the smart classroom environment during the lessons was 2.95 in the autumn semester and 3.94 in the spring semester. Accordingly, it is seen that indoor conditions are perceived as normal in terms of air quality in the autumn semester and good in the spring semester. However, it is noteworthy that the air quality was worse in the lessons held on 15.12.2022 and 22.12.2022 in the autumn term compared to other weeks. In these weeks, it is observed that the amount of CO_2 increases cumulatively in the smart classroom, while there are fluctuations in other classes. It is seen that the maximum amount of CO_2 measured in the lessons on these dates are 2913ppm and 2843ppm, respectively; the average values are 1745.90ppm and 1966.33ppm, respectively, and are high above the limit value of 1000ppm set by the WHO. This result can be attributed to the lack of natural ventilation during and/or between lessons. In addition, it should be noted that the number of people in the classroom also affects the rapid increase in CO_2 and reaching high amounts. In the measurements during the spring semester, it is seen that the highest average CO_2 amount was 1127.29 ppm in the lesson dated 13.05.2022 and was close to the limit value of 1000 ppm. The reason for the good air quality in the spring period is that the windows are generally preferred to be open depending on the season; therefore, natural ventilation is effective.The measurement results show that the mean values of acoustic comfort variables during the lessons in the smart classroom environment are 1.97 in the autumn semester and 2.19 in the spring semester. It is noteworthy that sound level measurements generally show instantaneous variability in both semesters. In the autumn term, the course with the highest standard deviation of 8.09 in sound level measurements was observed on 05.01.2022. In the spring term, the courses with the highest standard deviation were on 03.06.2022 and 10.06.2022, and their values were 7.54 and 7.49, respectively. Among the reasons for the poor acoustic comfort are human-induced noise in the classroom and/or vehicle and human-induced noise coming from the external environment, especially when the windows are open.

Table 8 Evaluation of Indoor Comfort Variables

	Comfort variables IEQ value			
	Thermal Environment	Visual	Air Quality	Acoustic
Autumn Term				
15.12.2021	3,83	1,00	2,00	3,00
22.12.2021	2,50	1,00	2,00	1,33
05.01.2022	2,50	1,00	4,50	2,00
12.01.2022	2,38	1,00	3,25	2,00
19.01.2022	2,25	1,00	3,00	1,50
Average	***2,69***	***1,00***	***2,95***	***1,97***
Spring Term				
22.04.2022	2,50	1,00	4,50	2,50
13.05.2022	2,50	1,00	3,50	2,00
20.05.2022	1,67	1,00	3,33	2,33
27.05.2022	2,38	1,00	4,25	3,25
03.06.2022	2,50	1,00	4,40	1,40
03.06.2022	2,50	1,00	3,67	1,67
Average	***2,34***	***1,00***	***3,94***	***2,19***

Table 8 Indoor Total Comfort Assessment

	IEQ value
Autumn Term	
15.12.2021	2,46
22.12.2021	1,71
5.01.2022	2,50
12.01.2022	2,16
19.01.2022	1,62
Spring Term	
22.04.2022	2,62
13.05.2022	2,25
20.05.2022	2,08
27.05.2022	2,72
3.06.2022	2,32
10.06.2022	2,21

3.8. THE VARIATIONS OF THE INDOOR ENVIRONMENTAL CONDITIONS IN THE TECHNOLOGY-ENRICHED CLASSROOM WHICH AFFECT THE LEARNING AND TEACHING PROCESS

3.8.1. CREATION OF A STUDY-SPECIFIC AMBIENT COMFORT CLASSIFICATION SYSTEM (IEQ)

A comfort classification system was created to examine the effect of indoor air temperature, relative humidity, light, CO_2, and sound level variables on the comfort of the classroom in the smart classroom environment and to reveal the effect of the comfort conditions of the classroom on student behavior comparatively.

The comfort classification system has four main headings: thermal comfort, visual comfort, indoor air quality and acoustic comfort. Intermediate headings in ambient comfort are directly related to the environment's air temperature, relative humidity, light intensity, CO_2, and sound intensity variables.

While creating the IEQ system, academic studies with high citation rates were examined, and IEQ value ranges were determined by comparing them with the standards in literature.

3.8.2.DETERMINATION OF REFERENCE VALUE RANGES

In this section, previous studies examining the effects of indoor air temperature, relative humidity, light intensity, CO2, and sound intensity variables on subjects, findings and common main ideas are summarized in tables. In addition, the value ranges obtained from the literature examined are included.

3.8.2.1. Temperature And Relative Humidity

It is seen that thermal comfort studies in which indoor air temperature and relative humidity are evaluated together are predominant in literature. Summary information, explanations and acceptable value ranges obtained from the reviewed articles are shown in *Table 10.*

Table 9 The findings obtained from the analyzed articles, the explanations made, and the value ranges to be used in the IEQ system (Indoor air temperature and relative humidity)

Author	Findings related to temperature	Explanations
Haverinen-Shaughnessy and Shaughnessy, 2015	In the temperature range of 20-25°C, attention increased with each temperature decrease.	Academic studies have shown that not-too-hot and not-too-cold temperatures improve students' learning performance. It is impossible to provide the optimum temperature for every student in a class (metabolism, skin thickness, fat tissue, etc.). The favorable ambient temperature triggered the individuals psychologically and increased the students' motivation. Students' classroom activities and clothing are among the most important factors affecting the
J. Perez et al., 2005	In the first experiment, the students' performance was 86.7% at 21 °C, 86.7% at 23 °C and 82.22% at 22 °C. At a cold temperature of 16°C, the success rate of the students was 76%, and at a temperature of 22°C it was 90%. In a hot environment of 27°C, students' achievement fell, declining to 72 per cent.	
Dear et al., 2015	The acceptable summer ambient temperature range for students is 19.5-26.5°C, and the preferred indoor environment for learning temperature is specified as 22.5°C.	

Park et al., 2016	When the ambient temperature increased from 22°C to 32°C, the students' success decreased by 12.3%. On the days of the exams, temperatures above 27°C negatively affected the student's success. For everyone °C, success decreased by 0.4%.	temperature of the environment and their thermal comfort. Opening windows, opening the door, and switching the air conditioner on can affect thermal comfort.
Park et al., 2016	When the ambient temperature increased from 22°C to 32°C, the students' success decreased by 12.3%. On the days of the exams, temperatures above 27°C negatively affected the student's success. For everyone °C, success decreased by 0.4%.	
Schoer and Shaffran, 1973	On average, students' achievement at 22.5°C is 5.7% higher than their achievement at 22.5- 26°C.	
Wyon, 1970	Students' homework performance was analyzed at 20°C, 27°C, and 30°C. Students' homework performance was slower at higher temperatures than at 27°C.	
Dorizas et al., 2015	Students were not satisfied with high- and low-temperature environment conditions; the optimum temperature value at which they were satisfied was between 22.5°C and 25°C.	
Wyon, Andersen, and Lundqvist, 1979	Students' learning performance decreased when the temperature increased from 20°C to 29°C.	
Harner, 1974	The best temperature range for student learning is 20°C-23°C; temperatures above this range reduce students' learning ability.	

Balazova, Clausen and Wyon, 2007	Studies were conducted in two environments with ambient temperatures of 23.5°C and 28°C; learning was less at higher temperatures.
Bánhidi et al., 1998	In the 20°C to 30°C temperature range, the note-taking speed of students at high temperatures has fallen.
Liffberg et al., 1975	Studies have been carried out at temperatures between 22°C and 27°C; students' performance has increased as we approach 22°C.
Staffan Hygge and Knez, 2001	Environment with temperatures between 21°C and 27°C created and analyzed; at 21°C students' performance is better
Fang et al., 1998	Environment with temperatures of 18°C and 21°C is analyzed. An environment with a temperature of 28°C was created and examined, with relative humidity ranging from 30 to 70. Increasing temperature and relative humidity negatively affect students' thermal comfort.
Accepted Value Ranges	
Temperature Good: Acceptable temperature range 18-25 °C Bad: Ambient temperature <15°C and ambient temperature >28°C *Relative humidity* Good: Acceptable relative humidity range 30%-75% Bad: Relative humidity percentage <20% and >80	

3.8.2.2. Light intensity

Summary information, explanations and acceptable value ranges related to light intensity obtained from the analyzed articles are shown in *Table 11.*

Table 10 The findings obtained from the analyzed articles, the explanations made, and the value ranges to be used in the IEQ system (Light intensity)

Author	Light Intensity and Findings	Explanations
Lifberg et al., 1975	The light intensity between 60,250 and 1000 lux is shown. Performance improves with increasing light intensity, as shown.	Illumination: Learning studies examining the effects on performance schools agree that the optimum light level that improves performance is at least 1000 lux. When illumination is low (<300 lux) or excessive (>2500), performance may decrease due to visual disturbance (headache, fatigue, distraction, etc.). Adequate lighting is necessary to enable students and teachers to fulfil their visual tasks easily.
Hathaway et al., 1992	The average illuminance levels measured in the study were 250-540 lux, 300-900 lux, 220-450 lux and 280-450 lux in the centre of the building. Light intensity affected the success rate of the students.	
Bánhidi et al., 1998	280 lux luminous intensity to 920 lux luminous intensity compared, students' attention decreased at low illumination levels.	
Staffan Hygge and Knez, 2001	The illuminance levels analyzed were 300 and 1500 lux. The attention span of the participants at 1500 lux is longer than the attention span at 300 lux.	
Winterbottom and Wilkins, 2009	Excessive light intensities above >2500 lux distort the visual sense of the students reduce overall performance.	
Barkmann et al., 2012	Seven different lighting combinations were applied, and the applied lighting combinations were grouped. These groups are Standard-(300 lux) Board focusing - Bright (1000 lux) and standard (300 lux) Board only - Lights off Concentrated- Bright and cold light (1060 lux) Active - slightly brighter and cooler light compared to standard lighting (675 lux) Relaxing - slightly warmer light than standard lighting (325 lux) Extremely relaxing - used when not reading or writing (275 lux). Students are more careful than with standard lighting.	
Singh and Arora, 2014	The measured light intensity values are between 570,38 and 760,63 lux and 195,84 and 269,16 lux. Class concentration increased with increasing illumination.	
Accepted Value Ranges		
Good lighting 300-2000 lux Poor illumination < 300 lux and > 2500 lux		

3.8.2.3. CO2

Table 12 shows the summary information, explanations, and acceptable value ranges of CO2 obtained from the analyzed articles.

Table 12 The findings obtained from the articles analyzed, the explanations made, and the value ranges to be used in the IEQ system (CO2

Author	Findings related to CO2	Explanations
Wargocki et al., 2017	CO_2 concentration greater than 2000 ppm and 1000 ppm students improved its performance.	According to the common results of the studies, low CO_2 levels (<1000 ppm) in the working (classroom) environment improved learning. High CO2 levels above 3000 ppm in the working (classroom) environment will make students less attentive, causing a lack of concentration in students, which, over time, students' learning performance negatively will have an impact. According to the results of the studies, when the CO_2 ratio of the working (classroom) environment exceeds 1000ppm, drowsiness, headache and inability to concentrate were observed in the working (classroom) environment. The presence of ventilation should also be taken into account in the measurements, For example, if CO_2 levels are low in an
Myhrvold et al., 1996	In the study CO 2 values, Value ranges According to three different. Group will create as Categorized has been made. 1. 0-999 ppm 2. 1000-1499 ppm 3. 1500-4000 ppm As the concentration of CO2 in the air increases, the performance of those in the environment reduces, and with low CO2 concentration, the best efficiency from the participants in the environment is taken.	
Petersen et al., 2016	CO2 with 900 ppm at a concentration of The reduction between 1500 ppm is the same as that of the students are given the right answer increased the number of students in the Tests reduced the number of errors.	
Bakó-Biró et al., 2012	CO_2 concentration decreases from 5000 ppm to approximately 1000 ppm; Reaction - 2.2% Identification - 15% Picture memory - 8% Alertness - 2.7 by a third.	
Coley and Greeves, 2004	In the study, low Two different environments with CO_2 concentrations (501-983 ppm) and high CO_2 concentrations (2096 - 4140 ppm) were analyzed. According to the study results, the subjects' attention in environments with CO_2 readings above 2000 ppm was approximately. A decrease of 5% was observed.	

Kajtár and Herczeg, 2012	The study examined the experimental environment with CO2 levels ranging between 600 ppm and 3000 ppm. In a 3000 ppm CO_2 level environment, the mental performance of the subjects, 600 ppm CO_2 then at the level of the level.	occupied classroom, this may be due to ventilation. There is an indication.
Santamouris et al., 2008	According to the study's results, when the CO2 ratio of the environment exceeds 2500 ppm, the subjects' attention is disintegrating.	
Gaihre et al., 2014	The CO_2 ratio of the environment examined in the study is between 922-1310 ppm and the average CO_2 ratio is 1086 ppm. An increase of 100 ppm of CO_2 in the environment increases the attention of the participants on average. by 0.2 per cent.	
Shendell et al., 2004	EnvironmenCO2 at a concentration of 1000 ppm reduction increased the attention of the students by 10-20%.	
Accepted Value Ranges		
Acceptable CO_2 level range: Good: CO_2 level <1000 ppm Bad : CO_2 level > 3000 ppm		

3.8.2.4. Sound intensity

The reviewed articles provided summary information, explanations, and acceptable value ranges about sound, as shown in *Table 13.*

Table 11 The findings obtained from the analyzed articles, the explanations made, and the value ranges to be used in the IEQ system (Sound intensity)

Author	Findings related to sound intensity	Explanations
Cohen et al., 1980	The study analyzed two different school environments: noisy schools and quiet schools. The average noise level in noisy schools was 74 dBA (highest reading 95), while the highest noise level in quiet schools was 56 dBA (highest reading 68 dBA). Prolonged exposure to noise distracted students' attention, negatively affecting their learning	When the studies on the effect of noise on learning performance were analyzed, it was found that high sound intensity levels decreased performance, and performance improvements were observed with decreases in sound intensity levels.

	level.	Excessive noise negatively affected the acoustic comfort level of the classroom. Students' dissatisfaction increased with the decrease in comfort level. The increased sound intensity of the environment caused stress in students; students did not understand what they read, and their inability to concentrate was observed. The increase in the level of sound intensity decreased the students' verbal interaction ability and cognitive ability. When analyzing the effect of sound level on students, it is important to consider the level, intensity, and duration of sound intensity.
Hygge, 1991	The students' recall of the information they learned increased as the sound intensity level decreased from 66 dBA to 38 dBA.	
Hygge, 1993	In the study, two different working environments with 55 dBA and 66 dBA sound intensity were analyzed, and the level of students' recall of the information they learnt was more determined at 55 dBA.	
Sanz et al., 1993	The study analyzed two different school environments, namely, a quiet school environment and a noisy school environment. Quiet school environment: The sound intensity level varied between 57.9 ± 2.5 dBA in the morning and 57.3 ± 1.4 dBA in the afternoon. The sound intensity levels measured throughout the day ranged between 47.5 and 69.1 dBA. Noisy school environment: The measured sound intensity level values were 64.4 ± 1.1 dBA on average in the morning and 66.2 ± 3.5 dBA in the afternoon. The sound intensity level values measured throughout the day ranged between 58.5 dBA and 76.6 dBA. When the students' attention was analyzed, the students' attention level in the quiet environment was higher than in the noisy environment.	
Evans and Maxwell, 1997	In the study, learning environments with sound intensity levels ranging from 65 dBA to 90 dBA were analyzed, and students'	

	learning performance decreased by up to 20% as the sound intensity level increased.
Haines et al., 2002	In the study, classroom environments with eight different sound intensity levels were analyzed (x<54 dBA, 54 dBA<x<57 dBA, 57 dBA<x<60 dBA, 60 dBA<x<63 dBA, 63 dBA<x<66 dBA, 66 dBA<x<69 dBA, 69 dBA<x<72 dBA, x>72 dBA) Students' reading and math courses' performance decreased as the noise level increased.
Lercher, 2003	In the study, the effect of sound intensity levels starting from 50 dBA and increasing up to 80 dBA on the students' comfort was examined; the increase in sound intensity negatively affected the acoustic comfort of the students.
Vilatarsana, (2004).	The study analyzed different working environments with sound intensity ranging from 55 dBA to 80 dBA. High noise levels affect pupils' performance.
Balazova et al., 2007	The study analysed two different noise levels (52 dBA and 60 dBA). At higher levels of loudness, decreases in pupils' performance and concentration were observed.
Bánhidi et al., 1998	The study analysed two different sound intensity levels (60 dBA and 70 dBA). Performance decreased as the noise level increased.
Christie & Glickman, 1980	The study analysed a classroom environment with a high sound level of 70' dBA and a classroom environment with a low sound level of 40' dBA. Students' performance showed a

	decreasing trend as the noise level increased.	
Pizzo, 1981	Low sound level (40 dBA) and high sound intensity level (75 dBA) environments were analysed. The subjects' performance in the environments is higher than in the environments with high sound levels.	
Accepted Value Ranges		
Acceptable range of loudness levels: Good: < 75 dBA Bad 75 > dBA		

3.8.3. IEQ SYSTEM EVALUATION MODEL

To investigate the relationship between indoor environmental conditions and students' comfort in learning environment, indoor air temperature, relative humidity, light intensity, CO_2 and sound intensity levels in the smart classroom should be monitored regularly. In the literature, IEQ coding methods that subjectively evaluate indoor environmental conditions are frequently encountered (Barrett et al., 2012; Heschong Mahone Group, 1999). In this study, an IEQ system was developed to evaluate smart classroom environment variables. The IEQ system allows the rating of the recorded indoor environmental variables in the smart classroom and converts them to a level that can be compared. The IEQ system is based on a simple classification that can be easily applied in buildings with different usage purposes and shows which environmental(s) should be intervened. The IEQ system is developed by determining the ambient variables' value ranges and the previous literature's studies. To match the ambient variables with the comfort level, reference value ranges of the ambient variables and a comfort scale ranging from 1 to 5 were created. In this system, 5 corresponds to the best acceptable IEQ level whereas 1 is the worst comfort level. The ambient comfort variables of the smart classroom, thermal environment, visual, air quality, and acoustics, are evaluated according to a score between 1 and 5. The effect of the weight of all comfort variables on the total comfort of the environment is considered equal. Details of the IEQ system and ambient variables are given in *Table 14*.

Table 12 IEQ Evaluation Model

No	Variable	Enumeration	Reference Value Ranges
1	Thermal Environment		
(a)	Temperature	1=Very Bad	<15 °C and >28 °C
		2= Poor	15 °C ≤ 17 °C and 26 °C - 27 °C
		3= Normal	18 °C and 25 °C
		4= Good	19°C and 23°C-24°C
		5= Very Good	20°C -22 °C
(b)	Relative humidity (%)	1=Very Bad	<20% and >80
		2= Poor	20%-30% and 76%-80%
		3= Normal	31%-45% and 71%-75%
		4= Good	45%-49% and 65%-70%
		5= Very Good	50%-65%
2	Visual		
(a)	Lumens	1=Very Bad	<300lx and 2500 lx
		2= Poor	2001 lx - 2500 lx
		3= Normal	1501 lx- 2000 lx
		4= Good	1000lx -1500 lx
		5= Very Good	<1000 lx
3	Air Quality		
(a)	Carbon Dioxide	1=Very Bad	> 3000 ppm
		2= Poor	2001 ppm- 3000 ppm
		3= Normal	1501 ppm- 2000 ppm
		4= Good	1000 ppm- 1500 ppm
		5= Very Good	<1000 ppm
4	Acoustic		
(a)	Sound Intensity	1=Very Bad	> 55 dBA - 55 dBA
		2= Poor	51 dBA - 55 dBA
		3= Normal	46 dBA - 50 dBA
		4= Good	41 dBA- 45 dBA
		5= Very Good	<40 dBA

IEQ code data analysis consists of three steps.

1. Average values are obtained from the measured raw data
2. Values between 1 and 5 are assigned to the raw data, which are the comfort scores of the environment.
3. The sample comfort scores obtained is reduced to a single variable, as shown in *Table 15*.

Phase 2			
Variable	Lesson 1	Lesson 2	Lesson 3
Thermal environment	4	5	4
Visual	5	4	5
Air Quality	4	3	2
Acoustic	3	3	4

Formula
$CS = \frac{Ts}{4}$

Phase 3		
Lesson 1	Lesson 2	Lesson 3
4	3,75	3,75

Merged IEQ Code	
Scale	Description
1	Ver y Bad
2	Bad
3	Normal
4	Good
5	Very Good

Table 13 IEQ Assessment Scale

3.8.4. FIELDWORK

Within the research scope, the weeks with the highest participation in the first and second-pilot study were selected to be evaluated in the experimental studies, and this section presents the indoor environment measurement results obtained during the lessons.

3.8.4.1. Smart Classroom First Pilot study

3.8.4.1.1. Indoor Air Temperature

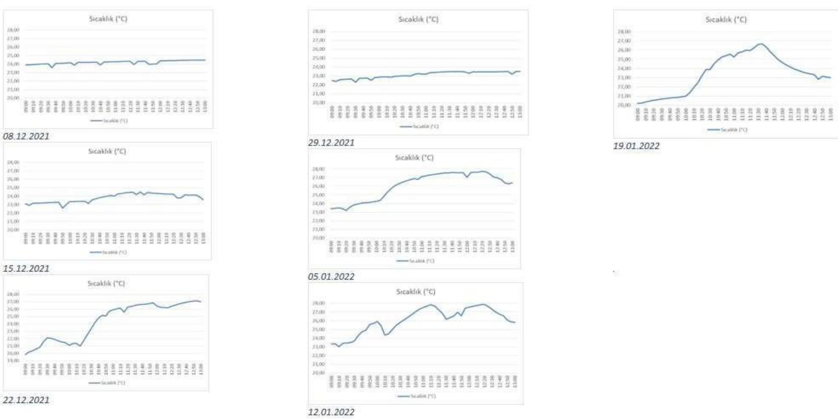

Figure 13 Time-Dependent Change Graphs of Indoor Air Temperature

<u>Indoor air temperature graphs for the days of classes</u>

* The dates of the graphs are given below.

* The graphs show the temperature values between 09:00-13:00, including class hours.

* Indoor air temperature values include 5-minute measurements between the specified hours. Descriptive statistics of indoor air temperature values are given in *Table 16*.

Table 16 Descriptive Statistics of Indoor Air Temperature Values

(°C)	Minimum	Maximum	Average	Standard Deviation	Variance
Temperature_08.12.2021	23,56	24,48	24,1978	,20625	,043
Temperature_15.12.2021	22,58	24,50	23,7798	,51948	,270
Temperature_22.12.2021	19,85	27,14	24,3822	2,51085	6,304
Temperature_29.12.2021	22,29	23,51	23,1265	,36615	,134
Temperature_05.01.2022	23,20	27,74	26,0778	1,57671	2,486
Temperature_12.01.2022	23,02	27,87	26,0349	1,46533	2,147
Temperature_19.01.2022	20,19	26,68	23,4327	2,07178	4,292

3.8.4.1.2. Relative Humidity

Figure 14 Time-Dependent Change Graphs of Relative Humidity

Relative humidity graphs for the days of classes:

*The dates of the graphs are given below.

*The graphs show relative humidity values between 09:00-13:00, including the class hours.

*Relative humidity values include 5-minute measurements between the specified hours.

Descriptive statistics of relative humidity values are given in *Table 17.*

Table 14 Descriptive statistics of relative humidity value

	Minimum	Maximum	Average	Standard Deviation	Variance
Relative humidity_08.12.2021	43,26	44,40	43,7965	,29416	,087
Relative humidity_15.12.2021	38,69	48,03	43,5796	3,07884	9,479
Relative humidity_22.12.2021	26,74	34,17	29,7261	2,14593	4,605
Relative humidity_29.12.2021	39,89	40,53	40,2533	,15756	,025
Relative humidity_05.01.2022	37,32	41,79	39,1922	1,67274	2,798
Relative humidity_12.01.2022	29,38	38,82	33,4506	2,38259	5,677
Relative humidity_19.01.2022	23,33	34,15	26,7657	3,03804	9,230

3.8.4.1.3. Light Intensity

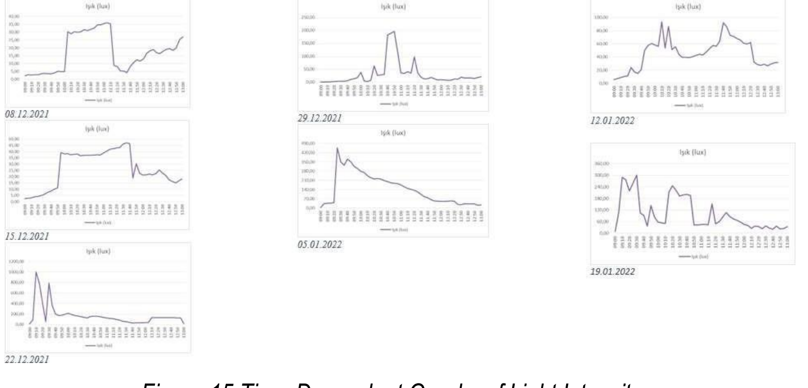

Figure 15 Time-Dependent Graphs of Light Intensity

<u>Light intensity graphs for the days of classes:</u>

* The dates of the graphs are given below.

* The graphs show the light values between 09:00-13:00, including class hours.

* Light values include 5-minute measurements between the specified hours. Table 18 provides descriptive statistics of light intensity.

Table 15 Descriptive statistics of light intensity

	Minimum	Maximum	Average	Standard Deviation	Variance
Light intensity _08.12.2021	2,25	36,02	16,7847	11,81178	139,518
Light intensity_15.12.2021	2,36	47,09	26,0700	14,22958	202,481
Light intensity _22.12.2021	11,87	998,92	170,5947	194,72136	37916,408
Light intensity _29.12.2021	,73	195,21	30,3786	46,63057	2174,410
Light intensity_05.01.2022	3,64	457,05	144,8810	116,82225	13647,437
Light intensity_12.01.2022	5,83	93,46	45,5147	22,45154	504,072
Light intensity_19.01.2022	9,04	300,43	100,5853	84,36757	7117,888

3.8.4.1.4. CO2

Figure 16 Time-Dependent Change Graphs of CO_2 Levels

<u>Graphs of CO_2 values for the days of classes</u>

* The dates of the graphs are given below.

* Graphs show Co2 values between 09:00-13:00, including class hours.

*CO_2 values include 5-minute measurements between the specified hours.

Descriptive statistics of CO_2 values are given in *Table 19*.

Table 16 Descriptive Statistics of CO_2 Values

	N	Openness	Minimum	Maximum	Average	Standard Deviation	Variance
CO_2 _08.12.2021	49	932,00	1096,00	2028,00	1350,71	159,56	25458,68
CO_2 _15.12.2021	49	2456,50	457,00	2913,50	1745,90	648,58	420650,96
CO_2 _22.12.2021	49	1622,50	1220,50	2843,00	1966,33	502,94	252944,27
CO_2 _29.12.2021	49	1043,00	548,50	1591,50	925,37	247,12	61066,80
CO_2 _05.01.2022	49	926,50	600,50	1527,00	1068,37	283,95	80626,91
CO_2 _12.01.2022	49	1316,00	411,00	1727,00	1337,27	391,54	153301,11
CO_2 _19.01.2022	49	939,00	982,50	1921,50	1498,34	207,01	42852,30

3.8.4.1.5. Sound Intensity

Figure 17 Time-Dependent Change Graphs of Sound Intensity

Sound intensity graphs for the days of the lessons:

* The dates of the graphs are given below.

* The graphs show the sound values between 09:00-13:00, including class hours.

* The sound values include 5-minute measurements between the specified hours.

Descriptive statistics of sound intensity are given in *Table 20* below.

Table 17 Descriptive statistics of sound intensity

	Minimum	Maximum	Average	Standard Deviation	Variance
Sound intensity _08.12.2021	40,16	58,72	43,7408	3,23039	10,435
Sound intensity_15.12.2021	39,67	64,82	45,7043	5,91907	35,035
Sound intensity_22.12.2021	41,26	68,12	51,0573	6,89681	47,566
Sound intensity_29.12.2021	40,16	44,80	42,1161	,99707	,994
Sound intensity _05.01.2022	40,65	70,44	47,9704	8,08671	65,395
Sound intensity_12.01.2022	40,65	67,63	49,4606	6,60715	43,654
Sound intensity _19.01.2022	39,92	66,90	47,3992	7,60029	57,764

3.8.4.2. Smart Classroom Second Pilot study

3.8.4.2.1. Indoor Air Temperature

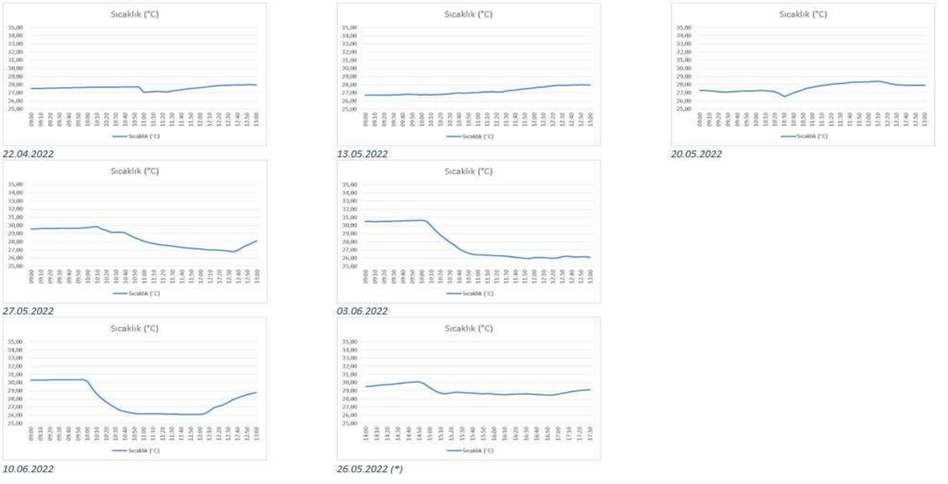

Figure 18 Time-Dependent Change Graphs of Indoor Air Temperature

<u>Indoor air temperature graphs for the days of classes:</u>

* The dates of the graphs are given below.

* The graphs with regular classes show the temperature values between 09:00-13:00, including class hours.

* The graph shows the temperature difference between 14:00-17:30, including the class hours.

* Indoor air temperatures include minute measurements between the specified hours. Descriptive statistics of indoor air temperature values are given in *Table 21*.

Table 18 Descriptive Statistics of Indoor Air Temperature Values

Regular Classes					
(°C)	Minimum	Maximum	Average	Standard Deviation	Variance
Temperature_22.04.2022	27,05	27,99	27,61	0,25	0,06
Temperature_13.05.2022	26,72	28,00	27,20	0,46	0,21
Temperature_20.05.2022	26,57	28,41	27,64	0,52	0,27
Temperature_27.05.2022	26,78	29,86	28,36	1,12	1,25
Temperature_03.06.2022	25,94	30,64	27,77	1,97	3,89
Temperature_10.06.2022	26,08	30,38	27,87	1,72	2,96
Additional Course					
Temperature_26.05.2022	28,47	30,11	29,03	0,54	0,30

3.8.4.2.2. Relative Humidity

Figure 19 Time-Dependent Change Graphs of Relative Humidity

Relative humidity graphs for the days of classes

* The dates of the graphs are given below.

* The graphs with regular classes show the relative humidity values between 09:00-13:00, including the class hours.

* The graph shows the temperature difference between 14:00-17:30, including the class hours.

* Relative humidity values include 5-minute measurements between the specified hours. Descriptive statistics of relative humidity values are given in *Table 22*.

Table 19 Descriptive statistics of relative humidity values

Regular Classes					
(%)	Minimum	Maximum	Average	Standard Deviation	Variance
Relative humidity_22.04.2022	30,79	35,68	34,40	1,50	2,25
Relative humidity_13.05.2022	30,74	35,68	33,27	1,54	2,37
Relative humidity_20.05.2022	25,90	30,92	28,93	1,27	1,62
Relative humidity_27.05.2022	30,93	40,26	35,16	3,30	10,86
Relative humidity_03.06.2022	29,61	36,56	32,75	2,53	6,41
Relative humidity_10.06.2022	29,25	42,09	35,94	3,35	11,23
Additional Course					
Relative humidity_26.05.2022	33,02	43,24	39,42	2,79	7,80

3.8.4.2.3. Light Intensity

Figure 20 Time-Dependent Change Graphs of Light Intensity

Light graphs for the days of classes:

* The dates of the graphs are given below.

* The graphs with regular classes show the light values between 09:00-13:00, including class hours.

* The graph shows the temperature difference between 14:00-17:30, including the class hours.

* Light values include 5-minute measurements between the specified hours. Descriptive statistics of light intensity are given in *Table 23*.

Table 20 Descriptive statistics of light intensity

Regular Classes					
(lux)	Minimum	Maximum	Average	Standard Deviation	Variance
Light intensity_22.04.2022	33,04	238,03	126,31	69,05	4767,91
Light intensity_13.05.2022	18,58	239,18	166,55	70,42	4959,48
Light intensity_20.05.2022	32,03	205,62	103,63	50,58	2558,47
Light intensity_27.05.2022	23,33	209,75	68,16	48,48	2350,54
Light intensity_03.06.2022	31,37	250,45	130,46	53,86	2900,53
Light intensity_10.06.2022	14,94	96,22	55,11	23,16	536,41
Additional Course					
Light intensity_26.05.2022	19,99	175,33	73,83	61,82	3821,88

3.8.4.2.4. CO2

Figure 21 Time-Dependent Change Graphs of CO_2 Values

<u>CO_2 graphs for the days of classes:</u>

* The dates of the graphs are given below.

* Graphs show CO_2 values between 09:00-13:00, including class hours.

* The graph shows the temperature difference between 14:00-17:30, including the class hours.

* CO_2 values include 5-minute measurements between the specified hours.

Descriptive statistics of CO_2 values are given in *Table 24* below.

Table 21 Descriptive Statistics of CO_2 Values

Regular Classes					
(ppm)	Minimum	Maximum	Average	Standard Deviation	Variance
CO_2 _22.04.2022	422,50	1593,50	858,77	464,75	215995,00
CO_2 _13.05.2022	438,00	1682,00	1127,29	382,21	146087,77
CO_2 _20.05.2022	406,00	1659,00	1014,59	507,27	257317,99
CO_2 _27.05.2022	427,00	1428,00	914,61	286,43	82043,69
CO_2 _03.06.2022	414,00	1499,00	834,10	349,48	122139,23
CO_2 _10.06.2022	405,00	1846,00	1154,35	462,68	214070,13
Additional Course					
CO_2 _26.05.2022	410,50	1744,50	1214,60	567,77	322360,95

3.8.4.2.5. Sound Intensity

Figure 22 Time-Dependent Change Graphs of Sound Intensity Values

<u>Sound graphs for the days of the lessons:</u>

*The dates of the graphs are given below.

*The graphs show the sound values between 09:00-13:00, including class hours.

*The graph shows the temperature values between 14:00-17:30, including the class hours.

*Volume values include 5-minute measurements between the specified hours. Table 25 provides descriptive statistics of sound intensity.

Table 22 Descriptive Statistics of Sound Intensity

Regular Classes					
(dB)	Minimum	Maximum	Average	Standard Deviation	Variance
Sound intensity_22.04.2022	38,33	61,65	45,15	6,46	41,68
Sound intensity_13.05.2022	38,33	64,21	48,87	5,94	35,34
Sound intensity_20.05.2022	37,84	61,77	47,65	6,67	44,45

Sound intensity_27.05.2022	39,07	55,91	44,62	3,27	10,68
Sound intensity_03.06.2022	39,68	67,63	51,53	7,54	56,82
Sound intensity_10.06.2022	39,55	62,50	48,68	7,49	56,05
Additional Course					
Sound intensity_26.05.2022	39,67	62,62	48,85	6,86	47,10

3.8.5. ASSESSMENT OF INDOOR ENVIRONMENTAL CONDITIONS ACCORDING TO IEQ SYSTEM

3.8.5.1. Smart Classroom First-Pilot study Results

3.8.5.1.1. 15.12.2021 Course Results

Using the IEQ calculation, the calculated comfort scores for 15.12.2021 are shown in *Table 26*. The calculation considered the average ambient parameter value in the examined time interval. The time intervals expressed in bold symbols in the table refer to the time intervals in which the lesson is held; comfort scores are scored out of 5, as stated in the section where IEQ calculations define the performance of ambient comfort out of 5.

Table 23 Calculation of ambient comfort levels using sensor data (15.12.2021)

1. Thermal environment

(a) Temperature_15.12.2021 (°C) (Class Time: 10:30-12:00)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	0,77	22,58	23,35	23,13	0,25	0,07	4
10:00-10:30	0,45	23,13	23,58	23,36	0,12	0,02	4
10:30-11:00	**0,52**	**23,58**	**24,10**	**23,87**	**0,17**	**0,04**	**4**
11:00-11:30	**0,47**	**24,01**	**24,48**	**24,30**	**0,15**	**0,03**	**4**

11:30-12:00	**0,35**	**24,15**	**24,50**	**24,33**	**0,12**	**0,02**	**4**
12:00-12:30	0,53	23,78	24,31	24,12	0,22	0,06	4
12:30-13:00	0,60	23,56	24,16	23,97	0,21	0,05	4

(b) Relative humidity_15.12.2021 (%) (Class Time: 10:30-12:00)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Varianc e	Comfort Score
09:30-10:00	1,26	38,69	39,95	39,34	0,46	0,25	3
10:00-10:30	3,56	38,91	42,46	40,48	1,20	1,67	3
10:30-11:00	**3,70**	**42,46**	**46,16**	**44,55**	**1,18**	**1,63**	**3**
11:00-11:30	**1,88**	**46,16**	**48,03**	**47,15**	**0,63**	**0,46**	**4**
11:30-12:00	**1,50**	**46,53**	**48,03**	**47,35**	**0,50**	**0,29**	**4**
12:00-12:30	1,72	44,82	46,53	45,65	0,57	0,38	3
12:30-13:00	1,39	43,43	44,82	44,11	0,46	0,24	3

2. Visual

(a) Luminous intensity _15.12.2021 (lx) (Class Time: 10:30-12:00)

Clock	Opennes s	Minimum	Maximu m	Averag e	Standard Deviation	Variance	Comfort Score
09:30-10:00	33,32	5,88	39,19	17,22	13,71	219,42	1
10:00-	1,64	36,78	38,42	37,74	0,59	0,40	1

10:30							
10:30-11:00	**1,74**	**37,04**	**38,78**	**37,45**	**0,56**	**0,37**	**1**
11:00-11:30	**7,30**	**38,78**	**46,07**	**42,25**	**2,12**	**5,26**	**1**
11:30-12:00	**28,12**	**18,97**	**47,09**	**33,29**	**11,93**	**166,02**	**1**
12:00-12:30	4,12	21,27	25,39	22,47	1,33	2,07	1
12:30-13:00	7,89	15,13	23,02	18,24	2,59	7,82	1

3. Air Quality

(a) CO_2_15.12.2021 (ppm) (Lecture Time: 10:30-12:00)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	1000,50	565,50	1566,00	1038,14	317,55	117641,89	4
10:00-10:30	274,00	1566,00	1840,00	1657,64	85,91	8610,14	3
10:30-11:00	**889,00**	**1700,50**	**2589,50**	**1940,57**	**275,80**	**88744,79**	**2**
11:00-11:30	**283,00**	**2503,00**	**2786,00**	**2588,93**	**87,87**	**9008,79**	**2**
11:30-12:00	**795,50**	**2118,00**	**2913,50**	**2550,71**	**224,52**	**58809,65**	**2**
12:00-12:30	436,50	1681,50	2118,00	1886,43	164,38	31522,95	3
12:30-13:00	86,50	1625,50	1712,00	1661,00	28,20	927,50	3

4.Acoustics							
(a) Sound intensity _15.12.2021 (dBA) (Class Time: 10:30-12:00)							
Clock	Opennes s	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	23,44	41,38	64,82	46,47	7,62	67,66	3
10:00-10:30	11,84	41,75	53,59	46,74	4,15	20,13	3
10:30-11:00	**16,11**	**41,75**	**57,86**	**50,89**	**5,34**	**33,26**	**3**
11:00-11:30	**19,29**	**41,99**	**61,28**	**51,34**	**7,63**	**67,91**	**2**
11:30-12:00	**10,62**	**41,14**	**51,76**	**44,05**	**3,34**	**13,00**	**4**
12:00-12:30	2,81	41,51	44,32	42,66	0,80	0,74	4
12:30-13:00	2,57	41,75	44,32	42,62	0,90	0,94	4

The average comfort scores of the environment at the times of the course are calculated by taking into account the average scores in the time interval of the course as in *Table 27* and represent the average comfort scores of the course.

Table 24 Course Average Comfort Scores (15.12.2021)

Clock	Variable	
10:30-12:00	Thermal environment	3,833333333
	Visual	1
	Air Quality	2
	Acoustic	3

In addition, the half-hourly average comfort values from 9:30 am to 1:00 pm are also given in *Figure* 23 to interpret the comfort levels of the environment before and after the class.

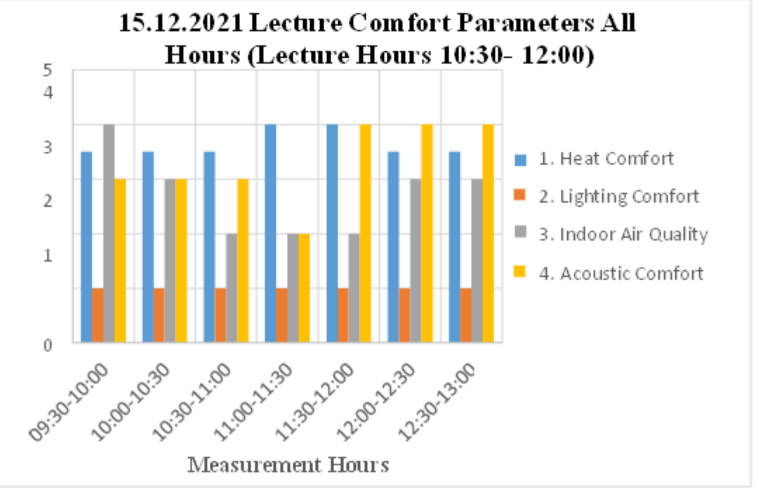

Figure 23 Comfort values during and outside class hours (between 9:30-13:00) (15.12.2021)

3.8.5.1.2. 22.12.2021 Course Results

Using the IEQ calculation, the calculated comfort scores for 22.12.2021 are shown in *Table 28*. The calculation considered the average ambient parameter value in the examined time interval. The time intervals expressed in bold symbols in the table refer to the hours of the lesson. Comfort scores are scored out of 5, as stated in the section describing IEQ calculations, and define the performance of ambient comfort out of 5.

Table 25 Calculation of ambient comfort levels using sensor data (22.12.2021)

1. Thermal Environment

(a) Temperature_22.12.2021 (°C) (Class Time: 10:30-12:00)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	1,00	21,11	22,10	21,69	0,33	0,13	5
10:00-10:30	2,38	21,01	23,38	21,78	0,81	0,76	5
10:30-11:00	**2,51**	**23,38**	**25,89**	**24,88**	**0,81**	**0,77**	**3**
11:00-	**0,93**	**25,57**	**26,51**	**26,12**	**0,29**	**0,10**	**2**

11:30							
11:30-12:00	**0,44**	**26,41**	**26,85**	**26,63**	**0,14**	**0,02**	**2**
12:00-12:30	0,51	26,19	26,70	26,39	0,17	0,03	2
12:30-13:00	0,45	26,70	27,14	26,96	0,15	0,03	2

(b) Relative humidity_22.12.2021 (%) (Class Time: 10:30-12:00)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	0,85	28,03	28,88	28,31	0,26	0,08	2
10:00-10:30	0,56	28,77	29,32	29,01	0,19	0,04	2
10:30-11:00	**2,04**	**28,93**	**30,97**	**29,90**	**0,71**	**0,58**	**2**
11:00-11:30	**1,97**	**30,97**	**32,94**	**31,97**	**0,70**	**0,57**	**3**
11:30-12:00	**2,87**	**31,30**	**34,17**	**33,27**	**0,90**	**0,94**	**3**
12:00-12:30	4,57	26,74	31,30	27,82	1,55	2,79	2
12:30-13:00	0,80	27,07	27,87	27,34	0,26	0,08	2

2. Visual

(a) Luminous intensity _22.12.2021 (lx) (Class Time: 10:30-12:00)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	616,92	174,07	790,99	303,06	208,17	50557,44	5
10:00-10:30	87,71	126,33	214,04	164,68	28,72	962,09	1

10:30-11:00	**30,33**	**126,33**	**156,66**	**143,40**	**12,73**	**188,95**	**1**
11:00-11:30	**71,73**	**54,66**	**126,38**	**93,12**	**25,80**	**776,88**	**1**
11:30-12:00	**26,14**	**28,52**	**54,66**	**37,24**	**7,81**	**71,23**	**1**
12:00-12:30	94,39	36,03	130,42	102,90	42,13	2070,60	1
12:30-13:00	111,10	18,07	129,16	112,19	38,44	1723,68	1

3. Air Quality

(a) CO_2_22.12.2021 (ppm) (Lecture Time: 10:30-12:00)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	266,50	1335,00	1601,50	1466,43	97,37	11060,45	4
10:00-10:30	803,00	1407,50	2210,50	1799,64	250,21	73038,89	3
10:30-11:00	**620,00**	**1811,00**	**2431,00**	**2048,64**	**204,54**	**48810,89**	**2**
11:00-11:30	**554,00**	**2269,00**	**2823,00**	**2682,43**	**171,72**	**34401,95**	**2**
11:30-12:00	**401,50**	**2441,50**	**2843,00**	**2714,50**	**127,06**	**18836,42**	**2**
12:00-12:30	711,50	1730,00	2441,50	1883,93	239,11	66704,45	3
12:30-13:00	28,50	1701,50	1730,00	1713,07	9,78	111,54	3

4.Acoustics

(a) Sound intensity _22.12.2021 (dBA) (Class Time: 10:30-12:00)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score

09:30-10:00	5,25	42,12	47,36	44,73	1,91	4,24	4
10:00-10:30	18,68	43,58	62,26	50,71	5,83	39,68	3
10:30-11:00	**22,22**	**45,90**	**68,12**	**56,07**	**7,16**	**59,77**	**1**
11:00-11:30	**9,28**	**52,00**	**61,28**	**57,70**	**2,89**	**9,73**	**1**
11:30-12:00	**15,02**	**45,90**	**60,91**	**53,94**	**5,12**	**30,54**	**2**
12:00-12:30	18,31	43,71	62,01	51,90	5,96	41,43	2
12:30-13:00	15,26	41,75	57,01	49,06	5,60	36,61	3

The average comfort scores of the environment at the time of the course are calculated by taking into account the average scores in the time interval of the course as in Table 29 and represent the average comfort scores of the course.

Table 26 Course Average Comfort Scores (22.12.2021)

Clock	Variable	
10:30-12:00	Thermal Environment	2,5
	Visual	1
	Air Quality	2
	Acoustic	1,3333333

In addition, Figure 24 also gives the half-hourly average comfort values from 9:30 a.m. to 13:00 p.m. to interpret the comfort levels of the environment before and after the class.

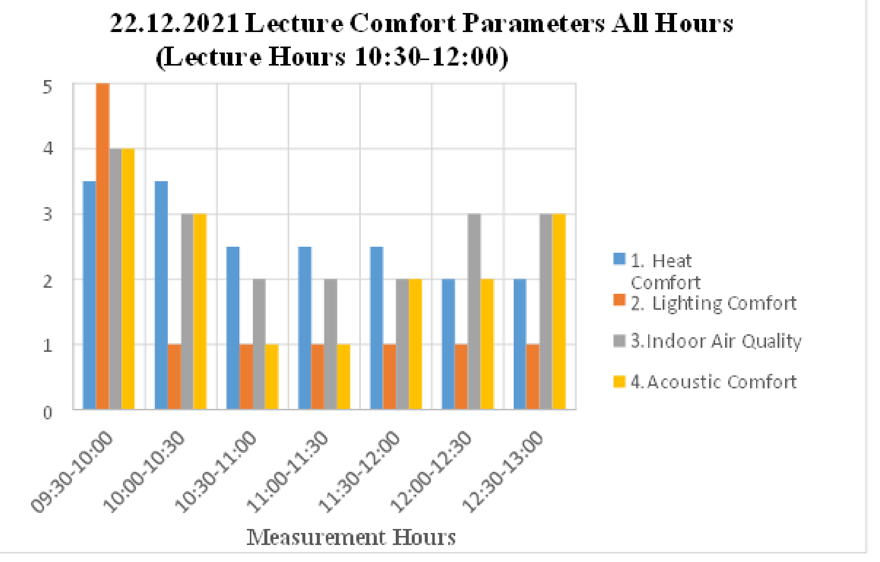

Figure 24 Comfort values during and outside class hours (between 9:30-13:00) (22.12.2021)

3.8.5.1.3. 05.01.2022 Course Results

Using the IEQ calculation, the calculated comfort scores for 05.01.2022 are shown *in Table 30*. The calculation considered the average ambient parameter value in the examined time interval. The time intervals expressed in bold symbols in the table refer to the hours of the lesson; comfort scores are scored out of 5, as stated in the section where IEQ calculations are defined, defining the performance of ambient comfort out of 5.

Table 27 Calculation of ambient comfort levels using sensor data (05.01.2022)

1. Thermal Environment

(a) Temperature_05.01.2022 (°C) (Class Time: 10:35-12:10)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	0,44	23,81	24,25	24,06	0,14	0,02	4
10:00-10:30	2,07	24,25	26,32	25,29	0,76	0,67	3
10:30-	**0,82**	**26,32**	**27,13**	**26,73**	**0,25**	**0,07**	**2**

11:00							
11:00-11:30	**0,43**	**27,13**	**27,57**	**27,36**	**0,15**	**0,03**	**2**
11:30-12:00	**0,54**	**27,06**	**27,61**	**27,51**	**0,18**	**0,04**	**2**
12:00-12:30	0,68	27,06	27,74	27,55	0,22	0,06	2
12:30-13:00	1,19	26,27	27,46	26,78	0,40	0,19	2

(b) Relative humidity_05.01.2022 (%) (Class Time: 10:35-12:10)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	0,17	41,62	41,79	41,70	0,06	0,00	3
10:00-10:30	2,26	39,52	41,78	40,74	0,82	0,79	3
10:30-11:00	**1,22**	**38,30**	**39,52**	**38,95**	**0,42**	**0,21**	**3**
11:00-11:30	**0,72**	**37,58**	**38,30**	**37,92**	**0,24**	**0,07**	**3**
11:30-12:00	**0,18**	**37,43**	**37,62**	**37,50**	**0,07**	**0,01**	**3**
12:00-12:30	0,21	37,32	37,53	37,42	0,07	0,00	3
12:30-13:00	1,09	37,53	38,62	38,13	0,37	0,16	3

2. Visual

(a) Luminous intensity _05.01.2022 (lx) (Class Time: 10:35-12:10)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	92,37	278,66	371,03	327,82	29,94	1046,04	5
10:00-10:30	58,96	219,71	278,66	241,18	22,80	606,66	1
10:30-11:00	**44,58**	**175,48**	**220,05**	**195,81**	**13,94**	**226,73**	**1**
11:00-11:30	**71,96**	**103,52**	**175,48**	**141,50**	**22,14**	**571,97**	**1**
11:30-12:00	**52,40**	**51,12**	**103,52**	**70,06**	**18,58**	**402,76**	**1**
12:00-12:30	28,70	24,74	53,44	44,37	11,75	161,11	1
12:30-13:00	10,63	21,88	32,50	28,35	4,21	20,68	1

3. Air Quality

(a) CO_2_05.01.2022 (ppm) (Lecture Time: 10:35-12:10)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	102,00	1106,50	1208,50	1142,36	36,22	1530,14	4
10:00-10:30	375,50	1114,00	1489,50	1311,14	151,98	26948,06	4
10:30-11:00	**221,00**	**1306,00**	**1527,00**	**1418,07**	**81,05**	**7663,62**	**4**
11:00-11:30	**241,50**	**1233,00**	**1474,50**	**1292,71**	**76,47**	**6822,90**	**4**
11:30-12:00	**563,00**	**677,00**	**1240,00**	**983,86**	**262,07**	**80127,23**	**5**
12:00-	593,00	625,50	1218,50	753,71	192,41	43190,24	5

12:30							
12:30-13:00	150,00	632,50	782,50	715,36	55,57	3603,23	5

4.Acoustics							
(a) Sound intensity _05.01.2022 (dBA) (Class Time: 10:35-12:10)							
Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	7,45	41,50	48,95	44,09	3,07	10,97	4
10:00-10:30	4,40	42,97	47,37	44,64	1,23	1,75	4
10:30-11:00	**18,19**	**43,21**	**61,40**	**52,53**	**6,60**	**50,75**	**2**
11:00-11:30	**25,14**	**42,85**	**67,99**	**54,97**	**8,33**	**80,97**	**2**
11:30-12:00	**25,88**	**44,56**	**70,44**	**56,41**	**9,99**	**116,36**	**1**
12:00-12:30	29,79	40,65	70,44	49,96	10,75	134,74	3
12:30-13:00	1,71	40,77	42,48	41,80	0,50	0,30	4

The average comfort scores of the environment at the time of the course are calculated by considering the average scores in the time interval of the course as in *Table 31* and represent the average comfort scores of the course.

Table 28 Course Average Comfort Scores (05.01.2022)

Clock	Variable	
10:35-12:10	Thermal Environment	2,5
	Visual	1
	Air Quality	4,5
	Acoustic	2

In addition, Figure 25 also gives the half-hourly average comfort values from 9:30 a.m. to 13:00 p.m. to interpret the comfort levels of the environment before and after the class.

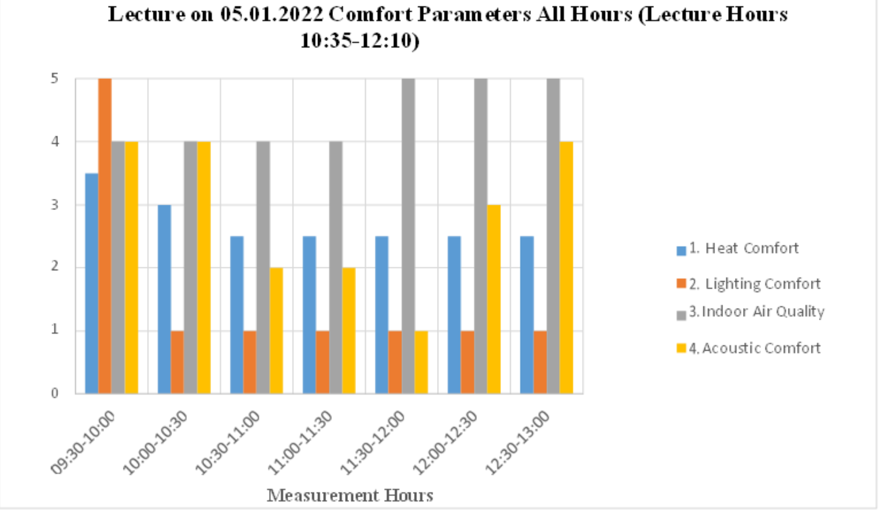

Figure 25 Comfort values during and outside of class hours (between 9:30-13:00) (05.01.2022)

3.8.5.1.4. 12.01.2022 Course Results

Using the IEQ calculation, the calculated comfort scores for 12.01.2022 are shown in *Table 32*. The calculation considered the average ambient parameter value in the examined time interval. The time intervals expressed in bold symbols in the table refer to the hours of the lesson; the comfort scores are scored out of 5, as stated in the section describing the IEQ calculations, defining the performance of the ambient comfort out of 5.

Table 29 Calculation of ambient comfort levels using sensor data (12.01.2022)

1. Thermal Environment

(a) Temperature_12.01.2022 (°C) (Class Time: 10:30-12:15)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	2,21	23,71	25,91	24,97	0,75	0,65	3
10:00-10:30	1,57	24,35	25,91	25,22	0,56	0,37	3

10:30-11:00	**1,73**	**25,80**	**27,53**	**26,70**	**0,59**	**0,41**	**2**
11:00-11:30	**1,68**	**26,16**	**27,84**	**27,29**	**0,55**	**0,35**	**2**
11:30-12:00	**1,40**	**26,16**	**27,56**	**26,80**	**0,50**	**0,29**	**2**
12:00-12:30	0,56	27,31	27,87	27,67	0,18	0,04	1
12:30-13:00	1,49	25,82	27,31	26,49	0,54	0,34	2

(b) Relative humidity_12.01.2022 (%) (Class Time: 10:30-12:15)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	5,02	32,53	37,55	34,99	1,47	2,50	3
10:00-10:30	3,15	29,38	32,53	30,82	1,15	1,56	2
10:30-11:00	**0,81**	**31,85**	**32,65**	**32,18**	**0,26**	**0,08**	**3**
11:00-11:30	**1,59**	**32,42**	**34,00**	**33,13**	**0,49**	**0,28**	**3**
11:30-12:00	**0,63**	**32,28**	**32,91**	**32,62**	**0,20**	**0,05**	**3**
12:00-12:30	1,24	32,16	33,40	32,85	0,42	0,21	3
12:30-13:00	0,26	32,16	32,42	32,31	0,09	0,01	3

2. Visual

(a) Luminous intensity _12.01.2022 (lx) (Class Time: 10:30-12:15)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score

09:30-10:00	45,30	15,17	60,47	39,97	19,48	442,86	1
10:00-10:30	42,26	51,20	93,46	64,97	15,96	297,04	1
10:30-11:00	**16,54**	**39,17**	**55,71**	**42,98**	**5,44**	**34,52**	**1**
11:00-11:30	**15,19**	**42,38**	**57,57**	**49,04**	**5,93**	**41,04**	**1**
11:30-12:00	**36,22**	**56,12**	**92,34**	**73,02**	**11,52**	**154,89**	**1**
12:00-12:30	39,46	28,47	67,93	53,93	15,15	267,90	1
12:30-13:00	4,83	26,88	31,70	29,20	1,69	3,33	1

3. Air Quality

(a) CO2_12.01.2022 (ppm) (Lecture Time: 10:30-12:15)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	556,00	727,50	1283,50	1109,21	188,10	41280,32	4
10:00-10:30	776,00	411,00	1187,00	828,64	324,31	122704,48	5
10:30-11:00	**397,50**	**1187,00**	**1584,50**	**1434,79**	**131,02**	**20027,49**	**4**
11:00-11:30	**65,50**	**1584,50**	**1650,00**	**1615,36**	**22,62**	**596,81**	**3**
11:30-12:00	**107,50**	**1528,00**	**1635,50**	**1595,21**	**33,06**	**1274,90**	**3**
12:00-12:30	106,00	1621,00	1727,00	1675,36	36,56	1559,48	3
12:30-13:00	77,00	1630,00	1707,00	1662,07	24,88	722,04	3

4.Acoustics							
(a) Sound intensity _12.01.2022 (dBA) (Class Time: 10:30-12:15)							
Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	13,31	47,00	60,30	50,68	4,31	21,62	3
10:00-10:30	5,74	44,56	50,29	47,89	1,88	4,13	3
10:30-11:00	**13,80**	**47,12**	**60,92**	**54,53**	**4,77**	**26,59**	**2**
11:00-11:30	**18,07**	**42,12**	**60,18**	**51,64**	**7,01**	**57,39**	**2**
11:30-12:00	**19,65**	**47,98**	**67,63**	**57,18**	**6,43**	**48,24**	**1**
12:00-12:30	13,80	40,77	54,57	47,92	4,87	27,68	3
12:30-13:00	5,62	40,65	46,27	42,50	1,91	4,25	4

The average comfort scores of the environment at the time of the course are calculated by taking into account the average scores in the time interval of the course as in *Table 33* and represent the average comfort scores of the course.

Table 30 Course Average Comfort Scores (12.01.2022)

Clock	Variable	
10:30-12:15	Thermal Environment	2,375
	Visual	1
	Air Quality	3,25
	Acoustic	2

In addition, Figure 26 also gives the average comfort values for half an hour from 9:30 a.m. to 13:00 p.m. to interpret the comfort levels of the environment before and after the lesson.

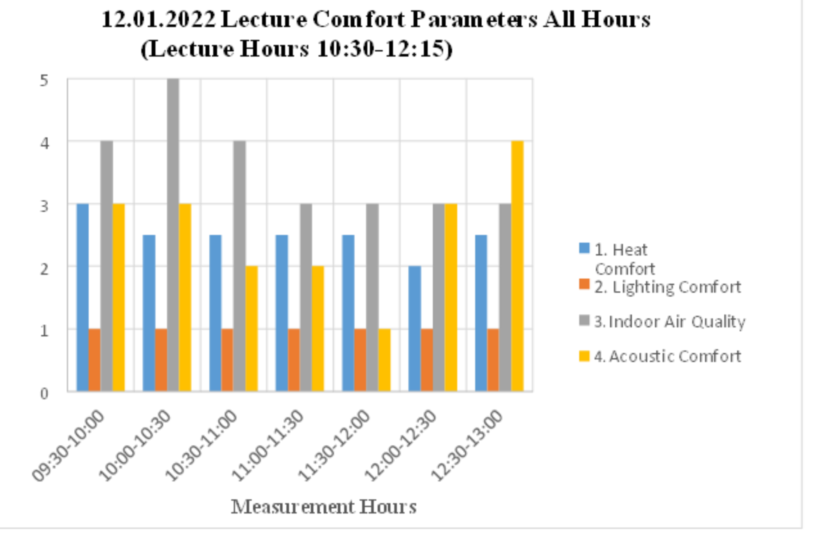

Figure 26 Comfort values during and outside of class hours (between 9:30-13:00) (12.01.2022)

3.8.5.1.5. 19.01.2022 Course Results

Using the IEQ calculation, the calculated comfort scores for 19.01.2022 are shown in Table 34. In the calculation, the average ambient parameter value in the examined time interval was taken into account. The time intervals expressed in bold symbols in the table refer to the hours of the lesson. Comfort scores are scored out of 5, as stated in the section where IEQ calculations are defined, defining the performance of ambient comfort out of 5.

Table 31 Calculation of ambient comfort levels using sensor data (19.01.2022)

1. Thermal Environment

(a) Temperature_19.01.2022 (°C) (Class Time: 10:30-11:30)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	0,31	20,66	20,97	20,82	0,10	0,01	5
10:00-10:30	2,91	20,97	23,88	22,53	1,08	1,36	5
10:30-11:00	**1,68**	**23,87**	**25,55**	**24,97**	**0,55**	**0,35**	**3**

11:00-11:30	**1,38**	**25,24**	**26,61**	**25,94**	**0,40**	**0,19**	**2**
11:30-12:00	**2,03**	**24,65**	**26,68**	**25,78**	**0,75**	**0,65**	**2**
12:00-12:30	1,14	23,52	24,65	24,01	0,38	0,17	4
12:30-13:00	0,70	22,82	23,52	23,19	0,22	0,06	4

(b) Relative humidity_19.01.2022 (%) (Class Time: 10:30-11:30)

Clock	Openness	Minimum	Maximum	<u>Average</u>	Standard Deviation	Variance	Comfort Score
09:30-10:00	1,75	28,90	30,64	29,97	0,52	0,32	3
10:00-10:30	3,84	25,06	28,90	26,97	1,32	2,04	2
10:30-11:00	**1,63**	**23,43**	**25,06**	**24,13**	**0,64**	**0,47**	**2**
11:00-11:30	**1,91**	**23,33**	**25,24**	**23,99**	**0,72**	**0,61**	**2**
11:30-12:00	**1,05**	**24,28**	**25,33**	**24,93**	**0,32**	**0,12**	**2**
12:00-12:30	0,32	25,33	25,65	25,51	0,10	0,01	2
12:30-13:00	0,11	25,58	25,69	25,64	0,03	0,00	2

2. Visual

(a) Light intensity _19.01.2022 (lx) (Lecture Time: 10:30-11:30)

Clock	Openness	Minimum	Maximum	<u>Average</u>	Standard Deviation	Variance	Comfort Score
09:30-10:00	263,04	37,39	300,43	117,30	81,01	7655,89	1

10:00-10:30	195,05	51,58	246,63	148,27	82,44	7928,33	1
10:30-11:00	**158,79**	**42,45**	**201,24**	**131,17**	**76,01**	**6740,01**	**1**
11:00-11:30	**108,14**	**44,60**	**152,74**	**68,68**	**36,63**	**1565,62**	**1**
11:30-12:00	**61,74**	**45,33**	**107,06**	**74,84**	**18,70**	**407,97**	**1**
12:00-12:30	21,78	23,55	45,33	35,46	7,43	64,33	1
12:30-13:00	17,79	21,00	38,79	29,04	6,70	52,41	1

3. Air Quality

(a) CO_2_19.01.2022 (ppm) (Lecture Time: 10:30-11:30)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	731,50	982,50	1714,00	1318,71	265,69	82353,82	4
10:00-10:30	768,00	982,50	1750,50	1261,64	275,03	88245,56	4
10:30-11:00	**383,50**	**1434,00**	**1817,50**	**1598,36**	**126,09**	**18548,98**	**3**
11:00-11:30	**195,50**	**1466,50**	**1662,00**	**1573,57**	**58,06**	**3932,95**	**3**
11:30-12:00	**63,00**	**1599,50**	**1662,50**	**1640,79**	**21,57**	**542,74**	**3**
12:00-12:30	354,50	1567,00	1921,50	1684,71	115,54	15574,24	3
12:30-13:00	487,50	1434,00	1921,50	1534,57	160,97	30230,70	3

4. Acoustics

(a) Sound intensity _19.01.2022 (dBA) (Class Time: 10:30-11:30)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	12,21	41,14	53,35	44,02	3,94	18,13	4
10:00-10:30	4,03	49,32	53,35	52,13	1,67	3,24	2
10:30-11:00	**18,80**	**48,10**	**66,90**	**54,69**	**6,55**	**50,01**	**2**
11:00-11:30	**12,21**	**49,81**	**62,01**	**58,73**	**3,92**	**17,93**	**1**
11:30-12:00	**18,80**	**40,04**	**58,84**	**44,14**	**6,21**	**44,93**	**4**
12:00-12:30	5,25	40,65	45,90	42,32	1,58	2,90	4
12:30-13:00	1,84	39,92	41,75	40,93	0,57	0,38	4

The average comfort scores of the environment at the time of the course are calculated by taking into account the average scores in the time interval of the course as in *Table 35* and represent the average comfort scores of the course.

Table 32 Course Average Comfort Scores (19.01.2022)

Clock	Variable	
10:30-11:30	Thermal Environment	2,25
	Visual Comfort	1
	Air Quality	3
	Acoustic	1,5

In addition, Figure 27 also gives the half-hourly average comfort values from 9:30 a.m. to 13:00 p.m. to interpret the comfort levels of the environment before and after the class.

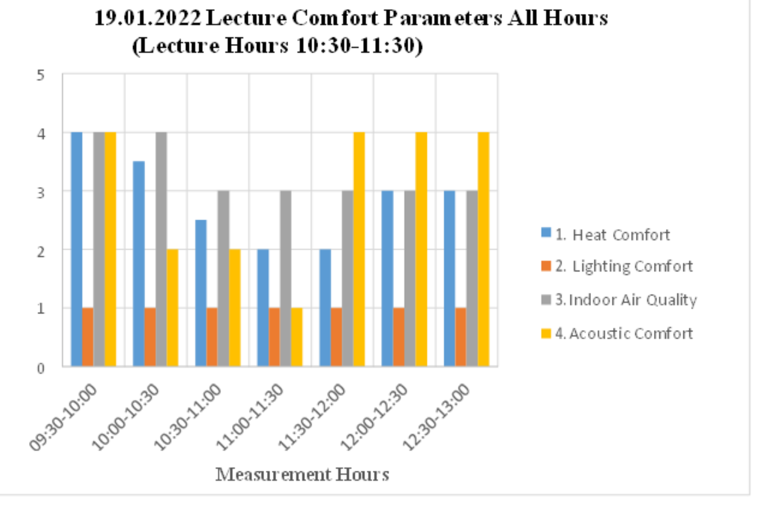

Figure 27 Comfort values during and outside of class hours (between 9:30-13:00) (19.01.2022)

3.8.5.2. Smart Classroom Second Pilot Implementation Results

3.8.5.2.1.1. 22.04.2022 Course Results

Using the IEQ calculation, the calculated comfort scores for 22.04.2022 are shown in Table 36. In the calculation, the average ambient parameter value in the examined time interval was taken into consideration. The time intervals expressed in bold symbols in the table refer to the hours of the lesson. Comfort scores are scored out of 5, as stated in the section describing IEQ calculations, defining the performance of ambient comfort out of 5.

Table 33 Calculation of ambient comfort levels using sensor data (22.04.2022)

1. Thermal Environment

(a) Temperature_22.04.2022 (°C) (Class Time: 11:00-12:00)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	0,07	27,59	27,67	27,63	0,03	0,00	2
10:00-10:30	0,03	27,67	27,70	27,68	0,01	0,00	2
10:30-	0,68	27,05	27,73	27,62	0,23	0,06	2

11:00							
11:00-11:30	**0,19**	**27,05**	**27,24**	**27,13**	**0,05**	**0,00**	**2**
11:30-12:00	**0,40**	**27,24**	**27,63**	**27,44**	**0,13**	**0,02**	**2**
12:00-12:30	0,29	27,63	27,93	27,80	0,11	0,01	2
12:30-13:00	0,07	27,93	27,99	27,96	0,02	0,00	2

(b) Relative humidity_22.04.2022 (%) (Class Time: 11:00-12:00)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	0,10	35,41	35,51	35,46	0,04	0,00	3
10:00-10:30	0,04	35,39	35,43	35,41	0,01	0,00	3
10:30-11:00	4,60	30,82	35,42	34,73	1,60	2,99	3
11:00-11:30	**1,23**	**30,79**	**32,01**	**31,39**	**0,47**	**0,26**	**3**
11:30-12:00	**2,25**	**32,00**	**34,25**	**33,02**	**0,76**	**0,67**	**3**
12:00-12:30	1,37	34,25	35,62	34,96	0,46	0,25	3
12:30-13:00	1,84	33,84	35,68	34,57	0,75	0,66	3

2. Visual

(a) Luminous intensity _22.04.2022 (lx) (Class Time: 11:00-12:00)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score

09:30-10:00	3,27	65,14	68,40	66,83	1,05	1,30	1
10:00-10:30	1,99	63,15	65,14	64,09	0,62	0,45	1
10:30-11:00	167,98	61,08	229,06	86,17	58,34	3970,53	1
11:00-11:30	**44,65**	**193,38**	**238,03**	**215,49**	**15,70**	**287,75**	**1**
11:30-12:00	**17,69**	**188,54**	**206,22**	**198,63**	**5,81**	**39,43**	**1**
12:00-12:30	37,64	165,34	202,98	181,84	12,12	171,51	1
12:30-13:00	174,82	33,04	207,86	148,61	71,27	5925,57	1

3. Air Quality

(a) CO2_22.04.2022 (ppm) (Lecture Time: 11:00-12:00)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	39,50	439,00	478,50	447,00	13,01	197,50	5
10:00-10:30	330,50	442,00	772,50	506,36	110,02	14121,31	5
10:30-11:00	325,50	447,00	772,50	520,86	112,86	14860,56	5
11:00-11:30	**621,50**	**474,00**	**1095,50**	**777,43**	**266,81**	**83054,12**	**5**
11:30-12:00	**467,00**	**1095,50**	**1562,50**	**1216,00**	**150,31**	**26357,67**	**4**
12:00-12:30	219,00	1374,50	1593,50	1511,14	83,11	8059,31	3
12:30-13:00	187,50	1406,00	1593,50	1514,07	70,44	5788,79	3

4.Acoustics							
(a) Sound intensity _22.04.2022 (dBA) (Class Time: 11:00-12:00)							
Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	1,59	39,06	40,65	39,95	0,46	0,24	5
10:00-10:30	2,32	38,33	40,65	40,04	0,74	0,64	5
10:30-11:00	12,58	38,82	51,39	41,14	4,20	20,59	4
11:00-11:30	**7,45**	**44,19**	**51,64**	**47,59**	**2,70**	**8,53**	**3**
11:30-12:00	**10,63**	**44,92**	**55,55**	**51,55**	**4,13**	**19,90**	**2**
12:00-12:30	8,06	48,71	56,76	53,24	2,48	7,15	2
12:30-13:00	22,71	38,94	61,65	48,74	7,15	59,62	3

The average comfort scores of the environment at the time of the course are calculated by considering the average scores in the time interval of the course as in *Table 37* and represent the average comfort scores of the course.

Table 34 Course Average Comfort Scores (22.04.2022)

Clock	Variable	
11:00-12:00	Thermal Environment	2,5
	Visual	1
	Air Quality	4,5
	Acoustic	2,5

In addition, the half-hourly average comfort values from 9:30 am to 1:00 pm are also. *Figure 28* is given to interpret the environment's comfort levels before and after the class.

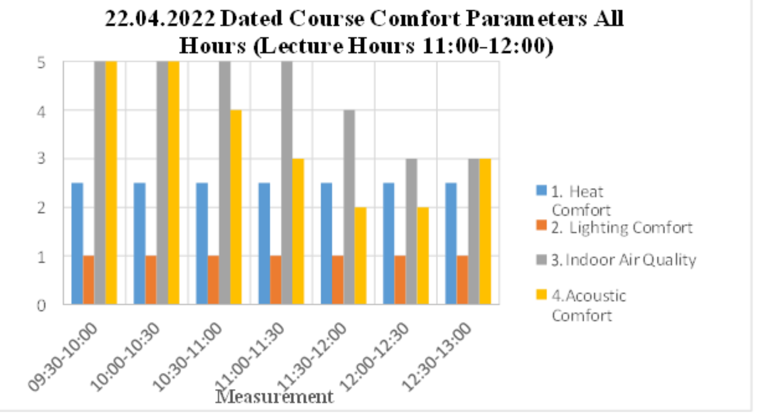

Figure 28 Comfort values during and outside of class hours (between 9:30-13:00) (22.04.2022)

3.8.5.2.2. 13.05.2022 Course Results

Using the IEQ calculation, the calculated comfort scores for 13.05.2022 are shown in Table 38. In the calculation, the average ambient parameter value in the examined time interval was considered. The time intervals expressed in bold symbols in the table refer to the hours of the lesson. Comfort scores are scored out of 5, as stated in the section where IEQ calculations are defined, defining the performance of ambient comfort out of 5.

Table 35 Calculation of ambient comfort levels using sensor data (13.05.2022)

1. Thermal Environment (a) Temperature_13.05.2022 (°C) (Class Time: 11:30-12:30)							
Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	0,09	26,75	26,83	26,78	0,03	0,00	2
10:00-10:30	0,15	26,75	26,89	26,80	0,05	0,00	2
10:30-11:00	0,16	26,89	27,05	26,98	0,05	0,00	2
11:00-11:30	0,18	27,04	27,22	27,12	0,05	0,00	2
11:30-12:00	**0,40**	**27,22**	**27,62**	**27,43**	**0,13**	**0,02**	**2**
12:00-12:30	**0,31**	**27,62**	**27,93**	**27,79**	**0,11**	**0,01**	**2**
12:30-13:00	0,07	27,93	28,00	27,96	0,02	0,00	2

(b) Relative humidity_13.05.2022 (%) (Class Time: 11:30-12:30)							
Clock	Openness	Minimum	Maximum	<u>Average</u>	Standard Deviation	Variance	Comfort Score
09:30-10:00	2,36	32,48	34,84	33,76	0,88	0,91	3
10:00-10:30	1,65	31,52	33,17	32,07	0,56	0,36	3
10:30-11:00	0,67	30,95	31,62	31,38	0,21	0,05	3
11:00-11:30	1,21	30,74	31,95	31,33	0,41	0,20	3
11:30-12:00	**2,41**	**31,82**	**34,23**	**32,97**	**0,80**	**0,74**	**3**
12:00-12:30	**1,35**	**34,23**	**35,58**	**34,94**	**0,46**	**0,24**	**3**
12:30-13:00	1,85	33,83	35,68	34,59	0,77	0,69	3

2. Visual (a) Light intensity _13.05.2022 (lx) (Lecture Time: 11:30-12:30)							
Clock	Openness	Minimum	Maximum	<u>Average</u>	Standard Deviation	Variance	Comfort Score
09:30-10:00	187,63	23,00	210,63	156,33	56,59	3736,59	1
10:00-10:30	9,39	203,33	212,72	207,71	3,51	14,35	1
10:30-11:00	28,01	200,79	228,79	212,33	9,00	94,60	1
11:00-11:30	64,87	174,31	239,18	217,95	22,04	566,57	1
11:30-12:00	**19,46**	**188,65**	**208,10**	**199,58**	**6,26**	**45,71**	**1**
12:00-12:30	**28,40**	**173,38**	**201,77**	**183,08**	**9,53**	**105,97**	**1**
12:30-13:00	175,52	34,68	210,20	149,61	71,51	5966,65	1

3. Air Quality

(a) CO_2_13.05.2022 (ppm) (Lecture Time: 11:30-12:30)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	639,00	806,00	1445,00	1210,79	252,20	74204,24	4
10:00-10:30	608,50	532,00	1140,50	795,50	188,46	41437,67	5
10:30-11:00	237,50	448,50	686,00	557,43	86,53	8734,70	5
11:00-11:30	670,00	438,00	1108,00	807,86	316,62	116955,98	5
11:30-12:00	**431,50**	**884,00**	**1315,50**	**1133,29**	**129,09**	**19441,49**	**4**
12:00-12:30	**366,50**	**1315,50**	**1682,00**	**1489,50**	**122,48**	**17502,67**	**3**
12:30-13:00	173,50	1414,50	1588,00	1494,36	74,84	6534,81	3

4.Acoustics

(a) Sound intensity _13.05.2022 (dBA) (Class Time: 11:30-12:30)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	19,78	40,04	59,82	47,71	5,62	36,81	3
10:00-10:30	17,95	46,27	64,21	50,66	6,13	43,85	3
10:30-11:00	11,23	46,15	57,37	48,58	3,69	15,85	3
11:00-11:30	7,57	46,02	53,59	49,79	3,07	10,97	3
11:30-12:00	**10,50**	**44,93**	**55,42**	**52,39**	**3,43**	**13,72**	**2**

12:00-12:30	**8,92**	**48,58**	**57,50**	**51,98**	**3,21**	**12,02**	**2**
12:30-13:00	18,19	39,67	57,86	1 4 5 9 4 2 3	6,30	46,32	3

The average comfort scores of the environment at the time of the course are calculated by taking into account the average scores in the time interval of the course as in *Table 39* and represent the average comfort scores of the course.

Table 36 Course Average Comfort Scores (13.05.2022)

Clock	Variable	
11:30-12:30	Thermal Environment	2,5
	Visual	1
	Air Quality	3,5
	Acoustic	2

In addition, Figure 29 also gives the average comfort values for half an hour from 9:30 a.m. to 13:00 p.m. to interpret the comfort levels of the environment before and after the lesson.

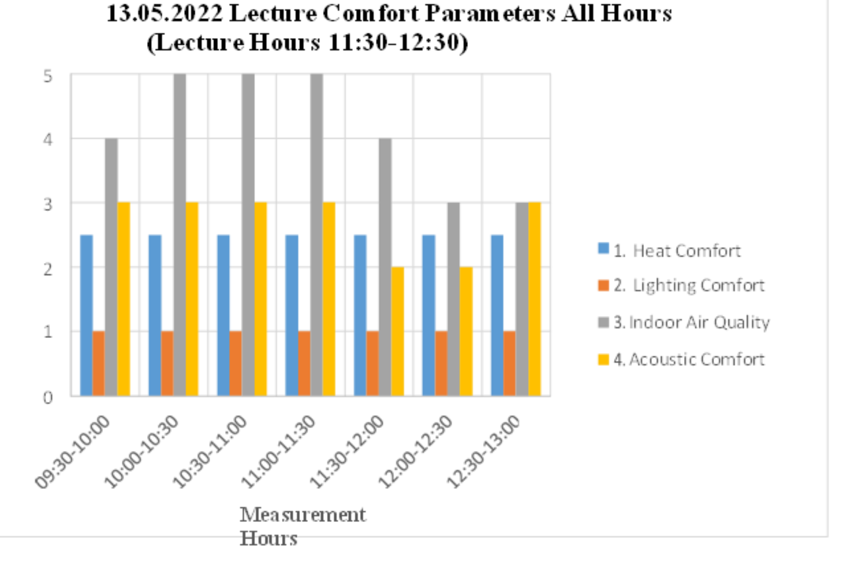

Figure 29 Comfort values in and out of class hours (between 9:30-13:00) (13.05.2022)

3.8.5.2.3. 20.05.2022 Course Results

Using the IEQ calculation, the calculated comfort scores for 20.05.2022 are shown in Table 40. In the calculation, the average ambient parameter value in the examined time interval was taken into account. The time intervals expressed in bold symbols in the table refer to the hours of the lesson. Comfort scores are scored out of 5, as stated in the section where IEQ calculations are defined, defining the performance of ambient comfort out of 5.

Table 37 Calculation of ambient comfort levels using sensor data (20.05.2022)

1. Thermal Environment

(a) Temperature_20.05.2022 (°C) (Class Time: 10:40-12:00)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	0,13	27,11	27,24	27,19	0,05	0,00	2
10:00-10:30	0,72	26,57	27,29	27,09	0,25	0,07	2
10:30-11:00	1,13	26,57	27,69	27,16	0,39	0,18	2
11:00-11:30	0,48	27,69	28,17	27,95	0,16	0,03	1
11:30-12:00	0,20	28,17	28,37	28,28	0,07	0,01	1
12:00-12:30	0,43	27,99	28,41	28,26	0,16	0,03	1
12:30-13:00	0,08	27,91	27,99	27,93	0,03	0,00	1

(b) Relative humidity_20.05.2022 (%) (Class Time: 10:40-12:00)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	0,45	28,53	28,98	28,71	0,16	0,03	2
10:00-	2,68	25,90	28,57	27,19	0,98	1,12	2

10:30							
10:30-11:00	4,65	26,28	30,92	28,94	1,58	2,90	2
11:00-11:30	0,85	30,07	30,92	30,52	0,30	0,11	1
11:30-12:00	0,47	29,61	30,07	29,78	0,17	0,03	1
12:00-12:30	2,24	27,51	29,74	28,84	0,86	0,87	1
12:30-13:00	0,39	27,51	27,90	27,73	0,14	0,02	1

2. Visual

(a) Luminous intensity _20.05.2022 (lx) (Class Time: 10:40-12:00)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	10,63	66,55	77,18	73,19	3,43	13,73	1
10:00-10:30	69,10	66,55	135,65	90,18	28,29	933,65	1
10:30-11:00	126,97	78,65	205,62	127,80	49,32	2837,64	1
11:00-11:30	8,65	162,63	171,28	168,02	3,08	11,09	1
11:30-12:00	6,16	156,72	162,87	159,90	2,19	5,61	1
12:00-12:30	122,90	34,50	157,39	100,76	48,52	2747,01	1
12:30-13:00	2,47	32,03	34,50	33,32	0,79	0,73	1

3. Air Quality

(a) CO_2_20.05.2022 (ppm) (Lecture Time: 10:40-12:00)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	162,50	458,50	621,00	508,93	49,83	2896,79	5
10:00-10:30	147,50	419,50	567,00	487,79	46,34	2505,07	5
10:30-11:00	1107,50	505,50	1613,00	1281,00	385,55	173419,92	4
11:00-11:30	163,50	1495,50	1659,00	1581,07	49,79	2892,29	3
11:30-12:00	103,50	1495,50	1599,00	1575,86	33,98	1346,89	3
12:00-12:30	839,50	755,00	1594,50	1379,86	299,53	104670,81	4
12:30-13:00	556,00	755,00	1311,00	842,00	191,58	42819,33	5

4.Acoustics

(a) Sound intensity _20.05.2022 (dBA) (Class Time: 10:40-12:00)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	16,85	42,24	59,09	47,59	5,51	35,43	3
10:00-10:30	15,75	43,34	59,09	50,07	5,41	34,11	3
10:30-11:00	21,12	40,65	61,77	50,61	6,58	50,49	3
11:00-11:30	19,54	40,65	60,19	53,54	6,31	46,43	2
11:30-12:00	16,73	43,46	60,19	52,44	5,84	39,74	2
12:00-	14,89	39,19	54,08	46,20	4,37	22,25	3

12:30							
12:30-13:00	2,57	37,84	40,41	39,17	0,77	0,68	5

The average comfort scores of the environment at the time of the course are calculated by taking into account the average scores in the time interval of the course as in *Table 41* and represent the average comfort scores of the course.

Table 38 Course Average Comfort Scores (20.05.2022)

Clock	Variable	
10:40-12:00	Thermal Environment	1,6666667
	Visual	1
	Air Quality	3,3333333
	Acoustic	2,3333333

In addition, Figure 30 also gives the half-hourly average comfort values from 9:30 a.m. to 13:00 p.m. to interpret the comfort levels of the environment before and after the class.

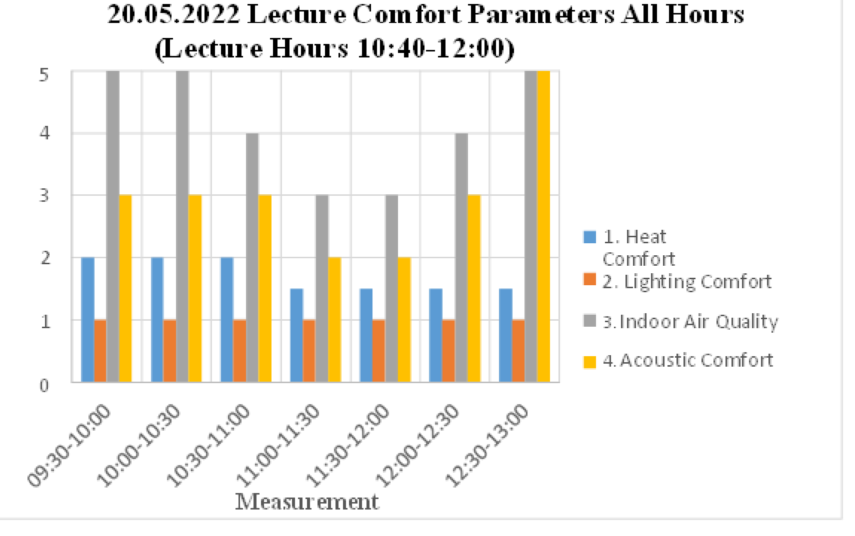

Figure 30 Comfort values during and outside of class hours (between 9:30-13:00) (20.05.2022)

3.8.5.2.4. 27.05.2022 Lesson Results

Using the IEQ calculation, the calculated comfort scores for 27.05.2022 are shown in *Table 42*. In the calculation, the average ambient parameter value in the examined time interval was taken into consideration. The time intervals expressed in bold symbols in the table refer to the hours of the lesson; comfort scores are scored out of 5, as stated in the section where IEQ calculations are defined, defining the performance of ambient comfort out of 5.

Table 39 Calculation of ambient comfort levels using sensor data (27.05.2022)

1. Thermal Environment

(a) Temperature_27.05.2022 (°C) (Class Time: 10:50-12:15)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	0,08	29,64	29,72	29,67	0,02	0,00	1
10:00-10:30	0,70	29,16	29,86	29,52	0,27	0,09	1
10:30-11:00	**1,12**	**28,06**	**29,18**	**28,72**	**0,41**	**0,20**	**1**
11:00-11:30	**0,61**	**27,46**	**28,06**	**27,71**	**0,20**	**0,05**	**2**
11:30-12:00	**0,34**	**27,12**	**27,46**	**27,27**	**0,11**	**0,01**	**2**
12:00-12:30	**0,28**	**26,84**	**27,12**	**26,99**	**0,08**	**0,01**	**2**
12:30-13:00	1,31	26,78	28,08	27,35	0,48	0,26	2

(b) Relative humidity_27.05.2022 (%) (Class Time: 10:50-12:15)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	0,95	38,88	39,83	39,59	0,30	0,11	3
10:00-10:30	3,45	35,43	38,88	37,01	1,37	2,20	3

10:30-11:00	**1,11**	**34,40**	**35,51**	**34,92**	**0,44**	**0,22**	**3**
11:00-11:30	**1,47**	**33,02**	**34,49**	**33,87**	**0,53**	**0,33**	**3**
11:30-12:00	**1,28**	**31,74**	**33,02**	**32,35**	**0,41**	**0,20**	**3**
12:00-12:30	**0,84**	**30,93**	**31,78**	**31,47**	**0,28**	**0,09**	**3**
12:30-13:00	2,21	30,93	33,14	31,82	0,77	0,70	3

2. Visual

(a) Luminous intensity _27.05.2022 (lx) (Class Time: 10:50-12:15)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	126,63	83,12	209,75	120,15	56,62	3740,06	1
10:00-10:30	154,72	54,86	209,58	139,64	63,58	4716,72	1
10:30-11:00	**76,13**	**46,84**	**122,97**	**60,45**	**25,56**	**762,09**	**1**
11:00-11:30	**2,83**	**45,35**	**48,18**	**47,08**	**0,89**	**0,92**	**1**
11:30-12:00	**4,72**	**40,63**	**45,35**	**43,16**	**1,53**	**2,73**	**1**
12:00-12:30	**2,28**	**38,35**	**40,63**	**38,99**	**0,73**	**0,63**	**1**
12:30-13:00	15,02	23,33	38,35	25,91	5,09	30,21	1

3. Air Quality

(a) CO_2_27.05.2022 (ppm) (Lecture Time: 10:50-12:15)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score

09:30-10:00	727,00	433,50	1160,50	1032,43	245,40	70257,12	4
10:00-10:30	84,00	427,00	511,00	475,93	32,52	1234,04	5
10:30-11:00	**143,50**	**481,50**	**625,00**	**525,50**	**48,27**	**2718,00**	**5**
11:00-11:30	**675,50**	**625,00**	**1300,50**	**1036,07**	**255,60**	**76218,54**	**4**
11:30-12:00	**530,50**	**897,50**	**1428,00**	**1132,21**	**182,98**	**39061,32**	**4**
12:00-12:30	**524,00**	**904,00**	**1428,00**	**1007,07**	**173,64**	**35174,37**	**4**
12:30-13:00	159,50	867,00	1026,50	908,71	54,73	3493,99	5

4.Acoustics

(a) Sound intensity _27.05.2022 (dBA) (Class Time: 10:50-12:15)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	4,15	40,65	44,80	41,71	1,45	2,45	4
10:00-10:30	5,50	42,85	48,34	46,21	1,68	3,30	3
10:30-11:00	**7,09**	**43,21**	**50,30**	**45,67**	**2,24**	**5,84**	**4**
11:00-11:30	**6,59**	**44,07**	**50,66**	**47,21**	**2,03**	**4,80**	**3**
11:30-12:00	**5,01**	**43,34**	**48,34**	**46,02**	**1,62**	**3,07**	**3**
12:00-12:30	**12,57**	**43,34**	**55,91**	**46,81**	**3,98**	**18,46**	**3**
12:30-13:00	5,25	39,07	44,32	42,20	1,70	3,38	4

The average comfort scores of the environment at the times of the course are calculated by taking into account the average scores in the time interval of the course as in *Table 43* and represent the average comfort scores of the course.

Table 40 Course Average Comfort Scores (27.05.2022)

Clock	Variable	
10:50-12:15	Thermal Environment	2,375
	Visual	1
	Air Quality	4,25
	Acoustic	3,25

In addition, Figure 31 also gives the half-hourly average comfort values from 9:30 a.m. to 13:00 p.m. to interpret the comfort levels of the environment before and after the class.

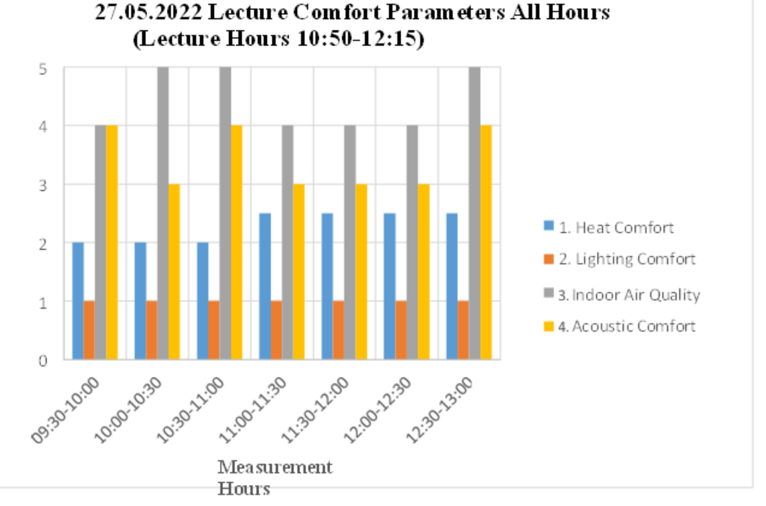

Figure 31 Comfort values during and outside of class hours (between 9:30-13:00) (27.05.2022)

3.8.5.2.5. 03.06.2022 Course Results

Using the IEQ calculation, the calculated comfort scores for 03.06.2022 are shown in *Table 44*. In the calculation, the average ambient parameter value in the examined time interval was considered. The time intervals expressed in bold symbols in the table are the hours of the course. refers to comfort scores.

Comfort scores are scored over 5, as stated in the section defining IEQ calculations. This defines the performance of ambient comfort over 5.

Table 41 Calculation of ambient comfort levels using sensor data (03.06.2022)

1. Thermal Environment

(a) Temperature_03.06.2022 (°C) (Class Time: 10:45-12:50)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	0,11	30,53	30,64	30,59	0,04	0,00	1
10:00-10:30	2,67	27,97	30,64	29,39	0,97	1,10	1
10:30-11:00	**1,56**	**26,41**	**27,97**	**27,00**	**0,55**	**0,35**	**2**
11:00-11:30	**0,14**	**26,27**	**26,41**	**26,34**	**0,05**	**0,00**	**2**
11:30-12:00	**0,33**	**25,94**	**26,27**	**26,08**	**0,10**	**0,01**	**2**
12:00-12:30	**0,20**	**25,96**	**26,16**	**26,05**	**0,06**	**0,00**	**2**
12:30-13:00	**0,15**	**26,11**	**26,26**	**26,17**	**0,04**	**0,00**	**2**

(b) Relative humidity_03.06.2022 (%) (Class Time: 10:45-12:50)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	0,20	36,30	36,50	36,40	0,07	0,01	2
10:00-10:30	5,06	31,34	36,40	34,08	1,79	3,72	2
10:30-11:00	**2,18**	**29,61**	**31,79**	**30,46**	**0,78**	**0,71**	**3**
11:00-11:30	**0,36**	**31,46**	**31,82**	**31,67**	**0,11**	**0,01**	**3**

11:30-12:00	**0,89**	**30,57**	**31,46**	**31,05**	**0,26**	**0,08**	**3**
12:00-12:30	**0,58**	**30,29**	**30,87**	**30,60**	**0,19**	**0,04**	**3**
12:30-13:00	**1,05**	**30,74**	**31,79**	**31,15**	**0,38**	**0,17**	**3**

2. Visual

(a) Luminous intensity _03.06.2022 (lx) (Class Time: 10:45-12:50)

Clock	Openness	Minimum	Maximum	<u>Average</u>	Standard Deviation	Variance	Comfort Score
09:30-10:00	206,82	43,63	250,45	74,35	71,90	6030,58	1
10:00-10:30	94,90	155,55	250,45	190,32	30,79	1105,90	1
10:30-11:00	**5,14**	**157,95**	**163,09**	**160,12**	**1,69**	**3,31**	**1**
11:00-11:30	**8,17**	**149,78**	**157,95**	**155,03**	**2,55**	**7,60**	**1**
11:30-12:00	**9,04**	**147,83**	**156,87**	**152,94**	**2,96**	**10,23**	**1**
12:00-12:30	**12,65**	**140,31**	**152,96**	**147,09**	**4,68**	**25,53**	**1**
12:30-13:00	**7,13**	**141,81**	**148,94**	**145,80**	**2,55**	**7,62**	**1**

3. Air Quality

(a) CO_2_03.06.2022 (ppm) (Lecture Time: 10:45-12:50)

Clock	Openness	Minimum	Maximum	<u>Average</u>	Standard Deviation	Variance	Comfort Score
09:30-10:00	8,00	503,00	511,00	506,14	2,36	6,48	5
10:00-10:30	314,00	414,00	728,00	521,29	97,56	11103,32	5

10:30-11:00	**740,50**	**510,00**	**1250,50**	**924,57**	**267,51**	**83491,54**	**5**
11:00-11:30	**540,50**	**505,00**	**1045,50**	**686,50**	**184,11**	**39545,83**	**5**
11:30-12:00	**882,00**	**617,00**	**1499,00**	**1001,14**	**286,08**	**95479,89**	**4**
12:00-12:30	**205,00**	**1174,50**	**1379,50**	**1245,71**	**60,89**	**4324,99**	**4**
12:30-13:00	**138,50**	**1210,50**	**1349,00**	**1258,64**	**49,60**	**2869,64**	**4**

4.Acoustics

(a) Sound intensity _03.06.2022 (dBA) (Class Time: 10:45-12:50)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	19,04	39,68	58,72	43,21	6,36	47,24	4
10:00-10:30	10,13	49,56	59,69	53,95	3,99	18,61	2
10:30-11:00	**7,94**	**49,56**	**57,50**	**52,61**	**2,78**	**9,03**	**2**
11:00-11:30	**13,43**	**48,95**	**62,38**	**55,80**	**4,54**	**24,10**	**1**
11:30-12:00	**16,36**	**49,44**	**65,80**	**55,58**	**5,25**	**32,11**	**1**
12:00-12:30	**9,76**	**47,37**	**57,13**	**52,09**	**2,87**	**9,58**	**2**
12:30-13:00	**20,27**	**47,37**	**67,63**	**57,34**	**7,35**	**62,97**	**1**

The average comfort scores of the environment at the times of the course are calculated by taking into account the average scores in the time interval of the course as in Table 45 and represent the average comfort scores of the course.

Table 42 Course Average Comfort Scores (03.06.2022)

Clock	Variable	
10:45-12:50	Thermal Environment	2,5
	Visual	1
	Air Quality	4,4
	Acoustic	1,4

In addition, Figure 32 gives the average comfort values for half an hour from 9:30 a.m. to 13:00 p.m. to interpret the comfort levels of the environment before and after the lesson.

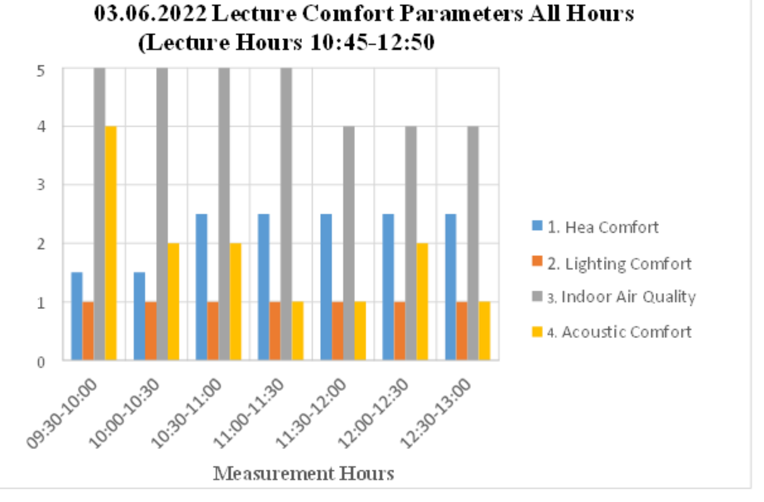

Figure 32 Comfort values during and outside of class hours (between 9:30-13:00) (27.05.2022)

3.8.5.2.6. 10.06.2022 Course Results

Using the IEQ calculation, the calculated comfort scores for 10.06.2022 are shown in *Table 46*. In the calculation, the average ambient parameter value in the examined time interval was considered. The time intervals expressed in bold symbols in the table refer to the hours of the lesson; comfort scores are scored out of 5, as stated in the section where IEQ calculations are defined, defining the performance of ambient comfort out of 5.

Table 43 Calculation of ambient comfort levels using sensor data (10.06.2022)

1. Thermal Environment

(a) Temperature_10.06.2022 (°C) (Class Time: 10:30-12:00)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	0,20	30,19	30,38	30,33	0,06	0,00	1
10:00-10:30	3,26	26,93	30,19	28,30	1,08	1,36	1
10:30-11:00	**0,76**	**26,17**	**26,93**	**26,41**	**0,26**	**0,08**	**2**
11:00-11:30	**0,06**	**26,12**	**26,18**	**26,16**	**0,02**	**0,00**	**2**
11:30-12:00	**0,06**	**26,08**	**26,14**	**26,10**	**0,02**	**0,00**	**2**
12:00-12:30	1,48	26,10	27,58	26,81	0,52	0,32	2
12:30-13:00	1,21	27,58	28,79	28,26	0,40	0,19	1

(b) Relative humidity_10.06.2022 (%) (Class Time: 10:30-12:00)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	0,90	34,29	35,18	34,98	0,29	0,10	3
10:00-10:30	5,04	29,25	34,29	31,14	1,76	3,62	3
10:30-11:00	**5,77**	**29,25**	**35,02**	**31,99**	**2,07**	**4,99**	**3**
11:00-11:30	**2,18**	**35,02**	**37,20**	**36,31**	**0,72**	**0,61**	**3**
11:30-12:00	**0,39**	**37,20**	**37,59**	**37,41**	**0,14**	**0,02**	**3**

12:00-12:30	4,53	37,56	42,09	40,40	1,59	2,96	3
12:30-13:00	2,30	38,77	41,06	39,80	0,77	0,68	3

2. Visual

(a) Luminous intensity _10.06.2022 (lx) (Class Time: 10:30-12:00)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	75,19	21,04	96,22	46,95	30,86	1111,14	1
10:00-10:30	30,10	66,12	96,22	73,10	9,69	109,65	1
10:30-11:00	**19,22**	**70,81**	**90,03**	**76,07**	**6,07**	**42,94**	**1**
11:00-11:30	**19,38**	**62,79**	**82,17**	**72,76**	**6,84**	**54,58**	**1**
11:30-12:00	**13,04**	**62,79**	**75,83**	**68,33**	**5,19**	**31,40**	**1**
12:00-12:30	35,13	30,73	65,86	53,83	13,83	223,06	1
12:30-13:00	5,56	25,17	30,73	27,19	1,74	3,55	1

3. Air Quality

(a) CO2_10.06.2022 (ppm) (Lecture Time: 10:30-12:00)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	178,50	497,00	675,50	559,21	75,08	6576,40	5
10:00-10:30	777,00	405,00	1182,00	738,86	325,82	123852,31	5

10:30-11:00	**228,00**	**1080,50**	**1308,50**	**1225,00**	**71,78**	**6010,42**	**4**
11:00-11:30	**331,00**	**1270,50**	**1601,50**	**1410,64**	**99,96**	**11658,39**	**4**
11:30-12:00	**370,50**	**1475,50**	**1846,00**	**1580,71**	**121,24**	**17149,07**	**3**
12:00-12:30	99,00	1558,00	1657,00	1609,43	29,70	1029,20	3
12:30-13:00	56,00	1526,50	1582,50	1558,07	18,40	395,04	3

4.Acoustics

(a) Sound intensity_10.06.2022 (dBA) (Class Time: 10:30-12:00)

Clock	Openness	Minimum	Maximum	Average	Standard Deviation	Variance	Comfort Score
09:30-10:00	14,77	39,55	54,32	43,51	5,50	35,24	4
10:00-10:30	5,62	48,71	54,32	51,93	1,92	4,30	2
10:30-11:00	**13,67**	**48,83**	**62,50**	**56,27**	**5,21**	**31,70**	**1**
11:00-11:30	**10,75**	**50,54**	**61,28**	**54,74**	**4,06**	**19,25**	**2**
11:30-12:00	**13,55**	**47,73**	**61,28**	**54,06**	**4,30**	**21,57**	**2**
12:00-12:30	18,31	41,26	59,57	49,68	6,39	47,62	3
12:30-13:00	1,95	39,92	41,87	40,74	0,63	0,46	4

The average comfort scores of the environment at the time of the course are calculated by taking into account the average scores in the time interval of the course as in *Table 47* and represent the average comfort scores of the course.

Table 44 Course Average Comfort Scores (03.06.2022)

Clock	Variable	
10:30-12:00	Thermal Environment	2,5
	Visual	1
	Air Quality	3,6666667
	Acoustic	1,6666667

Moreover, Figure 33 also gives the half-hourly average comfort values from 9:30 a.m. to 1:00 p.m. to interpret the comfort levels of the environment before and after the class.

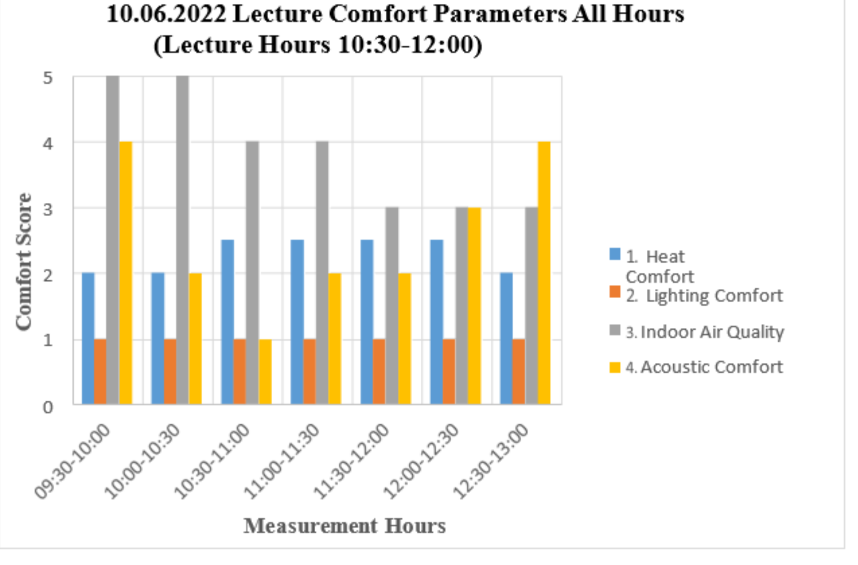

Figure 33 Comfort values during and outside of class hours (between 9:30-13:00) (03.06.2022)

DISCUSSION AND CONCLUSION

The present multidisciplinary endeavor examined the impact of environmental and transactional variables in a technology-enriched smart classroom within the context of higher education. It has been established that a technologically enhanced smart classroom environment constitutes a learning and teaching environment that facilitates transactions between instructor, content, and technology. During the learning-teaching process, instructor competence, interaction, environmental design, and adapting to learner needs are key factors for effective technology integration in a smart classroom. The competence of the instructor is explained by three factors: material design, professional development, and technology competence. The third factor, technology competence, is further explained by classroom management. Interaction was manifested through material contribution, active participation in the lesson, and feedback. The setting is characterized as a combination of two distinct elements: hybridity and preparation. The concept of learner adaptation encompasses both cognitive and affective dimensions. The infrastructure was addressed in the form of suggestions and system features. Recommendations are expressed in the form of effective software environment recommendations and orientation. The system features in question were determined as educational technologies and internal environment variables. Addressing the components of the internal environment, technological infrastructure, and teaching environment of the smart classroom environment will help increase the quality of teaching environments. The authors would like to emphasize the importance of student orientation for effective technology integration in education.

Moreover, extant literature on the subject indicates that this issue is frequently underestimated. The findings of the project further demonstrated that the students exhibited a preference for the blended learning model in a smart class. In this respect, the study can guide future research and help develop smart classroom designs which facilitate the integration of online and face-to-face learning.

Bautista and Borges (2013) posit that the convergence of classroom design, the effective integration of technology, and innovative pedagogical methods is instrumental in the transformation of an environment into a smart classroom. In their 2015 study, Hsu and Ching (2015) identified five distinct components, including pedagogy and the design of the learning environment, system design, technology acceptance, evaluation, and psychological structure. Consistent with the findings of preceding studies, the outcomes of the present project demonstrated favorable effects concerning the technology-enhanced and indoor parameters evaluated in a smart classroom. In consideration of the classroom environment, technology utilization, and pedagogical methodologies, students indicated that the instructional design promoted the progression of the courses, augmented learner interest in the classroom, and exerted a favorable influence on students who were engaged with technology, physical comfort, an interactive environment, and learner satisfaction. The project was regarded as exemplifying an ideal model of a smart classroom, with features that align with the literature on the subject. Consequently, it can be concluded that the present approach to designing an environment conducive to learning is effective.

With respect to the interactions among learners, teachers, and the environment, learners have expressed satisfaction with their teachers' use of interactive tools, as they actively participate in smart classrooms. The students articulated favorable sentiments regarding the utilization of tablets and the capacity to follow the software on both the tablet and the smartboard. This finding lends support to Khemka's (2018) assertion that specialized support software and materials are necessary to enhance teaching environments. As posited by Zhan et al. (2021), educators employ innovative pedagogical approaches within smart classroom environments to enhance students' verbal interaction. The integration of technology into the classroom environment has been shown to enhance students' active engagement and creativity, while concurrently reducing their passive listening and observing behaviors.

The incorporation of comfort into the classroom environment and the provision of a platform for learners to voice their concerns on this matter are noteworthy positive aspects, as perceived by the students. As posited by Al-Hunaiyyan et al. (2017), the integration of mobile tools and learning components is imperative within technology-enriched learning environments. The proposed structure has the potential to be applicable to all teaching processes, ranging from preschool to higher education. The proposed system's content, interaction, and classroom management are critical components. In this study, opinions on these components were collected, and the focal point of the study was determined.

In instances where educators and students lack familiarity with smart technologies, the learning process may be stifled, and a sense of uncertainty may prevail (Liu et al., 2017). However, these phenomena were not observed in the present study. The instructors who participated were consistently familiar with technology and had ready access to technical support and assistance for students. Concomitantly, the findings of Zha et al. (2021) are corroborated, indicating that the implementation of smart classroom environments is conducive to the facilitation of effective classroom management, the conservation of time, the enhancement of activity quality, and the promotion of interaction.

The findings concerning the negative perceptions of the smart classroom are predominantly associated with the physical environment. The study identified several areas of concern, including brightness, ventilation, and temperature. Concerning the software developed in the aforementioned project, minor issues have been reported. These issues include difficulties with taking notes and neglecting to verify the presentations. The smart classroom ontology proposed by Nagowah et al. (2019) is physically manifested in this study. While the design elements are given due consideration, the maintenance of student records (i.e., note-taking) is identified as a feature that necessitates enhancement, as indicated in the recommendations.

It is recommended for future studies to design a smart classroom with indoor parameters, considering that the software of the smart classroom system can be developed in line with the aforementioned suggestions. Consequently, university students in a smart classroom environment report a heightened sense of comfort and a stronger inclination to engage as active learners in a technology-enhanced learning environment, resulting in enhanced learning efficacy.

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APPENDICES

APPENDIX 1 COURSE EVALUATION QUESTIONNAIRE

PLEASE TAKE THE TIME TO READ THIS DOCUMENT CAREFULLY

We invite you to the research conducted by Instructional Technologies Research Group titled "The Effect of Technology Enriched Classroom Model on Learning Processes: The Smart Classroom" conducted by the Instructional Technology Research Group. Before deciding whether to participate in this research, you need to know why and how the research will be conducted. Therefore, it is very important to read and understand this form. If there are things that are not clear to you, or if you would like more information, please ask us.

Participation in this study **is** completely **voluntary**. You have the right **not to participate in** the study or to **withdraw from** the study at any time after participation. **Answering the questionnaire** will be interpreted as **your consent to participate in the study**. Do not be under any pressure or suggestion from anyone while answering the questions **on the forms** given to you. Personal information obtained from these forms will be kept completely confidential and will only be used for research purposes.

The purpose of this data collection tool is to get your opinions about the technology-enriched classroom environment. In this context, we kindly ask you to sincerely answer the following questions about the technology-enriched classroom environment you have experienced.

On behalf of our research group, we would like to thank you for your support.

I agree to participate in the study ☐

Your Name and Surname

Your Age

Your Gender

Questions

1. Evaluate the course process in general.

   1 (Very Bad) ☐ 2 (Bad) ☐ 3 (Medium) ☐ 4 (Good) ☐ 5 (Very Good) ☐

2. Evaluate the lesson process from a technical point of view.

   1 (Very Bad) ☐ 2 (Bad) ☐ 3 (Medium) ☐ 4 (Good) ☐ 5 (Very Good) ☐

3. Evaluate the lesson in terms of teaching process.

   1 (Very Bad) ☐ 2 (Bad) ☐ 3 (Medium) ☐ 4 (Good) ☐ 5 (Very Good) ☐

4. Evaluate the course in terms of digital materials.

   1 (Very Bad) ☐ 2 (Bad) ☐ 3 (Medium) ☐ 4 (Good) ☐ 5 (Very Good) ☐

5. Evaluate the course in terms of instructor behaviours.

   1 (Very Bad) ☐ 2 (Bad) ☐ 3 (Medium) ☐ 4 (Good) ☐ 5 (Very Good) ☐

6. Did you have any technical problems/issues during the course? Explain if there are any.
7. What are your opinions about the digital materials used in the course?
8. What are your opinions about the lecturer's behaviours during the course?
9. What are your general opinions about the lesson process?
10. Would you like to take a course with this method again?
11. If you have any comments, you can write them below.

APPENDIX 2 STUDENT OPINION SURVEY

We invite you to the research conducted by Instructional Technologies Research Group titled "The Effect of Technology Enriched Classroom Model on Learning Processes: The Smart Classroom" conducted by the Instructional Technology Research Group. Before deciding whether to participate in this research, you need to know why and how the research will be conducted. Therefore, it is very important to read and understand this form. If there are things that are not clear to you, or if you would like more information, please ask us.

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The purpose of this data collection tool is to get your opinions about the technology-enriched classroom environment. In this context, we kindly ask you to sincerely answer the following questions about the technology-enriched classroom environment you have experienced.

On behalf of our research group, we would like to thank you for your support.

1. Your Name – Surname
2. Your Age
3. Your Gender
4. What are your views on teaching in a technology-enriched classroom environment?
5. What are the specialities that you find glourious?
6. What are the specialities that you find unsatisfactory?
7. Your feelings on this matter?
8. Can you describe the contributions of teaching in a technology enriched-classroom environment?
9. What are the positive contributions?

10. What are the negative consequences?
11. Evaluate the teaching materials used in the technology-enriched-classroom environment?
12. Evaluate the contribution of the materials to your content knowledge?
13. Evaluate the contribution of the materials to your learning process?
14. Explain your feelings towards the materials?
15. If any, what are the positive contributions of this experience?
16. If any, what are the negative consequences of this experience?
17. If you have a chance, how do you design the classroom environment?

Section 2

18. What do you think about the materials used by your teacher during the course?
19. How did the materials you used in lesson contribute to your learning process?
20. What is the most difficult part of using the materials in class?
21. What do you think about designing other lessons like the materials you use in the smart classroom?

Section 3

22. Your gender

    Female ☐Male ☐
23. Your Age

    18-24 ☐ 25-34 ☐ 35-44 ☐ 45-54 ☐ 55-64 ☐ 65+ ☐
24. Your birthdate location? (city)
25. Your grow- up location (city)
26. Where are you living (city)
27. What is your monthly expense? (TL)

    Under 2000 ☐ 2000- 2500 ☐ 2500- 3000 ☐ 3000- 3500 ☐

    3500- 4000 ☐ 4000-5000 ☐ Over 5000 ☐
28. Do you smoke?

    Yes ☐ No (I used to smoke) ☐ Never ☐

29. How often do you exercise? (gym, cycling, walking, swimming, etc.)

I do not ☐ Once a week ☐ Twice a week ☐

Three times a week ☐ More than three times a week ☐

30. What are your illnesses in the last year?

Asthma ☐	Bronchitis ☐	Chest wheezing ☐
Other chest diseases ☐	Hay fever ☐	Allergic disorders ☐
Eczema ☐	Skin inflammation ☐	Other skin diseases ☐
High cholesterol ☐	Diabetes ☐	High blood pressure ☐
Heart-related disorders ☐	Migraine ☐	Depression ☐
Anxiety (anxiety disorder) ☐	Psychiatric problems ☐	Other problems ☐

31. How important is it .... in your classroom so that you feel comfortable? (1: not important, 4: very important)

	1	2	3	4
To have the right temperature	☐	☐	☐	☐
To have good lighting	☐	☐	☐	☐
To have no noises like ventilation or traffic	☐	☐	☐	☐
to have fresh air	☐	☐	☐	☐
to have functional classroom	☐	☐	☐	☐

32. To what extent do you think your class meets your needs in the following areas? (1: very little, 4: very much)

	1	2	3	4
indoor air temperature	☐	☐	☐	☐
air quality	☐	☐	☐	☐
daylight	☐	☐	☐	☐
noise	☐	☐	☐	☐
temperature control capabilities	☐	☐	☐	☐

33. Describe your location in the classroom?

Away from the window (more than 2 meters from the window) ☐

Center of the room/classroom ☐

Next to the window (within 2 meters) ☐

34. Are you close to a heating/cooling system? (within 2m)

Yes ☐ No ☐

35. What are the uncomfortable experiences you have while in the classroom? (At least once every 2-3 weeks)

Dry eyes ☐ Itchy or watery eyes ☐ Nasal congestion ☐

Runny nose ☐ Sneeze ☐ Dry throat ☐

Numbness ☐ Headache ☐ Dry, itchy, irritated skin ☐

Breathing difficulty ☐ Other Symptoms ☐

36. How would you evaluate your current internal environment?

Cold ☐ Cool ☐ Little cool ☐ İdeal ☐ Little warm ☐ Warm ☐ Hot ☐

37. How satisfied are you with the indoor temperature?

I am not happy at all ☐ I am not satisfied ☐ I'm a little dissatisfied ☐

I can't decide ☐ I'm a little happy ☐ I'm pleased ☐

I am very pleased ☐

38. What would you prefer the indoor temperature to be?

Very cold ☐ Cold ☐ Little cold No change needed ☐

Little hot ☐ Hot ☐ Very hot ☐

39. How satisfied are you with your indoor air quality?

I am not happy at all ☐ I am not satisfied ☐ I'm a little dissatisfied ☐

I can't decide ☐ I'm a little happy ☐ I'm pleased ☐

I am very pleased ☐

40. What would you prefer indoor air quality to be?

Less suffocating ☐ More fresh air ☐ No change needed ☐

Different or less odor ☐

41. How would you evaluate the illumination level of your environment?

Very dim ☐ Loess ☐ Little dim Normal ☐

Little bright ☐ Shiny ☐ Very bright ☐

42. How satisfied are you with the visual comfort level?

I am not happy at all ☐ I am not satisfied ☐ I'm a little dissatisfied ☐

I can't decide ☐ I'm a little happy ☐ I'm pleased ☐

I am very pleased ☐

APPENDIX 3 ACADEMICIAN INTERVIEW FORM

PLEASE TAKE THE TIME TO READ THIS DOCUMENT CAREFULLY

We invite you to the research conducted by Instructional Technologies Research Group titled "The Effect of Technology Enriched Classroom Model on Learning Processes: The Smart Classroom" conducted by the Instructional Technology Research Group. Before deciding whether to participate in this research, you need to know why and how the research will be conducted. Therefore, it is very important to read and understand this form. If there are things that are not clear to you, or if you would like more information, please ask us.

Participation in this study **is** completely **voluntary**. You have the right **not to participate in** the study or to **withdraw from** the study at any time after participation. **Answering the questionnaire** will be interpreted as **your consent to participate in the study**. Do not be under any pressure or suggestion from anyone while answering the questions **on the forms** given to you. Personal information obtained from these forms will be kept completely confidential and will only be used for research purposes.

The purpose of this data collection tool is to get your opinions about the technology-enriched classroom environment. In this context, we kindly ask you to sincerely answer the following questions about the technology-enriched classroom environment you have experienced.

On behalf of our research group, we would like to thank you for your support.

I agree to participate in the study ☐

1. Your Name and Surname Your Age
2. Your Gender

Questions (Smart Classroom Environment)

1. What are your views on teaching in a technology-enriched classroom environment?
   a) What are positive features?

b) What are negative features?

c) Please express your feelings about it?

2. Can you explain the contributions of teaching in a technology-enriched classroom environment?

   a) What are the positive contributions/advantages?

   b) What are the negative effects/disadvantages?

3. Evaluate the teaching materials used in the technology-enriched classroom environment?

   a) Evaluate the contribution of the materials to the content knowledge?

   b) Evaluate the contribution of the material to your learning?

   c) Describe your feelings towards the material?

4. Did this experience cause you any positive advantages? What were they?
5. Did this experience cause you any disadvantages? What were they?
6. How do you design the classroom environment, if you had such an opportunity?
7. How did the smart classroom environment contribute to your teaching experience?
8. Would you recommend teaching in this environment to your colleagues? Why?

Questions (Digital materials)

1. What do you think about the materials you use during the lesson?
2. What kind of support did you need while preparing the materials that you used in the lesson?
3. What was the most difficult part of preparing the course materials?
4. Would you be a volunteer again to prepare course material to be used in this environment? Why?
5. Would you recommend teaching in this environment to your colleagues? Why?

Questions (Classroom Management)

1. What do you think about managing the smart classroom during the lesson process?

2. If you compare the traditional classroom environment with the smart classroom environment, how do you think there are differences in terms of classroom management?
3. Which skills do you think are important for managing a smart classroom? Why?
4. If you were asked to describe your smart classroom management process experience in 5 words, which words would you prefer?
5. Please write if you have anything to add about smart classroom management.

APPENDIX 4 COURSE OBSERVATION FORM

Before starting the observation, the seating arrangement of the students should be coded. For example, if it is the third week, the first student can be coded as H3Ö1 (week 3, student 1). For example; 11.15 H3Ö1

Course Observation Form

Status	Observed (2 points)		Partially observed (1 point)		Not observed (0 points)	
Activism in the course teaching process	Clock	Person	Clock	Person	Clock	Person
Answering the questions.						
Asking questions about the subject						
Suggesting a solution						
Giving examples						
Taking notes						
Following the lesson on the tablet						
Research from other sources						
Effective communication						
Listening carefully to the instructor						
Listening carefully to the friends						
Taking responsibility in group work						
Fulfilling his/her duties in group work.						
Encouraging the friends						
Motivation						
Making observation in the lesson						

Making an effort to understand the lesson						
Paying attention to the lesson						
Being enthusiastic in the lesson						
Worry about lesson						
think that it is hard						
Inability to concentrate/distraction of attention						
Fatigue						
Interest and Attitude						
Bored						
Watcing around						
Dealing with phone						
Chatting with a friend except the lesson subject						
Sleeping/napping during lesson						
Fatigue in class						
Stress/anger in class						
Patience in the lesson						

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