PEOPLE: International Journal of Social Sciences
ISSN 2454-5899

Radosavljevic et al., 2019

Volume 5 Issue 2, pp. 680-699

Date of Publication: 26th September 2019

DOI- https://dx.doi.org/10.20319/pijss.2019.52.680699

This paper can be cited as: Radosavljevic, V., Radosavljevic, S., & Jelic, G., (2019). Smart Classroom Environmental Parameters as a Parameter of Adaptive Learning. PEOPLE: International Journal of Social Sciences, 5(2), 680-699

SMART CLASSROOM ENVIRONMENTAL PARAMETERS AS A PARAMETER OF ADAPTIVE LEARNING

Vitomir Radosavljevic
ICT College of vocational studies, Belgrade, Serbia
vitomir.radosavljevic@ict.edu.rs

Slavica Radosavljevic
ICT College of vocational studies, Belgrade, Serbia
slavica.radosavljevic@ict.edu.rs

Gordana Jelic
ICT College of vocational studies, Belgrade, Serbia
gordana.jelic@ict.edu.rs

Abstract

This paper presents results of the research aimed at establishing the possibility of using a physical environmental parameter (λ) as one of the parameters of adaptive learning in smart classrooms. In this research, the parameter quantifying physical environmental parameters of a smart classroom into a single value was introduced and the relevance of the usage of the introduced parameter as a criterion of adaptive learning in a smart classroom was evaluated. The presentation of multiple environmental parameters through one unique parameter facilitated the realization of adaptation process, especially in the case of applying several adaptation criteria. An overall of 64 third-year students of the ICT College in Belgrade participated in the research. The implemented research drew certain conclusions. The relevance of using the parameter (λ) as the criterion of adaptive learning in smart classrooms was confirmed.

Keywords
Smart Classroom, Adaptive Computer Learning, Learning Environment, Dynamic Environmental Parameter

1. Introduction

Smart classrooms represent a field of study of technology-supported learning environments. They use technology to facilitate processes of learning and teaching for students and teachers, respectively, as well as to enable the transfer of knowledge in both effective and efficient ways (Zhu, Yu & Riezebos, 2016). Smart classrooms should enable presentation of various instructional materials and provide necessary requirements for personalized learning, group learning, mobile and virtual learning and also support adaptive learning, student-based learning and all other activities related to learning (Li, Kong & Chen, 2015) (Pace, 2017). Smart educational environments are suitable for the implementation of adaptive forms of education (Brusilovsky & Peylo, 2003).

The research presented in this paper aims at establishing the possibility of introducing a physical environmental parameter as one of relevant parameters of adaptive learning in smart classrooms. The facility of a smart classroom to continuously monitor a large number of physical environmental parameters is used to set a unique parameter that describes the state of working environment in a smart classroom.

Two main contributions are outlined in this paper.

- Firstly, the parameter (Dynamic environmental parameter) quantifying physical environmental parameters of a smart classroom into a single value is introduced.
- Secondly, the relevance of the usage of the introduced parameter as a criterion of adaptive learning in a smart classroom is evaluated.

2. Literature Review

The classroom is a key environment for performing activities of formal education. Learning environment can be interpreted through

- psychological context,
- through the roles teachers and students take,
- the aims set in front of teachers and students,
- methods and materials used in the teaching/learning process.

Implementation of new technologies into the learning environment affects each of the abovementioned factors. Smart classrooms are an example of technology-supported learning environments (TSLEs). Technology-supported learning environments are instructional systems applying technology which helps students in the learning process and provides additional support to teachers and students in the learning process (Wang & Hannafin, 2005). Technology-supported learning environments can help students to acquire skills and knowledge in a more efficient way compared to conventional environment (Mayer, n.d.). New technologies in a learning environment have positive influence on knowledge quality, skills acquisition and students' attitude towards learning (Wu, Lee, Chang, & Liang, 2013).

Technology-supported learning environment also includes the monitoring of physical parameters of learning environment. The physical parameters of the classroom can affect the behaviours of both students and teachers and can improve students' academic outcomes (Yang & Huang, 2015). Sensor networks monitoring physical parameters of learning environments are seen as a form of IoT (Internet of Things) networks in smart classrooms. Sensors evaluating physical parameters should be connected to the centralized system which can act both manually and automatically on the calculated parameter's values. Learning space which can affect the parameters of students' learning environment is known in literature as Personal Leaning Environment (PLE). The majority of researches has considered temperature, noise, lighting and air quality, as parameters for the evaluation of learning environment quality (Vilčeková, Kapalo, Mečiarová, Burdová & Imreczeová, 2017) (Mihai & Iordache, 2016) (Al-Hemoud et al., 2017) (Sala & Rantala, 2016) (Peng, Zhang & Wang, 2017) (Mekacher, 2019).

The researches evaluating the correlation of working environment temperature and students' working performance have come to certain conclusions. The optimal temperature values of the working environments are between 20°C and 24°C. In some researches, subjective evaluation of thermal comfort has been used for the description of desired temperature features of working environment (Zaki, Damiati, Rijal, Hagishima & Abd Razak, 2017) (Kim & de Dear, 2018) (Singh et al., 2018). Thermal comfort has been described as the state in which a person is dressed comfortably, feeling neither cold nor warm, and in which air temperature, humidity and wind speed are within certain range described as 'comfort zone' (Fabbri, 2015). However, some authors have correlated air temperature with the parameter of air humidity. Consequently, a humidex parameter has been introduced based on the values of these two physical categories. It describes working environment from both temperature and humidity aspects (Uzelac, Gligorić & Krčo, 2018).

Air quality refers to the existence of certain gases or chemical compounds, the quantity of carbon-dioxide in the air, as well as the frequency of room ventilation. Research has shown that inadequate ventilation and high concentration of carbon-dioxide in the classroom decrease students' attention, their learning performances, as well as the speed of data processing and the realization of assignments ("Carbon monoxide, industry and performance", 1975) (Coley, Greeves & Saxby, 2007). In addition, some research has been conducted to investigate the impact of volatile organic compounds on students' performance during a learning process and concluded that high quantity of volatility had negative influence on students' concentration, while low quantities had no impact, altogether (Otto, Hudnell, House, Mølhave & Counts, 1992).

Lighting has influence on students' physical and mental states (Wurtman, 1975). Research has pointed out that learning in a well lit room correlated with the acquisition of good learning outcomes. Students learning in a well-lit classroom show better results compared to students learning in an insufficiently lit classroom. Furthermore, a special attention has been paid to the effects of daily light which produces biological effects on human body. Classrooms without daily light may cause the misbalance of hormone cortisol, which stimulates concentration (Ricciardi & Buratti, 2018) (Küller & Lindsten, 1992) (Wurtman, 1975) (Walberg, 1982).

Noise affects students' performance. Students' learning abilities decrease due to noise. (Crook & Langdon, 1974) (Green, Pasternack & Shore, 1982) (Grossberg, 1999). Loud noise brings about frequent disruption of a learning process, thus reducing time efficiency of learning. Noise also decreases students' concentration. In an environment with background noise, students experience difficulties in following lectures and have to put extra effort to learn instructional material. In this way, students are being additionally burdened both physically and mentally, which causes fatigue. The noise made by two people talking in a classroom disturbs students more than any ambient noise (Gómez, Huete, Hoyos, Perez, & Grigori, 2013).

The analysed research papers have arrived at a number of conclusions pertaining to the influence of physical environmental parameters on the learning performance. (Egong, 2014).

2.1 Adaptive Learning

Adaptive learning is defined as a dynamic learning process allowing students to opt for a learning style in pursuit of successful academic outcomes (Beldagli & Adiguzel, 2010). Adaptive learning system is personalized according to the learning goals, student's personality and his/her prior knowledge. Adaptive learning programs give better results compared to classic non-adaptive learning programs (Mihalca, Salden, Corbalan, Paas & Miclea, 2011).

Adaptive approach is realized through the adaptation of certain elements of educational process with pre-defined criteria. The set criteria are the result of student's individual characteristics, motivation level, fatigue, working environment, learning material (Brusilovsky & Peylo, 2003). The often-used criteria in the research of adaptive learning environments are individual criteria such as:

- students' prior knowledge (Dwic & Basuki, 2012) (Sancho, Martinez, & Fernandez-Manjon, 2005) (Klašnja-Milićević, Vesin, Ivanović, & Budimac, 2011), students' learning styles (Hamada, 2012) (Kim, Lee & Ryu, 2013) (Klašnja-Milićević, Vesin, Ivanović, & Budimac, 2011),
- students' preferred multimedia for learning (Chorfi & Mohamed, 2004) (Bouzeghoub, Carpentie, Defude, & Duitama, 2003),
- students' physical and cognitive characteristics (Yang, Hwang, & Yang, 2013).

The goal of adaptive learning is the maximum adjustment of e-learning environment to a student's learning style, which will help him/her to achieve best results (Despotović-Zrakić et al., 2012) (Khenissi et al., 2016).

3. Adaptive Learning in Smart Classrooms

Adaptive learning environment should be so designed to recognize information of interest and adapt a learning process to students' needs according to the appropriate criteria (Brahim, Jemaa, Jemni & Laabidi, 2013) (Mamat & Yusof, 2013). Adaptive learning aims to positively influence the state of students' motivation and the reduction of cognitive load during learning (Sevindik, 2010). In the process of learning adaptation multiple adaptation criteria are combined for this purpose. The smart educational environment has the possibility, in addition to the individual adaptation parameters, to consider physical parameters of the environment and to introduce them into the process of learning adaptation. What physical parameters of the environment should be taken into consideration in the realization of adaptive learning in a smart classroom determines the model of adaptation applied in a smart educational environment. The authors of this paper claim that all physical parameters in an environment that can be measured should be considered and combined into a unique parameter that would describe the physical characteristics of a workload in a smart classroom. The way individual environmental factors will participate in defining the value of this parameter depends on the number and type of physical parameters being monitored. The value that would be added to the parameter described should numerically determine the state of the physical environment of a smart classroom.

The proposal of the architecture of the system for adaptive learning in a smart classroom consists (Figure 1) of 5 parts:

- Core of smart educational system
- Smart classroom environment
- Adaptive learning process management
- Interaction with other systems outside smart classrooms
- Database

The core of the smart educational system is the part of the system which controls the adaptation of instruction, manages multimedia contents used as learning materials, mediates in communication between a student and a teacher, as well as between a smart system and other (outer) systems. Smart classroom environment is the part which manages smart classroom devices. Adaptive learning process management includes the control function as well as the function of monitoring and controlling of the adaptation process. The part which manages interaction with other systems should enable integration of a smart classroom with other, external systems such as LMS platforms (e.g. Moodle, Canvas, Edmodo etc.), cloud systems and other types of smart educational environments. Database in a smart educational system is a central point for storage of all relevant educational data.

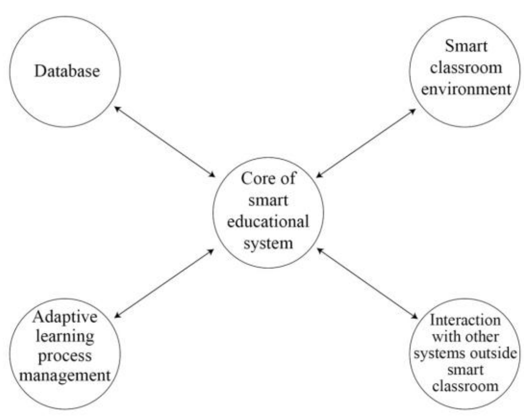

Figure 1: *Architecture of a Smart Educational System*

3.1 Dynamic Environmental Parameter

In order to describe the influence of working environment on the learning process in a smart classroom, a new parameter is introduced named Dynamic environmental parameter (λ). Dynamic environmental parameter (λ) is defined by a numerical value that describes the conditions of physical working environment. Basically, this parameter shows environmental factors in a collective manner, such as noise, temperature values, amount of carbon-dioxide in the air, humidity and air pressure. This list can also include physical characteristics of a student, such as blood pressure, heart beat rate, EEG signal and the size of pupil. The described parameters are obtained by analysing sensor network data in a smart classroom. The obtained values are sent to the core of a smart educational system which calculates the value of the dynamic environmental parameter according to the appropriate model. The model for accurate calculation of the parameter λ should be developed in accordance with the possibilities provided by the smart educational environment for monitoring both physical parameters of the environment and individual physical parameters of the students. Depending on the parameters that can be monitored in the smart classroom and the influence they have on the learning process, the model for the calculation of the parameter be developed. Numerical value in range 0-1 is given to the Dynamic environmental parameter. Due to the resulting values, it is possible to define the working conditions in a smart classroom.

Minimum value, λ=0, is used to describe smart classroom environment which is highly favourable for learning and work. Favourable learning environment is defined by: optimal physical characteristics of learning environment. Working environment with air temperature from 20℃ to 24℃, air humidity from 40% to 60%, normal air pressure, well-lit learning space and no noise is described as favorable working condition (Zaki et al., 2017) student's state of mind when he/she is not being exposed to stress factors (such as the time limit for learning and work).

Maximum value of Dynamic environmental parameter (λ=1) describes smart classroom environment as highly unfavourable for learning and work. This value refers to bad physical conditions for learning and work (badly-ventilated room, inadequate air temperature, poor lighting, high air humidity, inadequate air pressure, stressful working environment.

The dynamic nature of Dynamic environmental parameter is reflected in its variability and is a function of time. Although Dynamic environmental parameter represents the parameter which smart classroom system calculates according to the pre-defined criteria, smart classroom system should have the option of manual value input. Teacher should be provided with the opportunity to control and manually define the value of parameter λ.

4. Research

The research intended to explore the impact of different physical parameters of the environment on a learning process in a smart classroom. The aim of such a research is to determine the relevance of introducing a parameter that will unify the physical environmental factors for modeling adaptive learning in smart classrooms.

4.1 Research Plan

As part of the research, the experiment was performed at the ICT College of Vocational Studies in Belgrade (Serbia) in April 2018. The experiment was carried out within the course of Digital telecommunications. An overall of 64 third-year students of the study programme of Telecommunications participated in the experiment. Students had the task to master the instructional material through the Moodle LMS learning platform, complete the assessment test, and fill in the questionnaires for a period of 60 minutes. After the experiment was conducted, the obtained results were considered.

The experiment was set up in a classroom where physical environmental parameters could be controlled. The classroom is located in the basement of the building, has no windows or natural light, and is isolated from street noise. The smart classroom used for performing the experiment was not equipped with integrated sensor network which could continually monitor physical parameters. Instead, the adequate mobile applications, instruments and calculations were used. The analysed physical parameters were air temperature, lighting, air ventilation and noise.

Students were divided into two experimental groups and two control groups, each group consisting of 16 students (in total 64 students). The students were grouped by their index numbers (a unique identification number each student is given upon admission to school).

At the beginning of the experiment, students were seated at their work stations. Each student had his own work station containing a computer with the Internet access. Student logged onto the Moodle e-learning platform which contained the instructional material he/she had to acquire. Before the student began to study, he/she did an entrance test of pre-knowledge. The pre-knowledge test was used to examine the insignificant statistical deviation between experimental and control group. The instructional material was presented in the form of multimedia contents containing text, images, animation, hyperlinks and video. Students from both groups (experimental and control) learned from the same instructional material. The instructional material referred to the field of digital signal processing. Students were given 40 minutes for the acquisition of instructional material. Upon completion of learning, students were given 15 minutes to do the assessment test aimed at checking the acquired knowledge, and another 15 minutes to do the questionnaire in order to examine their subjective evaluation physical environmental parameters. During the experiment, all physical parameters of the environment set for the control groups were kept at optimal values, unlike the inappropriate values set for the experimental groups.

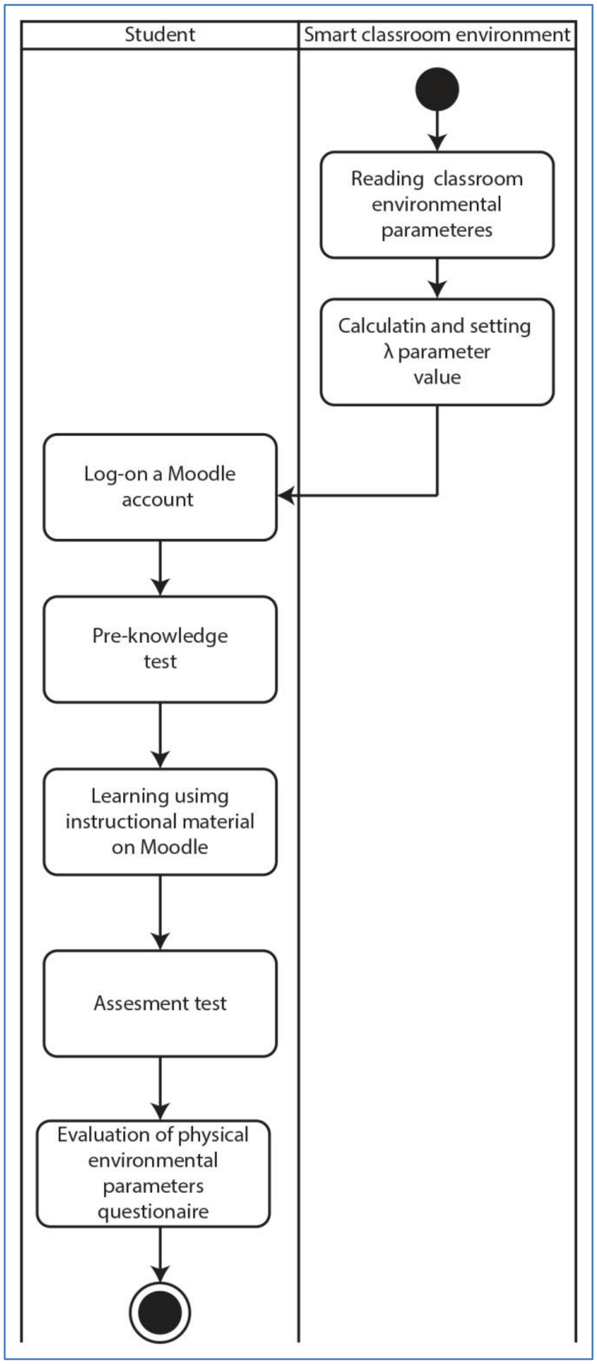

Figure 2: *Research Flowchart*

4.2 Instruments

The assessment test was done electronically via the Moodle LMS platform and was graded in 0-10 range.

The questionnaire examining the subjective experience of physical parameters of the environment consisted of statements that were evaluated on the 7-step Likert scale. Students could also express their views on the impact of the physical environment on the learning process in the questionnaire.

The temperature of the working environment was measured using a digital thermometer, quality of lighting was described on the basis of the calculation, the ventilation was controlled by the ventilation system, and the noise was measured by the appropriate application. For the purpose of the experiment, each of the physical parameters of the environment was assigned to one of the two values, either "optimal value" or "non-optimal value", depending on the measured value or corresponding value calculation.

Measured temperature values that were in the range from 20℃ to 24℃ were described as “optimal value”. Other temperature values were described as "non-optimal value".

The source of light in the classroom comprised 11 panels, each containing 4 neon tubes (L18W/765, 6500K, 1050lm) (Figure 3). According to data from RSTenergy blog, specialized for lighting calculation (Ecoenergy, 2017), the amount of artificially generated lighting which is necessary for proper lighting of a classroom is 250-550 lux (1 lux = 1lumen/m2). Since the dimensions of the classroom are 5m x 8m x 2.3m (W x L x H), it was calculated that from 23 000 lm to 50 600 lm is required for proper lighting. The total of 11 panels with 4 neon tubes, each generating 1050 lm, summed up to 46 200 lm, which confirmed the proper lighting of the classroom. The lighting with all 11 panels turned on was described as "optimal value", as opposed to "non-optimal value" assigned to lighting produced by 5 panels.

Classroom has no windows and thus two ventilation systems are used for ventilation, namely, two Stylvent HV-230RC ventilation systems capable of entering 330m3/h of fresh air into the room. In case of both ventilation systems working, the total flow of air sums up to 660 m^3/h. The volume of classroom is 92m^3 and it is optimized for 16 students and a teacher.

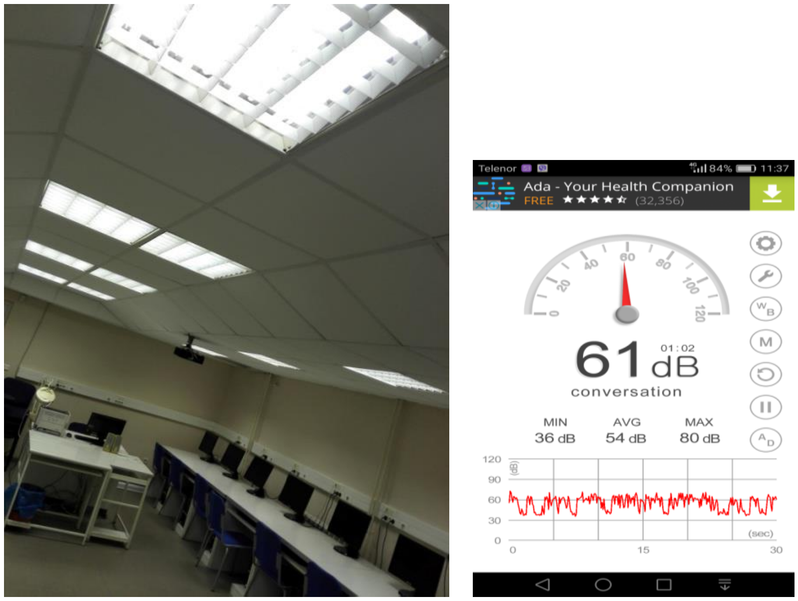

Figure 3: *Lighting of the Classroom & Sound Meter Application used to Measure Sound Level*

According to the implemented parameters, the air flow of 640m^3 per hour is considered as sufficient quantity of fresh air in the classroom (Hydroponics, 2017). When the ventilation system was switched on, the value of the air ventilation parameter was set to "optimal value". However, when the ventilation system was switched off the value of the air ventilation parameter was set to "non-optimal value".

Sound levels obtained through the Sound Meter (Play.google.com, 2018) application that were less than 50dB described the noise parameter as “optimal value”, while the values greater than 50dB were described as “non-optimal value”.

Based on the obtained values of the parameters monitored, the values of the dynamic environmental parameter (λ) were defined. Parameter (λ) was discretized to two extreme values. When all the parameters that were monitored in the experiment were assigned "optimal value" the parameter got value $\lambda = 0$. The maximum value $\lambda = 1$ was assigned in case all environmental parameters were described as "non-optimal value". The medians of the parameter λ were not considered in this paper and require additional experiments.

5. Results

Students were given a pre-knowledge test and an assessment test within the research. A pre-knowledge test was used to determine whether students of control and experimental groups have approximately the same pre-knowledge level at the beginning of the learning process. An assessment test was conducted at the end of the learning process in order to determine whether the dynamic environmental parameter (λ) had an impact on their learning outcome. Test results of control and experimental groups were compared.

The maximum number of points students could achieve on the pre-knowledge test was 10. The results of the pre-knowledge assessment test are presented in Figure 4. The results indicate that the students of both groups had approximately the same level of pre-knowledge before the start of the learning process.

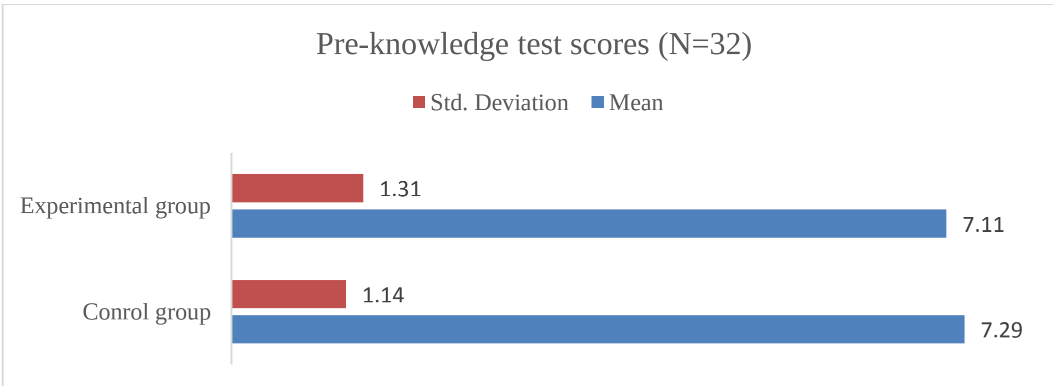

Figure 4: *Pre-Knowledge Test Scores*

The maximum number of points students could achieve on the assessment test was 10. The assessment test included questions from materials that students learned during the experiment. The results of the pre-knowledge assessment test are presented in Figure 5. The results of t-test showed the same significance value of .002 in both assessment tests ($p<0.05$), which rejected zero hypothesis. Mean values of assessment tests were thus confirmed to be statistically different.

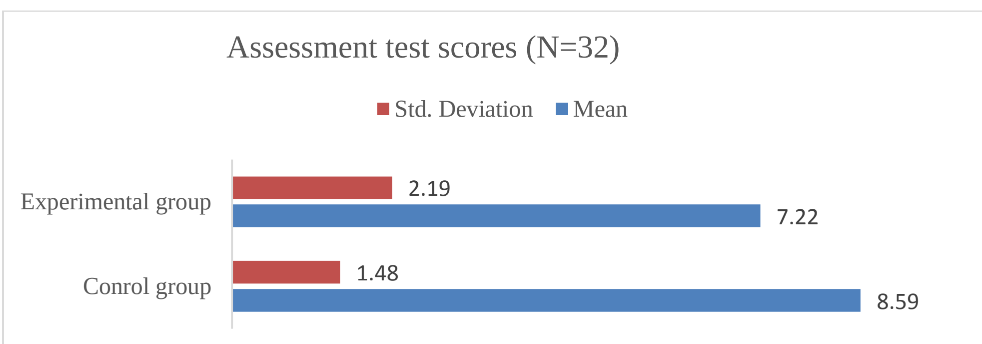

Figure 5: *Assessment Test Scores*

5.1 Physical Environmental Parameters

The evaluation of physical parameters of the system in the experiment was realized by objective measurements of parameters as well as by students' completion of the questionnaire examining their subjective experience of changes in environmental parameters. The objective measurement scores are given in Table 1.

Table 1: *Objective Measurements of Physical Environmental Parameters*

Time and class			Parameter		
	Temperature [˚C]	Noise [dB]	Ventilation system	Mean value of student's work station lighting(lux)	Total amount of lighting
1st control group (N=16)	23	45	On	77	11x4x1050lm=46200lm
2nd control group (N=16)	23	45	On	77	11x4x1050lm=46200lm
1st experimental group (N=16)	25	60	Off	29	5x4x1050lm=21000lm
2nd experimental group (N=16)	26	60	Off	29	5x4x1050lm=21000lm

The questionnaire contained items, referring to subjective experience of air temperature, ventilation, lighting and noise level of classroom working environment. In a 7-degree Likert scale, students evaluated the given items in the range from 1 (strongly disagree) to 7 (strongly agree). The value of Cronbach's alpha coefficient in the questionnaire is α=0.91. The results are presented in Figure 6.

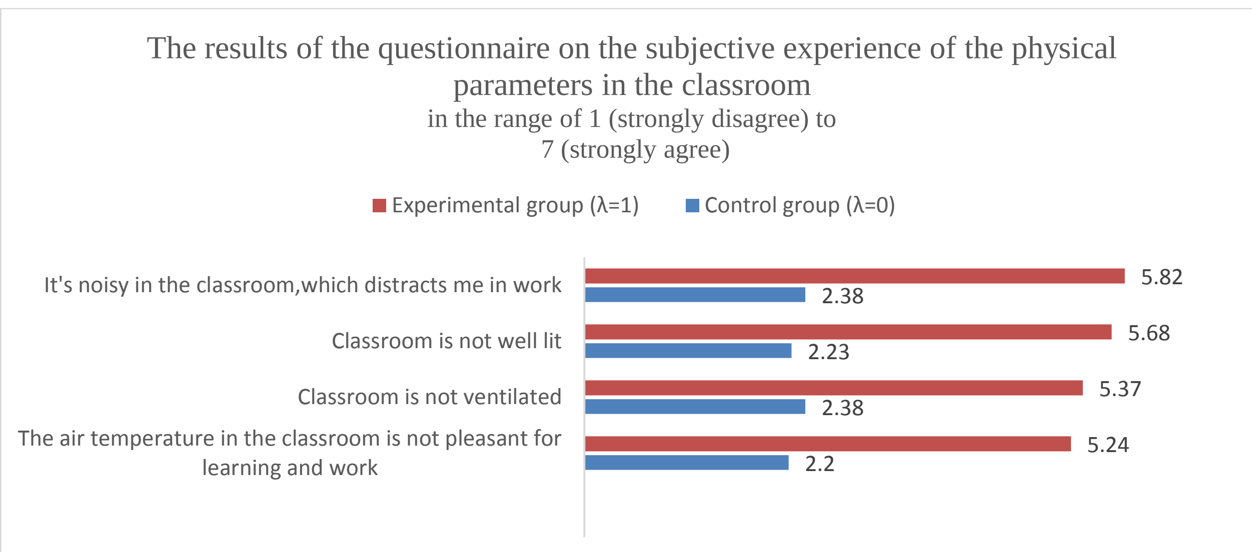

Figure 6: *A Part of the Results of the Questionnaire on the Subjective Experience of the Physical Parameters in the Classroom*

Based on the Figure 6, it is noticeable that students of the experimental groups detected the non-optimal values of the physical environmental parameters.

In the part of the questionnaire left for additional comments, students of the experimental groups commented in significant numbers on the negative impact of the physical environment on the learning process. The students did not comment on individual physical parameters, but gave their general impressions of the working environment. The comments mostly pointed to the need for additional mental engagement of a student to master the material due to disturbing environmental factors.

6. Discussion

The implemented research aimed at establishing the possibility of using the Dynamic environmental parameter (λ) as the parameter of adaptive learning in smart classrooms. The results of the research, presented in this paper, have drawn certain conclusions.

The first conclusion refers to students' assessment test results. Students learning in the control groups achieved better results in the assessment test compared to students in experimental groups. In the 10-degree knowledge scale students achieved a full grade better results when learning in favourable working environment. Better assessment test results are due to better attention and less stress in the learning process. The difference in the success of acquired knowledge can be explained through the cognitive load theory (Sweller, 1988) (Sweller, van Merrienboer & Paas, 1998). Physical environmental factors are described as extraneous cognitive load. Extraneous cognitive load are data that do not have a high cognitive value, but at certain times the student must accept and process them. In the case of non-optimal physical learning conditions, the student's attention is diverted from the information that is relevant to the learning process to the impeding factors from the learning environment. This dissipates the student's attention and reduces the efficiency of the cognitive process. In this case, the student's mental engagement is not only applied to the learning part but also to compensating for disturbing factors in the environment (Sweller, 1988) (Sweller, van Merrienboer & Paas, 1998).

The second conclusion refers to the impact of working environment on learning in smart classrooms. The conclusions drawn by similar researches (Egong, 2014), (Gómez, Huete, Hoyos, Perez, & Grigori, 2013), (Crook & Langdon, 1974) (Green, Pasternack & Shore, 1982) (Grossberg, 1999) (Ricciardi & Buratti, 2018) (Küller & Lindsten, 1992) (Wurtman, 1975) (Walberg, 1982) (Otto, Hudnell, House, Mølhave & Counts, 1992) (Uzelac, Gligorić & Krčo, 2018) performed in the environment of traditional classrooms can be applied to smart classrooms as well. Physical environmental parameters also affect the success of students' learning outcomes in smart classrooms. The advantage of smart classrooms compared to traditional classrooms is the possibility of monitoring physical environmental parameters. Sensor networks in the classroom can monitor the change of different parameters and affect the working environment through the control system. Therefore, the value marked as the Dynamic environmental parameter (λ) was introduced in this paper. It denoted the corresponding value in the range [0,1] to determine the total state of physical environmental parameters in the smart classroom. In the implemented research, this parameter was defined as only two extreme values. Parameter $\lambda=0$ marked favourable working environment, while parameter $\lambda=1$ referred to unfavourable working environment.

The third conclusion was based on the additional comments in the questionnaire in which students expressed their opinions on the overall impact of physical environment on the learning process. The conjoint influence of the environment gives a different subjective impression of the state of physical parameters of the environment, compared to the situation when individual parameters are observed. The introduction of a dynamic environmental parameter combines more physical parameters into one value and it is therefore more relevant to describe the physical state of the environment in smart classrooms than the individual physical parameters.

The drawn conclusions are indicative of the influence of physical environmental parameters on the learning process in a smart classroom. Dynamic environmental parameter may be used as a criterion of adaptive learning in smart classrooms. The representation of multiple environmental factors through one unique parameter facilitates the realization of the process of adaptation, especially in the case of utilizing several adaptation criteria.

6.1 Research Limitations

The limitations of this paper are related to:

- The technical equipment of a smart classroom. Depending on the technical equipment of the classroom it is possible to monitor different physical parameters of the environment.
- The values that the system treats as optimal. They must be taken with a reserve depending on the specific requirements for the realization of particular types of teaching (such as, for example, training of medical students for work in an unfavorable environment).
- Individual experience of physical environmental parameters. Students experience different values of physical parameters in different ways.
- Number of physical parameters that would combine the dynamic environmental parameter.

7. Conclusion

The objective of adaptive learning in smart classrooms is a student-centered e-environment which would best fit into the individual styles of learning the students find most beneficial for achieving successful learning outcomes. The implemented research indicates that the Dynamic environmental parameter may be utilized as one of the parameters for adaptive learning in smart classrooms. Parameter λ in smart educational environments interprets the values of various environmental factors as one unique value, which is thus suitable to be used in the process of adaptation in smart educational environment. The analysis of parameter λ provides grounds for further research in pursuit of establishing the relation of λ with other criteria of adaptive learning in smart classrooms. The introduction of a new model of adaptation comprising multiple adaptation criteria represents only one of the possible guidelines of future research.

References

Al-Hemoud, A., Al-Awadi, L., Al-Rashidi, M., Rahman, K., Al-Khayat, A., & Behbehani, W. (2017). Comparison of indoor air quality in schools: Urban vs. Industrial 'oil & gas' zones in Kuwait. Building And Environment, 122, 50-60. http://dx.doi.org/10.1016/j.buildenv.2017.06.001

Beldagli, B., & Adiguzel, T. (2010). Illustrating an ideal adaptive e-learning: A conceptual framework. Procedia - Social And Behavioral Sciences, 2(2), 5755-5761. http://dx.doi.org/10.1016/j.sbspro.2010.03.939

Bouzeghoub, A., Carpentie, C., Defude, B., & Duitama, F. (2003). *A Model of Reusable Educational Components for the Generation of Adaptive Courses*. Paris: Institut National des Télécomm.

Brahim, H., Jemaa, A., Jemni, M., & Laabidi, M. (2013). Towards the Design of Personalised Accessible E-Learning Environments. *2013 IEEE 13Th International Conference On Advanced Learning Technologies*. http://dx.doi.org/10.1109/icalt.2013.128

Brusilovsky P. and Peylo C., "Adaptive and Intelligent Web-based Educational Systems" , International Journal of Artificial Intelligence in Education, 13, 2003, pp.156-169

Carbon monoxide, industry and performance. (1975). The Annals of Occupational Hygiene. http://dx.doi.org/10.1093/annhyg/18.1.1

Chorfi, H. & Mohamed, J. (2004). PERSO: Towards an Adaptive e-Learning System, *Journal of Interactive Learning Research* (ISSN-1093-023X), 433-447

Coley, D., Greeves, R., & Saxby, B. (2007). The Effect of Low Ventilation Rates on the Cognitive Function of a Primary School Class. *International Journal of Ventilation*, *6*(2), 107-112. http://dx.doi.org/10.1080/14733315.2007.11683770

Crook, M., & Langdon, F. (1974). The effects of aircraft noise in schools around London airport. *Journal of Sound and Vibration*, *34*(2), 221-232.

Deleawe, S., Kusznir, J., Lamb, B. and Cook, D. (2010). Predicting air quality in smart environments. *Journal of Ambient Intelligence and Smart Environments*, 2(2), pp.145-154.

Despotović-Zrakić, M., Marković, A., Bogdanović, Z., Barać, D., & Krčo, S. (2012). Providing Adaptivity in Moodle LMS Courses. *Journal of Educational Technology & Society*, *15*(1), 326-338. http://dx.doi.org/ISSN 1436-4522 (online) and 1176-3647 (print).

Dwic, A. & Basuki, A. (2012). Personalized Learning Path of a Web-based Learning System. *International Journal of Computer Applications*, *53*(7), 17-22. http://dx.doi.org/10.5120/8434-2206

ECOENERGY, R. (2018). *LED Lighting Calculation- How to Calculate the requirement of LED Lights- RST LED Lights*. *RST Blog*. Retrieved 19 October 2017, from http://rstenergy.com/blog/led-lighting-calculation-how-to-calculate-the-requirement-of-led-lights-rst-led-lights/

Egong, A.I. (2014). Reading culture and academic achievement among secondary school students. *Journal of Education and Practice.* 5. 132-136., ISSN 2222-288X

Fabbri, K. (2015). A Brief History of Thermal Comfort: From Effective Temperature to Adaptive Thermal Comfort. *Indoor Thermal Comfort Perception*, 7-23. http://dx.doi.org/10.1007/978-3-319-18651-1_2

Gómez, J., Huete, J., Hoyos, O., Perez, L., & Grigori, D. (2013). Interaction System based on Internet of Things as Support for Education. *Procedia Computer Science*, *21*, 132-139. http://dx.doi.org/10.1016/j.procs.2013.09.019

Green, K., Pasternack, B., & Shore, R. (1982). Effects of Aircraft Noise on Reading Ability of School–Age Children. *Archives of Environmental Health: An International Journal*, *37*(1), 141-145. http://dx.doi.org/10.1080/00039896.1982.10667528

Grossberg, S. (1999). The Link between Brain Learning, Attention, and Consciousness. *Consciousness and Cognition*, *8*(1), 1-44. http://dx.doi.org/10.1006/ccog.1998.0372

Hamada, M. (2012). Learning Style Model for e-Learning Systems. *Active Media Technology*, 186-195. http://dx.doi.org/10.1007/978-3-642-35236-2_19

Hydroponics, (2018). Retrieved 19 October 2017, from (https://www.hydroponics.eu/calculating-size-capacity-air-exchange-of-your-extractor-fan_575.html

J. Sweller, *Cognitive load during problem solving: Effects on learning*, Cognitive Science, 12 (1988), pp. 257-285

Khenissi, M., Essalmi, F., Jemni, M., Kinshuk, Graf, S., & Chen, N. (2016). Relationship between learning styles and genres of games. Computers & Education, 101, 1-14. http://dx.doi.org/10.1016/j.compedu.2016.05.005

Kim, J., & de Dear, R. (2018). *Thermal comfort expectations and adaptive behavioural characteristics of primary and secondary school students*. Retrieved 10 January 2018, from

Kim, J., Lee, A., & Ryu, H. (2013). Personality and its effects on learning performance: Design guidelines for an adaptive e-learning system based on a user model. *International Journal of Industrial Ergonomics*, *43*(5), 450-461. http://dx.doi.org/10.1016/j.ergon.2013.03.001

Klašnja-Milićević, A., Vesin, B., Ivanović, M., & Budimac, Z. (2011). E-Learning personalization based on hybrid recommendation strategy and learning style identification. *Computers & Education*, *56*(3), 885-899. http://dx.doi.org/10.1016/j.compedu.2010.11.001

Küller, R., & Lindsten, C. (1992). Health and behavior of children in classrooms with and without windows. Journal of Environmental Psychology, 12(4), 305-317. http://dx.doi.org/10.1016/s0272-4944(05)80079-9

Li, B., Kong, S., & Chen, G. (2015). Development and validation of the smart classroom inventory. Smart Learning Environments, 2(1). http://dx.doi.org/10.1186/s40561-015-0012-0

Mamat, N. & Yusof, N. (2013). Learning Style in a Personalized Collaborative Learning Framework. *Procedia - Social and Behavioral Sciences*, *103*, 586-594. http://dx.doi.org/10.1016/j.sbspro.2013.10.376

Mayer, R. *The Cambridge handbook of multimedia learning*.

Mekacher, D. L. (2019). Augmented Reality (AR) and Virtual Reality (VR): The Future of Interactive Vocational Education and Training for People with Handicap. PUPIL: International Journal of Teaching, Education and Learning, 3(1).

Mihai, T., & Iordache, V. (2016). Determining the Indoor Environment Quality for an Educational Building. *Energy Procedia*, *85*, 566-574. http://dx.doi.org/10.1016/j.egypro.2015.12.246

Mihalca, L., Salden, R., Corbalan, G., Paas, F., & Miclea, M. (2011). Effectiveness of cognitive-load based adaptive instruction in genetics education. Computers in Human Behavior, 27(1), 82-88. http://dx.doi.org/10.1016/j.chb.2010.05.027

Otto, D., Hudnell, H., House, D., Mølhave, L., & Counts, W. (1992). Exposure of Humans to a Volatile Organic Mixture. I. Behavioral Assessment. *Archives of Environmental Health: An International Journal*, *47*(1), 23-30. http://dx.doi.org/10.1080/00039896.1992.9935940

Pace, M. (2017). Adapting Literature to the Language Classroom. *PUPIL: International Journal of Teaching, Education and Learning*, *1*(1).

Peng, J., Zhang, H., & Wang, D. (2017). Measurement and analysis of teaching and background noise level in classrooms of Chinese elementary schools. Applied Acoustics, 131, 1-4. http://dx.doi.org/10.1016/j.apacoust.2017.10.012

Play.google.com. (2018). [online] Available at: https://play.google.com/store/apps/details?id=com.gamebasic.decibel&hl=en_US [Accessed 27 Sep. 2018].

Ricciardi, P., & Buratti, C. (2018). *Environmental quality of university classrooms: Subjective and objective evaluation of the thermal, acoustic, and lighting comfort conditions*. Retrieved 8 January 2018, from

Sala, E., & Rantala, L. (2016). Acoustics and activity noise in school classrooms in Finland. Applied Acoustics, 114, 252-259. http://dx.doi.org/10.1016/j.apacoust.2016.08.009

Sancho, P., Matrinez, I., & Fernandez-Munjon, B. (2005). Semantic Web Technologies Applied to e-learning Personalization in <e-aula>. *Journal Of Universal Computer Science*, *11*(9), 1470-1481. http://dx.doi.org/10.3217/jucs-011-09-1470

Singh, M., Kumar, S., Ooka, R., Rijal, H., Gupta, G., & Kumar, A. (2018). Status of thermal comfort in naturally ventilated classrooms during the summer season in the composite climate of India. *Building And Environment*, *128*, 287-304. http://dx.doi.org/10.1016/j.buildenv.2017.11.031

Sweller, J., van Merrienboer, J., & Paas, F. (1998). Educational Psychology Review, 10(3), 251-296. http://dx.doi.org/10.1023/a:1022193728205

Uzelac, A., Gligorić, N., & Krčo, S. (2018). *System for recognizing lecture quality based on analysis of physical parameters*. Retrieved 8 January 2018, from

Vilčeková, S., Kapalo, P., Mečiarová, Ľ., Burdová, E., & Imreczeová, V. (2017). Investigation of Indoor Environment Quality in Classroom - Case Study. *Procedia Engineering*, *190*, 496-503. http://dx.doi.org/10.1016/j.proeng.2017.05.369

Walberg, H. (1982). *Improving educational standards and productivity*. Berkeley (California): McCutchan.

Wang, F. & Hannafin, M. (2005). Design-based research and technology-enhanced learning environments. *ETR&D*, *53*(4), 5-23. http://dx.doi.org/10.1007/bf02504682

Wu, H., Lee, S., Chang, H., & Liang, J. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers & Education*, *62*, 41-49. http://dx.doi.org/10.1016/j.compedu.2012.10.024

Wurtman, R. (1975). The Effects of Light on the Human Body. Scientific American, 233(1), 68-77. http://dx.doi.org/10.1038/scientificamerican0775-68

Yang, J., & Huang, R. (2015). Development and validation of a scale for evaluating technology-rich classroom environment. *Journal of Computers in Education*, *2*(2), 145-162. http://dx.doi.org/10.1007/s40692-015-0029-y

Yang, T., Hwang, G., & Yang, S. (2013). Development of an Adaptive Learning System with Multiple Perspectives based on Students ' Learning Styles and Cognitive Styles. *Educational Technology & Society*, *16*(4), 185-200. http://dx.doi.org/ISSN 1436 -4522 (online) and 1176- 3647 (print)

Zaki, S., Damiati, S., Rijal, H., Hagishima, A. and Abd Razak, A. (2017). Adaptive thermal comfort in university classrooms in Malaysia and Japan. *Building and Environment*, 122, pp.294-306

Zhu, Z., Yu, M., & Riezebos, P. (2016). A research framework of smart education. Smart Learning Environments, 3(1). http://dx.doi.org/10.1186/s40561-016-0026-2