THE USE OF INTERNET OF THINGS TECHNOLOGY IN THE PEDAGOGICAL PROCESS

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Abstract

Today's trend is the use of information technology in all areas of our lives. Emotions are a basic human characteristic, although they are difficult to define, recognise and classify. Proper assessment and recognition of human emotions can lead to a better understanding of user behaviour. The aforementioned technologies can also be used as a suitable teaching aid, which forms the core of the research and is able to guarantee an increase in the success rate of the teaching process itself in terms of students' understanding of the learning materials. The aim of the research was the use of sensor networks as an element of information and communication technologies in the educational process. Using the possibility of measuring physiological functions through smart wristbands in order to identify changes in students' emotional states. The overall proposed system was able to identify changes in students' emotional state, specifically levels of arousal. Based on the results from the proposed system, teachers should be able to adjust their teaching style in specific situations to suit the students and provide a basis for better teaching and learning.
Keywords: *emotional states, internet of things, physiological functions, teaching process, smart wristbands, sensory networks*

Introduction

In teaching computer science, information and communication technology can be used as a suitable tool to achieve higher-category objectives. Nowadays, ICT is becoming an integral part of the teaching process. Through ICT, even younger generations of students can master the curriculum more easily and effectively, as the teaching of theoretical matters can be directly linked to practical ones (Horváthová, 2005). With the advent of new technologies in the field of computer science come new trends in teaching using information and communication technologies. For example, interactive

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tests for students, on which the author has worked. Students can test themselves in an interactive way and have the opportunity for direct feedback to compare success rates. Author (Bílek & Machková, 2016) described the inquiry-oriented way of teaching the subject and also the possibility of discussing a certain topic via videoconferencing with other students from different parts of the world.

The learning environment is an important outcome of the educational process, not just a stage for the actual teaching. The term Virtual Learning Environment (VLE) is broadly understood as the creation of conditions for learning with limited personal participation of the teacher and with the use of information and communication technologies. LMS (Learning Management System) is an information management system for e-learning. The purpose of LMS role is to collect information on how individual students have been assigned to lessons and courses, how and when they have completed them, to which groups the student is assigned, and to manage communication within the learning system (Horváthová, 2005).

While E-learning and the use of various LMS systems for learning management is a relatively common phenomenon, especially in universities and secondary schools, mobile learning is coming to Slovak schools gradually. In doing so, many of the portable devices are increasingly found in children's hands. With these devices, access to the information that is needed is made possible. The essence of mobile learning is that it creates opportunities for learning in context, in the context of where the learner is at the moment (Wei et al., 2021).

Sensor networks can also be used in education and teaching. The effort to incorporate sensory networks into the classroom is to make the teaching process itself more efficient for the educator. The goal of sensory networks in teaching is to provide information to the educator about the feelings of the students. The endeavour in the research represents the use of a sensory network to provide the educator with information and emotional states of the learners. IoT elements can be incorporated into sensor networks for the purpose of aiding teaching in the teaching process. These include IOT-enabled devices such as smart devices in the form of wristbands and other items that can be worn by students (Kummerfeld & Kay, 2017).

In the teaching process, IoT technology can be envisioned as the interconnection of multiple devices that communicate with each other in lecture rooms. These are devices that would monitor the activities of students, such as cameras that would have the role of a motion sensor, also smart wristbands that would monitor the change in physiological functions of students. By combining these devices, the educator would have a visualization of the processed information about the change in the emotional states of the students and based on that, he would be able to adjust the teaching in a different direction.

The educational process gradually begins to focus on the learner's personality, and the teacher acts as a tutor. Mass education in the classroom or through classical e-learning is not capable of responding to the individual needs of the learner. Personalized education represents the way in which students learn with respect to their prior knowledge, skills, and learning styles. Viewing teaching from an emotional perspective means that a distinction needs to be made between two aspects of teaching and student learning: cognitive processes of information processing—the actual mechanisms of learning that produce changes in the memory system—and emotional-motivational processes that

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are indirectly involved in the learning process and influence the cognitive aspects of learning, such as its dynamics (Krapp, 2005).

Emotions are fundamental to the human experience, even though they can be difficult to define, recognize, and classify. Feelings and emotions play an important role in human life because they are part of the motivational structure. The extent to which a person is focused, determined, and consistent often depends on their emotions. Emotions are also significant and important in a student's learning, and they significantly affect the results of their learning activities. Positive emotions can facilitate or enhance the procedural aspect of learning, while negative emotions can also have a good impact on the learning outcome. However, the difference between positive and negative emotions is that negative emotions only affect the outcome of learning, such as forgetting material, difficulties in transferring knowledge, etc., and not the process of learning itself (Petlák, 2018).

The aim of current research was to use data obtained from individual sensory features, such as sight, smell, touch, hearing, and taste, to determine the overall emotional state of the user and to understand their actions and mindset. The research focused on the monitoring and evaluation of students' emotional states during the teaching process. One of the basic problems of the teaching process is a lack of focus among students. It is assumed that the emotional state of students also influences this lack of focus. To detect these states as objectively as possible, physiological data such as heart rate can be used. These data can be measured using sensor networks. Based on the research conducted by the aforementioned researchers, it is possible to confirm that sensory networks are a suitable tool for recording and analysing changes in students' emotional state during teaching.

Research Methodology

The research methodology focuses on evaluating human emotions through physiological functions, particularly heart rate, in the context of optimizing the teaching process. The methodology consists of the following steps.

General Background

The research was conducted during the teaching period of the Operating Systems course, which is a compulsory subject consisting of two parts: lectures and exercises. The course concludes with an examination test, and the research was carried out throughout the semester, culminating in the final exam. The primary objective of the Operating Systems (OS) course is to provide students with a foundational understanding of operating system construction and the theoretical underpinnings of computer science. To facilitate the research, an e-learning course was developed in the LMS Moodle environment.

Sample Selection

The students who took the course were divided into two groups. At the beginning of the semester, students who agreed to participate in the research were provided with a

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smart wristband that could measure heart rate. They were instructed to wear the wristband throughout the entire class, including lectures and Operating Systems exercises.

Instrument and Procedures

Heart rate was used as a physiological indicator to assess the level of arousal in students. This was accomplished using wristbands that contained sensors capable of measuring heart rate, with measurements taken throughout the entire semester. Special attention was given to students' physiological responses during the self-test phase, which involved revisiting lecture material. The wristbands sent heart rate data to a mobile app for processing at regular intervals, with Xiaomi devices set to record data every second.

The data for the experiment was obtained from smart bracelets that students wore during class. The wristbands recorded heart rate data over time, which was then exported and analysed for each student. In addition to heart rate data, time stamps were recorded for various class activities, including exercises and lectures throughout the semester. Information on the timing of self-tests was also obtained from the virtual learning portal Moodle, which was exported in order to identify the time intervals at which students took the tests.

Data Analysis

During the pre-processing of the input files, it was necessary to perform data cleaning in order to remove unnecessary records, such as data from wristbands that were measured prior to the teaching process. Next, the data was merged into a single data matrix, which involved creating a new variable to represent the unique identifier of each student assigned to a specific wristband. Using this identifier, the data from the wristbands was merged with the data from Moodle, and new artificial variables were created to represent information about the type of activity, whether it was an exercise, a lecture, or a self-test. The data was transformed by creating additional variables that explored various factors in combination with heart rate data from the wristbands. These variables included information about the minute of exercise/lecture, the specific activity being performed at a given time, average heart rate, and the difference in heart rate at a given time compared to the average heart rate, among others.

Research Results

According to research (Francisti et al., 2020; Francisti & Balogh, 2020) networks, including smart wristbands, have been found to be effective tools for identifying changes in emotional states. In the research, students wore smart bracelets during the teaching process without any restrictions. The devices were equipped with sensors that measured the physiological function of the heart rate, to identify emotional states. Based on the tests, it was assured that these devices were effective in measuring changes in emotional states during the teaching process.

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Data Normalization

Since the heart rate values of different students were in different ranges, it was necessary to create a standardization, or standard variable, to be able to compare the data of students with each other. Through standardization, the research did not work directly with heart rate values, but with the deviation from the average heart rate value that was measured for a given student. The adjusted value was given as a percentage of how much the heart rate in each situation deviated from the mean heart rate of that student. In the first step, normalization had to be implemented since the data obtained did not have the form of normalized data. Subsequently, after normalization, it was also possible to compare the students with each other. As part of the data normalization, the average heart rate of a given student was calculated from all the records that were obtained during the conduct of the research. The obtained average heartbeats of *Rate_Means* were considered as a reference for a given student. Subsequently, new variables were created in the protocol file that were calculated as the differences of the actual heart rate from the *RateAVG* average heart rate. This created variables *rateDiff* (calculated as *rateAVG* - rate, i.e., the deviation of actual heart rate from average heart rate in units of beats per minute). The normalization of the heart rate data represented an intermediate step that allowed us to proceed with further comparisons of the students.

Comparison of Normalized Heart Rate Data According to the Activities of the Pedagogical Process

The students' activities during the semester were diverse and included exercises, self-tests, lectures, presentations, and exams. In order to analyse the data collected from the smart bracelets more accurately and to track changes in heart rate values during these activities, the activities were divided into groups. The categorization was done in such a way that the different activities could be compared with each other.

Creating categories for each activity was also an important step for using the Kruskal Wallis ANOVA statistical method. Through the statistical method used, the changes in heart rate values for each activity were found, as shown in Table 1.

Table 1

Kruskal-Wallis ANOVA Results Comparing Categories of Pedagogical Process Activities

	Valid N	Sum of Ranks	Mean Rank	Means	Std.Dev.
Activity	19	404	21.263	0.308	2.208
Test	11	419	38.091	3.543	2.129
Other	1	17	17	-0.388	-
Lecture	6	33	5.5	-3.793	2.654
Presentation	10	273	27.3	1.478	2.54
Exam	4	180	45	5.045	2.263

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The activity in the form of an exam test represented the final grade for the entire semester and had the greatest weight on the final course grade. Therefore, the importance of the activity in terms of student motivation and excitement is also significant.

The self-test activity was designed to serve as a summary of the material covered in the lecture and was conducted at the beginning of each exercise. During the self-test, students were required to answer several questions within a defined time interval. The self-test was administered sequentially, and students were not allowed to return to previous questions. The high heart rate readings during the self-test demonstrated the level of excitement and engagement of the students with the material covered.

The presentation as part of the exercise was ranked third according to the statistical method. During the presentation, the students were familiarized with the objective of the exercise, the issues on the topic were discussed and a discussion took place as the students answered the questions posed. The assumption was that students were quiet during the presentation until they were asked to answer a specific question. In case they were not actively following the lesson, the question might have surprised them and aroused a change in the heart rate value, as demonstrated by the statistical method used.

The activity labelled "Activity" represented the students' independent activity during the exercise. Based on the instructions from the presentation, students worked independently on practical tasks. Subsequently, the results from the task had to be uploaded to the course. The students had sufficient time to complete and submit the practical tasks, which was confirmed by the statistical method.

According to the statistical method conducted, students were most relaxed during lectures when they were going over the theoretical part of the course in the form of a presentation. In addition to the Kruskal_Wallis ANOVA statistical method, the parametric ANOVA method was performed for comparison and confirmed the same order of results.

Comparison of Normalized Heart Rate Data by Self-Test Activity

The self-test was a quiz activity. The main objective was to test the knowledge of students acquired in lectures. Each self-test contained only questions that belonged to the last topic covered.

In the first step of analysing the aforementioned activity, differentials were created for each self-test separately (Table 2).

Table 2
Differences in Heart Rate Values Distributed by Self-Tests

Self-test number	rateDiff Means	rateDiff N	rateDiff Std. Dev.
7	1.45714	5146	8.13073
8	4.35060	6068	7.57225
9	1.94337	4111	7.82053
10	-1.90831	5094	7.06820
11	-1.33549	62249	14.17801

From the calculated differences, students were the calmest on self-tests 10 and 11. Self-test 10 was created on the topic of computer networks. Students also showed interest in this topic in the exercise where practical matters of communication of devices in computer networks were implemented.

The results obtained suggest that students were familiar with the questions on self-test 11 and did not experience significant arousal during the test. This was confirmed by the evaluation of the test results. Self-test 11 was a review of the learning materials and contained the same questions as self-test 7. The aim of repeating the self-test was to observe how students would physiologically respond to the same questions after a time interval of 5 weeks. Based on the calculated heart rate values, it can be inferred that there was no significant physiological response, suggesting that the students were familiar with the material and did not experience any significant cognitive load during the test.

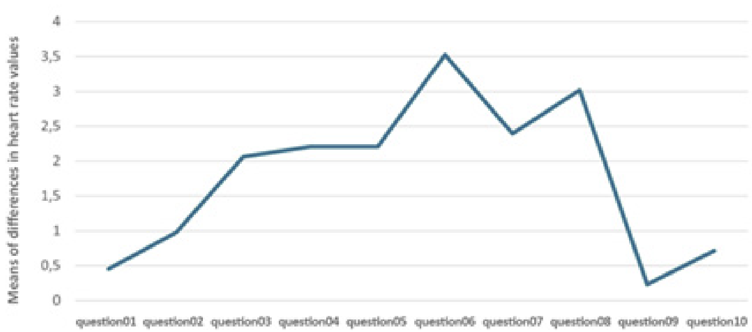
According to the analysis of the physiological function of the heartbeat, students were most excited during self-test 8, which consisted of questions related to computerized mechanical disks. This topic was one of the most content-dense, with detailed descriptions of the methods and principles of mechanical disk function. Based on the highest difference in mean heart rate, it was shown that self-test 8 was more challenging than the others, as evidenced by the physiological function of the heart rhythm, which may have influenced the test results.

Continuing to analyse the data collected, individual questions in the self-tests were identified in more detail, as well as significant changes in the students' heart rate values. Students were most excited when asked to mark one correct answer and least excited when asked to complete the answer. This observation indicates that students might have experienced more difficulty in choosing the correct answer when given multiple options, compared to when they had to recall the information and write down the answer.

In addition to inter-question comparisons within the self-tests, inter-question rankings were also analysed with physiological values of heart rate function. The investigated self-tests were created sequentially. It was investigated whether the heart rate (*rate_Diff*) of students would tend to increase or decrease with higher-order questions in the self-test.

Figure 1

Averages of Heart Rate Values Distributed According to the Order of the Questions



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It is also possible that the content of the questions in the later part of the test was less challenging, leading to a decrease in arousal and a subsequent decrease in heart rate. The decrease in heart rate for question 10 may be attributed to the fact that it was the last question of the self-test and the students knew that they had completed the test, resulting in a sense of relief and relaxation. Overall, the results suggest that the order of the questions in the self-test can influence the physiological response of the students.

Since the self-tests included in the analysis were sequential, the optimal number of clicks for successful completion was calculated. The optimal number of clicks included pressing the button for the next question and pressing the button at the end to exit the test (the type of clicks was filtered out in the course log file). The analysis of the self-tests also found that for each self-test, there was an average of 6% of students who had more records in their record set than the optimal number of clicks to pass the self-test. Students whose number of clicks was different from the optimal number of clicks scored lower overall compared to other students who took the self-test according to the calculated optimal number of clicks.

The results obtained in research directly helped us to confirm the claim that based on the physiological function of the heart rate, it is possible to identify the change in the emotional state of students. In research, it has been found and proven that heart rate has an impact on students' behaviour in particular activities and on their performance.

Discussion

The utilization of physiological data, such as heart rate, has been demonstrated in prior research to be an efficacious approach to expose implicit emotions (Kreibig, 2010). Consistent with prior investigations, our study employed bracelets equipped with sensors to monitor heart rate as an indicator of physiological function and gauge fluctuations in the emotional state during self-tests and other educational activities.

The veracity of using heart rate as a reliable indicator of emotional arousal has been established by prior literature. For instance, research published in the Journal of Personality and Social Psychology found that heart rate could be used as a dependable measure of emotional arousal across various contexts (Lang et al., 1993). Furthermore, a study published in PLOS ONE found that heart rate could predict changes in emotional valence with moderate accuracy (Sørensen et al., 2018).

Furthermore, the findings align with previous legal precedent recognizing heart rate as a valid form of evidence in certain contexts, including in litigation in the Slovak Republic where heart rate was utilized to indicate changes in emotional state, specifically arousal (Lacko, 2017). This underscores the potential of physiological data to elicit valuable insights into the emotional states of individuals and enhance our comprehension of human behaviour.

The research centred on utilizing sensor networks and physiological data to refine teaching methodologies and augment student engagement. By leveraging this technology to collect data on students' emotional responses, we were able to create a more personalized and effective educational environment. This is in line with prior research that has recognized the potential of using physiological data to discern emotional states in educational settings (Leppink et al., 2017).

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It is imperative that we contextualize, confirm, and elucidate our findings by comparing and contrasting our results with those of others. The findings are consistent with previous research that has established the effectiveness of physiological data in assessing emotional responses. However, the research specifically focuses on utilizing physiological data to enhance teaching methodologies and student engagement.

Conclusions and Implications

The data collected makes it possible to conduct research similar to research that has been conducted in the past. The end result of the research was the creation of a tool designed to optimize the teaching process.

During the research, the students wore wristbands during each teaching process, allowing us to compare the values obtained with the activities. The assumption was made that students would be excited during the writing of the self-tests and the final test. It was also set that students would be calm during lectures and activities in which they worked independently. These assumptions were confirmed during the research. In addition, it was found that the change in the students' emotional state affected their grades in the course.

The results from the wristbands confirmed that the physiological function of the heart rate was able to identify changes in the emotional state of the students. The result of the research demonstrated the possibility and the way in which to distinguish differences in student behaviour during different classroom activities and to determine which activities made students more excited and which made them calmer. Research showed that this approach can be used to optimize the learning process and improve learning outcomes.

In the future, the aim is to create a system that can identify changes in the emotional state of students based on the physiological functions obtained in real time and would serve as an aid for the teacher because it would be able to predict in real time how students behave in a particular activity and whether the activity needs to be modified.

The proposed system should serve as an indirect method of suggesting recommendations for educators. Based on the research in this thesis, educators will be able to implement such an alternative into the teaching process. The research conducted indicates that this approach will be helpful in improving and enhancing the teaching process.

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Declaration of Interest

The authors declare no competing interest.

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