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Harnessing personal smart tools for enhanced STEM education: exploring IoT integration

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Abstract. In the realm of STEM education, various computer-based methodologies have been employed to invigorate student motivation, personalize learning experiences, and elevate the overall quality of education. However, the integration of Internet of Things (IoT) and smart tools for measuring parameters during educational research processes has garnered insufficient attention thus far. This neglect becomes all the more pronounced in light of the burgeoning popularity of personal smartwatches and bands among individuals. In this study, we develop innovative techniques for incorporating personal smart tools into STEM classes and research endeavors. By employing the Colmi Land 1, Xiaomi Mi Band, Samsung Smart Fitness Band, and Xiaomi Mi Smart Scale as testbeds, we conduct a comprehensive evaluation using the As Is – To Be Business Process Model and Notation method. The findings substantiate that our proposed methods exhibit superior efficacy compared to conventional educational processes. Moreover, this paper represents a pioneering effort in describing and offering ready-to-use techniques for utilizing personalized smart tools to measure parameters during experiments within educational contexts[1].

Keywords: Internet of Things (IoT), personal smart tools, STEM education, motivation, personalization, parameter measurement, BPMN

1. Introduction

The acronym STEM, originally known as SMET, was introduced by the US National Science Foundation in 2001. However, it gained prominence in the United States in 2009 with the inception of the "Educate to Innovate" program. In Ukraine, the implementation of STEM

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education has been relatively limited compared to traditional educational approaches, despite its numerous advantages [19, 26].

One of the primary focuses in STEM lessons is enhancing student motivation. These lessons also foster the development of critical skills such as communication, data processing, and project management, which heavily rely on information technology.

The tools used in STEM education can be broadly categorized into three groups: general tools, software, and specific modern tools. General tools encompass digital laboratories, digital equipment, mobile phones, mobile phones with additional sensors, and smart tools. Software tools include process calculators, modeling environments, virtual reality (VR) videos and applications [10], augmented reality (AR) applications [2, 4, 11, 15, 23, 29], educational environments [10], 3D printing, and 3D modeling tools [28]. However, in our view, the Internet of Things (IoT) holds significant untapped potential in education due to its ability to leverage cloud computing, data visualization, and personalized data generated by interconnected devices.

Unlike cloud services, IoT incorporates machine-to-machine (M2M) connections, enabling autonomous measurement and interaction without human involvement. Personalized smart tools, as part of IoT, represent a particularly promising avenue within STEM education.

Smart tools, which form part of IoT, are electronic devices connected via the Internet, Bluetooth, NFC, or other means, capable of capturing and transmitting measured data to the cloud for storage. Users can access this information from anywhere using Android/iOS applications or web interfaces. The key advantages of smart tools lie in their personalization, allowing for individual device connections within personal application or web interface profiles. Noteworthy features of smart tools include:

- Real-time performance measurement
- Calculation of various indicators
- Data analysis
- Providing feedback or displaying crucial information to users

Examples of smart tools encompass fitness bands, smartwatches, smart scales, and smartphones. Particularly promising for educational contexts are the utilization of smartwatches/bands, scales, temperature sensors, humidity sensors, and specialized plant sensors. The significance of this research is underscored by the growing adoption of personal wearable devices due to their increased affordability and user-friendly nature [7]. Projections indicate a substantial rise, from 100 million devices in 2016 to over 373 million in 2020 [24], and potentially reaching 1.1 billion by 2022, driven by the transition from 4G to 5G mobile internet connectivity [13].

2. Literature review and problem statement

The pervasive adoption of smart tools in various domains, such as everyday life, sports, medicine, and healthcare, has been well-documented. For instance, wearable devices are utilized in clinics to monitor patients' conditions and provide timely alerts to medical professionals [31].

In the realm of education, IoT technologies and cloud services are gaining traction and are increasingly recognized for their potential to revolutionize the learning landscape [32]. The integration of IoT in education holds the promise of creating more personalized and dynamic learning experiences, offering novel avenues for instructional delivery [1, 32]. Moreover, IoT presents a remarkable opportunity to provide tailored educational opportunities for individuals with disabilities, fostering inclusive learning environments [17].

Numerous countries have embarked on initiatives to leverage technology for educational advancement. Singapore, for instance, introduced the Intelligent Nation Masterplan in 2006, with a significant focus on technology-enabled education [9]. South Korea initiated the Smart Education Project, aimed at educational system reform and improvement of pedagogical practices [37]. Australia collaborated with IBM to design a cutting-edge, interdisciplinary education system [27]. In Ukraine, the new school program concept underscores the importance of smart tools and e-learning [5].

Scholars have explored the development of educational systems based on wearable devices and IoT technologies, integrating IoT tools and specialized applications to foster interactive and innovative learning experiences [14, 16]. Such systems not only enhance classroom interactions between teachers and students but also inspire and captivate students, fostering greater engagement during lessons [25]. Moreover, the integration of IoT technologies in the educational process has been shown to improve the quality of learning and unleash the creative potential of both educators and learners [25].

Previous research has proposed the utilization of mobile Internet devices to enhance the general scientific competency of electromechanics students, emphasizing the prospect of leveraging such devices to elevate the overall quality of education [20, 21]. Examples of suggested tools include mobile augmented reality tools, mobile computer mathematical systems, cloud-oriented tabular processors as modeling tools, and mobile communication tools to facilitate collaborative modeling activities.

The integration of the Internet of Things in education offers the exciting prospect of connecting and educating students in smart campus environments. Scholars have explored the implementation of smart tools to provide a range of services accessible via handheld devices, fostering seamless connectivity among various entities within the educational ecosystem. These systems aim to collect classroom data, not only to disseminate information to students but also to gather insights from their interactions. Additionally, these data can be uploaded and accessed through smart e-learning applications. In smart classrooms, tools focus on real-time monitoring of teaching spaces and providing multifunctional support to students [3, 33, 34].

Despite the promising potential of IoT in education, its widespread adoption remains limited. To date, there is no comprehensive, systematic list of techniques that can be employed in classrooms. While smartphones currently dominate as the most popular smart tool, this work proposes methods that utilize smart scales and smart bands/watches to enhance educational processes.

3. Methods

The research employed a combination of theoretical and empirical methods, including analysis and synthesis, to investigate the prevailing trends in the utilization of IoT in both global contexts and educational settings. Conceptual-comparative analysis was employed to examine exemplary pedagogical practices, while structural-system analysis and synthesis were utilized to construct a comprehensive theoretical model of the existing and desired educational processes. The following devices were selected for the experimental phase: Colmi Land 1, Xiaomi Mi Band 4, Samsung Smart Fitness Band, and Xiaomi Mi Smart Scale 2.

To facilitate a thorough analysis of the proposed modifications to the teaching process, the "As is-to be" method was employed, leveraging the principles of Business Process Model and Notation (BPMN) [6, 35]. BPMN, traditionally used in business analysis, was adapted to document the current state of the process and outline the proposed approach, encompassing both technological and pedagogical aspects. By employing BPMN, the complex processes were deconstructed into discrete elements and interconnected through directional arrows, providing a holistic visualization of the entire process. Moreover, BPMN employs "lines" to delineate process elements based on the actors involved, such as teachers and students, rendering it an appropriate tool for justifying the viability of the proposed approaches. Notably, the application of BPMN in educational research remains limited, with only a handful of studies utilizing this methodology to describe educational processes [22, 36].

To assess the capabilities of devices capable of measuring specific parameters, a hotline service and its filters were employed. The evaluation of the device's content involved the utilization of the following formula: $N/N_a \times 100$, where N represents the number of specific gadgets possessing the desired parameters, and N_a denotes the total number of gadgets from the selected brand. This approach facilitated a comprehensive examination of the device's functionalities and its alignment with the research objectives.

4. Results and discussion

4.1. Existing IoT ecosystems

Among the popular IoT devices, those integrated within smart homes and interconnected through Wi-Fi or Bluetooth protocols stand out. The most prevalent categories of devices include scales, watches, and fitness trackers. Leading manufacturers in this domain encompass Samsung, Xiaomi with its Amazfit/Huami sub-brands, Apple, Google Nest, and others.

Samsung smartphones serve as a central hub within the ecosystem, enabling users to seamlessly control their watches, devices, and headphones. These devices allow for tasks such as note-taking, with the ability to continue working on them across different devices. The synchronization process is streamlined, requiring internet connectivity for optimal functionality. Additionally, Samsung Flow facilitates data exchange between tablets and smartphones, even without an internet connection. At the core of Samsung's developments lies Bixby 2.0, an intelligent assistant that effortlessly connects to Samsung devices. Bixby 2.0 functions as the central hub of the IoT ecosystem, leveraging machine learning to understand and anticipate user needs through daily interactions [12, 18].

Xiaomi, with its expansive range of over two hundred companies and start-ups, has established a formidable presence in the IoT market. Under the Xiaomi umbrella, various subsidiaries specialize in specific product types. Amazfit focuses on developing fitness trackers and smartwatches, while Ninebot expands the company's portfolio with personal electric vehicles. SmartMi focuses on smart home appliances. Wearable electronics, once considered a novelty, now play an integral role in monitoring physical activity, sleep quality, and overall health for millions of users worldwide. Xiaomi, in collaboration with Amazfit, has secured its position as one of the leading manufacturers of smart wearable gadgets. The Xiaomi Mi Band, known for its outstanding functionality and affordability, has garnered significant popularity and continues to enhance its capabilities with each new generation [12, 18].

Xiaomi's influence extends beyond wearable gadgets, encompassing household medical devices like electronic thermometers, inhalers, and tonometers. Additionally, Xiaomi has recently entered the realm of home fitness equipment, exemplified by the WalkingPad A1 folding treadmill. It is highly likely that Xiaomi will expand its product line to encompass a broader range of home sports equipment in the near future.

Apple's HomeKit and Health app serve as platforms designed to integrate various smart technologies within homes. Apple introduced the HomeKit platform in 2014, followed by the availability of compatible devices for sale a year later. With iOS 8 and subsequent versions, Apple mobile devices gained the ability to manage compatible home appliances and life support systems. Notably, HomeKit boasts seamless integration with the Siri virtual assistant, enabling voice command control and presenting immense opportunities for home appliance and software developers. While third-party software has been utilized to control smart home appliances, iOS 10 introduced a native application capable of managing all HomeKit-enabled devices. Apple's Health app allows users to monitor health metrics, daily activity, and share vital information with family and friends when necessary. This functionality proves invaluable in emergencies, sudden illnesses, and fitness tracking scenarios. The Health app works seamlessly with the Apple Watch, which can measure blood oxygen levels and perform electrocardiograms [12, 18].

Google embarked on its smart home journey in 2016 with the introduction of the first Google Home speaker, offering functionalities similar to Amazon Echo. The Google Cast application, initially used to configure and manage Chromecast devices, later transitioned into the Google Home app, expanding its capabilities to support the new smart speaker. Notably, Google unveiled the Google Home Hub, a tablet featuring a display that consolidates information from various smart devices within the Google Home ecosystem. In May 2019, Google presented the Nest Hub Max, which incorporates a camera and multiplayer functionalities. Google Assistant serves as the central operating tool within the Google Nest ecosystem. Beyond devices developed directly by Google, there exists a vast array of third-party manufacturers producing products compatible with the Google Assistant ecosystem, exceeding 500 companies and continuing to grow steadily [12, 18].

Analyzing the ecosystems of these companies based on the parameters measurable by specific equipment appears relevant. Key parameters frequently employed in educational research include heart rate, blood pressure, electrocardiograms (ECG), blood oxygen content, weight, and body composition (including muscle, fat, bone, and water content). Table 1 provides examples of devices from different companies capable of measuring these specific parameters.

4.2. Advantages of utilizing smart tools in the educational process

The utilization of Internet of Things (IoT) devices in the educational process offers several distinct advantages. These advantages can be categorized as follows:

1. *Training functions*: IoT devices serve as valuable tools in the study of individual subjects, particularly in the fields of science, technology, engineering, and mathematics (STEM).

Table 1
Examples of devices from different companies capable of measuring specific parameters.

	Samsung	Xiaomi	Apple	Google	Other brands
			Smart watches/bands		
Heart rate	100% of devises: Samsung Galaxy Watch 1, Samsung Galaxy Watch 2, Samsung Galaxy Watch 3	100% of devises: Amazfit T-Rex, Amazfit Bip S, Amazfit Stratos	100% of devises: Apple Watch Series 1, Apple Watch Series 2, Apple Watch Series 3	N/A	100% Aspolo SmartWatch U8, UWatch U8, SmartYou DZ09
Blood pressure	-(3,9%)Samsung Galaxy Watch 3	- (0%)	- (0%)	N/A	5.5% Havit HV-H1100, UWatch DT88 Pro, Aspolo DT88 Pro
ECG	(0 %)	+ (4.4 %) Xiaomi Mi Watch Color, Xiaomi Haylou Smart Watch	+ (52.5 %) Apple Watch Series 5, Apple Watch Series 6, Apple Watch SE	N/A	7 % No.1 DT28, Lige Smart, Gelius GP-L3
Oxygen content	- (3,9 %) Samsung Galaxy Watch 3	- (0 %)	10,2 % of devises: Apple Watch Series 6	N/A	11.7% Aspolo M1Plus, Aspolo DT35, UWatch E66
Sleep quality (stages of the sleep)	100% of devises: Samsung Smart Charm, Samsung Galaxy Fit E, Samsung Galaxy Watch Active	100% of devises: Xiaomi Mi Band 4, Xiaomi Mi Band 5, Amazfit GTS,	100% of devises: Apple Watch Series 5, Apple Watch Series 6, Apple Watch SE	N/A	100% Aspolo SmartWatch U8, UWatch U8, SmartYou DZ09
			Smart scales		
Weight measuring	N/A	+ (100%) Xiaomi Mi Smart Scale 1, Xiaomi Mi Smart Scale 2	N/A	N/A	100% Laretti LR BS0015, HUAWEI Body Fat Scale, AEG PW 5653 BT Black
Muscle, fat, bone, and water content in the human body	N/A	+ (100%) Xiaomi Mi Smart Scale 1, Xiaomi Mi Smart Scale 2	N/A	N/A	100 % Yunmai Mini Smart Scale, Garmin Index Smart Scale, Acme Smart Scale

These devices are often employed to facilitate learning tasks, research activities, and experimental tasks.

2. *Health-preserving function*: IoT devices are utilized as tools for monitoring key physiological indicators, promoting healthy lifestyles, and developing skills in maintaining physical

fitness. They can also be employed to monitor vital signs in individuals who require such monitoring.

3. *Control function*: IoT devices function as self-control tools, allowing individuals to monitor their own activities, as well as being used by parents, guardians, or teachers to supervise and control the activities of children, particularly in the case of primary and preschool children. This fosters the development of self-control habits and provides a means for external control when necessary.
4. *Ergonomic function*: IoT devices contribute to improved productivity by assisting in tasks such as planning, time management, and enhancing the efficiency of educational processes. The rational use of IoT devices and effective time management enables the control of acceptable physical, mental, and emotional workloads, thereby increasing overall productivity.

The integration of smartwatches/bands into the learning process promotes the development of essential competencies. These competencies include:

1. *Mathematical competence*: The use of smartwatches/bands enables students to engage in navigation, calculations, and data analysis based on the indicators provided by the devices.
2. *Competencies in natural sciences, engineering, and technology*: Smartwatches/bands facilitate the acquisition of skills related to working with physical parameters, vital signs, geolocation data, and the ability to interact with various models of devices and their analogues. This cultivates competencies in the fields of natural sciences, engineering, and technology.
3. *Innovation*: By utilizing leading technologies in the context of personal and public health, smartwatches/bands foster the development of innovation skills.
4. *Information and digital competence*: The process of connecting smartwatches/bands with smartphones introduces students to concepts such as cloud technology, synchronization, and remote access, thereby contributing to the formation of information and digital competencies.
5. *Social competencies*: The use of smartwatches/bands encourages students to be aware of their personal well-being and develop the ability to listen to their own internal needs, promoting the importance of maintaining a healthy lifestyle.
6. *Health-preserving competencies*: Smartwatches/bands facilitate the accurate measurement of heart rate, blood oxygen concentration, and stress levels, enabling students to develop competencies related to personal health management.

For instance, students can observe how negative emotions such as anger or aggression accelerate heart rate by monitoring their smartwatches/bands. This provides an opportunity to create motivation for a healthy lifestyle. Practical experiments can be conducted by offering students substances like coffee or energy drinks and measuring their heart rate, demonstrating the effects of such substances on the functioning of individual organs and systems.

Smartwatches/bands also have significant potential for fostering useful skills and habits. Many of these devices have reminder functions, allowing students to establish habits through repeated prompts. For example, a student can initially set a reminder to take a break and exercise every 40 minutes while studying. After 40 repetitions, this behavior becomes a habit that can be sustained without relying on the smart device.

The pedagogical potential of smartwatches/bands is particularly pronounced in developing research competencies. The European Qualifications Framework for Lifelong Learning [8] emphasizes the importance of research competence in specialized fields. Smartwatches/bands enable students to gather large amounts of data, facilitating the acquisition of new knowledge, and analyze this data using mathematical tools to create a structured knowledge system.

Moreover, smartwatches/bands can be employed to stimulate motivation within a STEM approach. For instance, students can investigate the phenomenon of increased heart rate after physical activity, prompting them to ask questions about the regulation of heart activity. This inquiry can then form the basis for an entire lesson.

Additionally, smartwatches/bands hold promise for students with special needs. For example, these devices can assist in teaching children with hearing disabilities how to measure their pulse, providing a solution to this particular challenge.

In this article, we present various methods for incorporating smartwatches/bands into the learning process. These methods can be categorized based on their duration of use:

A. Methods that can be directly employed during regular classroom instruction.
B. Methods that facilitate long-term experiments, such as those spanning 24 hours. The latter approach is particularly relevant for research projects or student-led investigations.

In conclusion, the integration of smartwatches/bands in the educational process offers the following benefits:

- Motivation for learning activities.
- Promotion of a healthy lifestyle.
- Development of information-digital, health care, and research competencies.

4.3. Analysis of proposed modification to the teaching process

The integration of smart tools holds tremendous potential for providing transformative educational experiences. By utilizing these tools, students can engage directly with objects and actively investigate them. For instance, students can assess their blood oxygen levels, heart rate, and more. To facilitate a smart-lesson, it is necessary to establish connectivity between smart tools and smartphones through dedicated applications, such as Xiaomi Mi Fit.

In the current state of the STEM lesson process ("As is"), the teacher typically begins by explaining the theory, which students often find challenging to comprehend. This is followed by an explanation of the parameters that influence the object or process under study. In most cases, the teacher explains the experiment using the classroom board, with minimal opportunities for actual research. Demonstrations may occasionally be provided, and group experiments are rarely conducted. As a result, students may struggle to grasp the material effectively. Furthermore, the skills and competencies developed through this process are limited to those explicitly outlined in the lesson topic, which may not align with the latest international and Ukrainian educational standards.

Moreover, the technical aspects of demonstrations and group experiments are mostly carried out manually by students or teachers. Data obtained from these activities are recorded and written on the board or worksheets. Subsequently, calculations are performed manually, although this manual computation can still be beneficial. The optimal approach would involve a combination of manual and automatic calculations. The data is then interpreted through graphs, boards, or worksheets, and finally, the graphics and data are analyzed. The current process (including technical interaction) is illustrated in figure 1.

In the proposed modified process ("To be"), the teacher begins classes with theory but promptly transitions to a more practical-oriented approach, explaining the factors that influence a particular object or process. Depending on the availability of smart tools, students engage in demonstrations, group experiments, or personal experiments. The enhanced speed of research leads to better understanding of the materials. Automatic calculations and graph creation streamline the process, allowing students to work with personal data and graphs. They gain proficiency in working with graphics and data while utilizing individual wearable smart tools to conduct research, which enhances motivation and promotes the importance of health care. During personal experiments, students demonstrate heightened curiosity compared to the "As is" process due to increased motivation. Similar to the "As is" process, classes conclude with the investigation and discussion of results.

The key features of the "To be" approach are time-saving and increased motivation. Technically, the "To be" process is significantly more automated. The teacher and students are responsible for methods of measuring and analysis. The analysis process, including sending measured data to smartphones, saving and processing data, and creating graphs, is conducted by the teacher or students. Additional software can be used to import data into Excel for further processing. The "To be" process (including technical interaction) is presented in figure 2.

In summary, the "To be" process offers a more interactive, engaging, and beneficial experience for students, fostering their motivation to conduct personal research and learn how to utilize individual smart gadgets for healthcare. This approach also saves time, allowing for more effective utilization. It is worth noting that the "As is" process teaches students how to manually process data, and therefore, it may be valuable to combine aspects of both approaches.

4.4. Advantages of incorporating smart tools in educational practices

4.4.1. Integration of smart tools into classroom instruction

Topic: Heart rate measurement before and after physical activity using smartwatches / bands (figure 3).

Objective: The aim of this experiment is to demonstrate to students the ability of smartwatches/bands to measure heart rate and its response to physical activity.

Equipment: Internet of Things (IoT) devices, smartwatches/bands, or fitness trackers equipped with heart rate monitoring features; optional blood pressure and oxygen concentration sensors.

Experimental procedure: The experimental procedure involves selecting 10 participants of each gender. Each participant's heart rate, and optionally blood pressure and oxygen concentration, are measured at rest. The participants then perform 20 squats, after which the measurements are taken again. The collected data can be presented in personalized graphs on the participants'

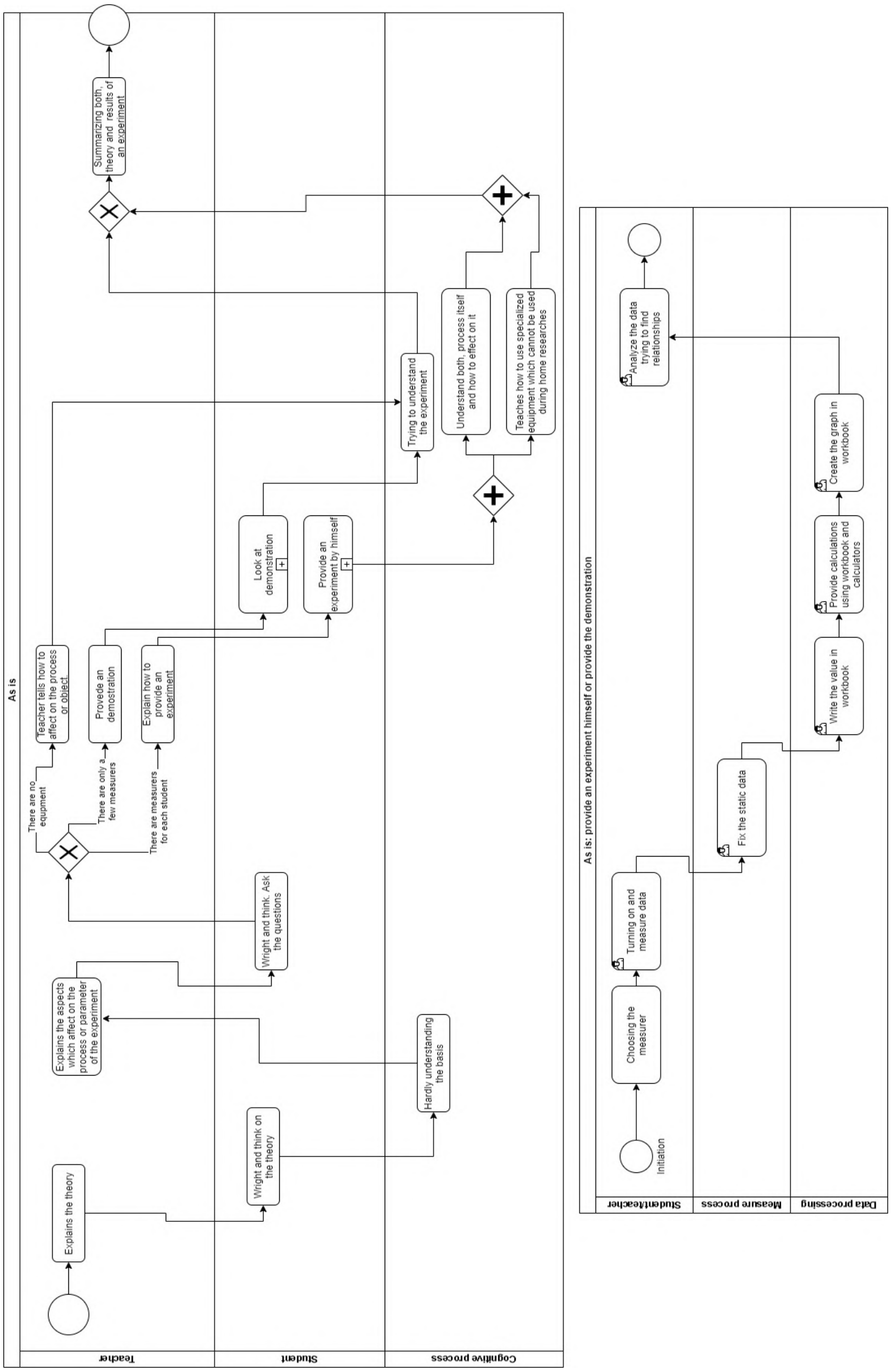


Figure 1: "As is" process (including technical interaction).

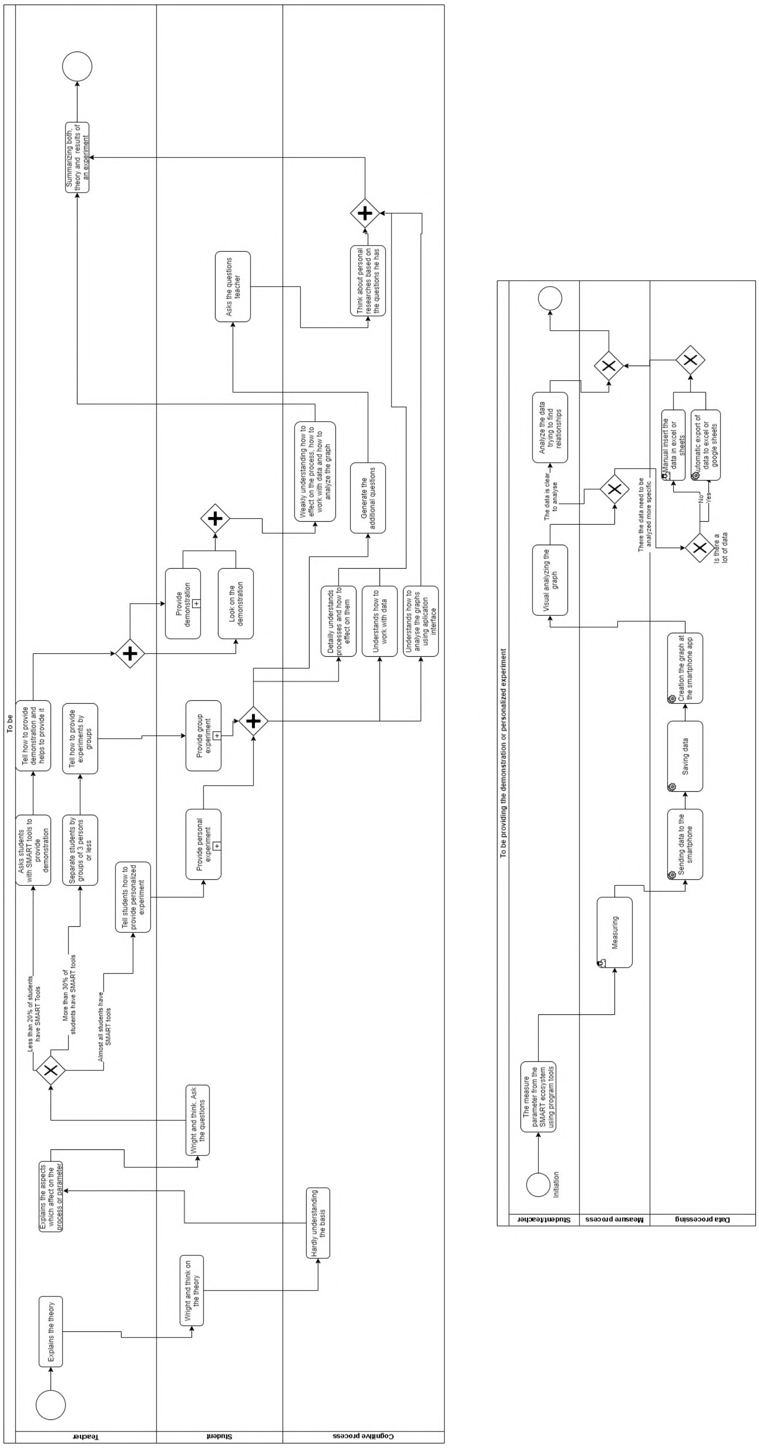


Figure 2: "To be" process (including technical interaction).

(a) (b) (c)

Figure 3: Experimental setup (a), heart rate before (b) and after exercise (c).

smartphones and as a table on a blackboard. The teacher can analyze the data, identify patterns among the students (including factors such as gender, weight, and age), and explain these findings to the class.

Data analysis: The analysis focuses on identifying patterns in the data before and after physical activity. It involves comparing the actual and relative changes in indicators after physical activity between boys and girls, as well as exploring correlations with other factors such as height and weight.

Topic: The influence of sleep duration on heart rate (figure 4).

Objective: This experiment aims to demonstrate to students the impact of sleep duration on the functioning of the circulatory system, emphasizing the importance of consistent sleep habits.

Equipment: Smartwatches/bands equipped with heart rate, blood pressure (optional), oxygen concentration (optional), and electrocardiogram (ECG) (optional) monitoring capabilities.

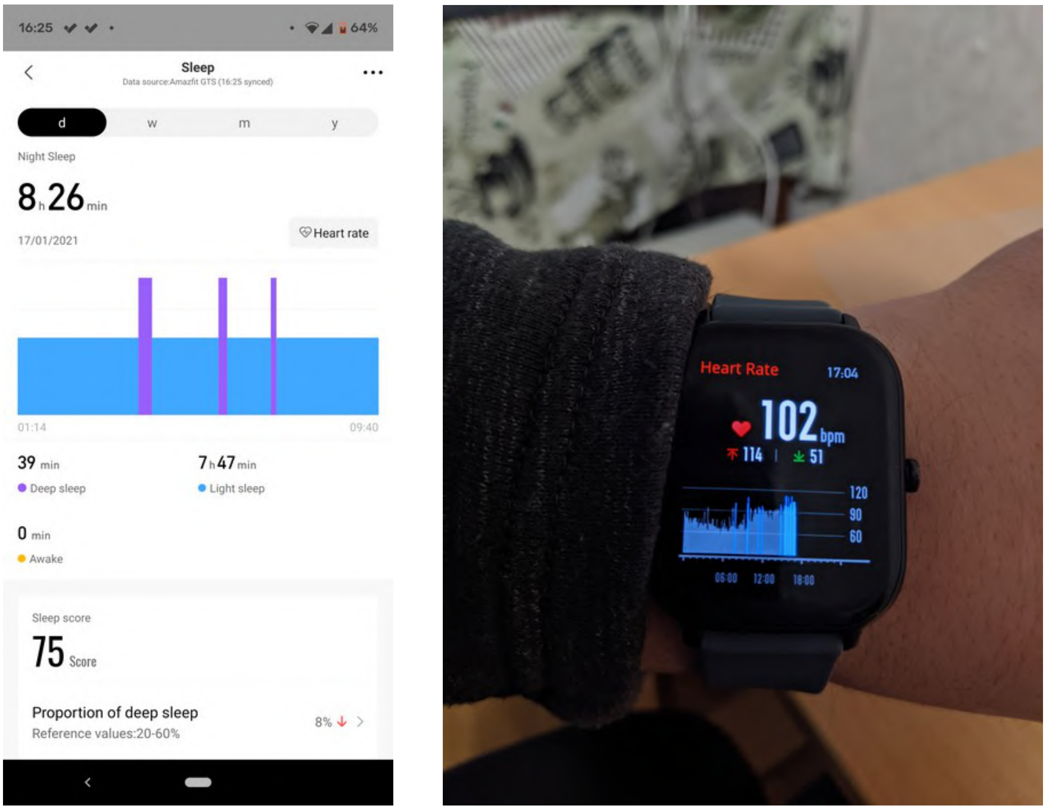
Experimental procedure: Each student conducts a personalized experiment, adjusting their sleep schedule in two stages. Initially, students follow a sleep schedule of 22:00 to 7:00 for seven consecutive days. Upon waking up, they measure their heart rate, and optionally blood pressure, oxygen concentration, and the quality of their sleep. After the first seven days, the students shift their sleep schedule to 23:00 to 6:00 and repeat the measurements upon waking up.

Data analysis: The analysis involves comparing heart rate and oxygen concentration in the blood between the two stages of the experiment (22:00-7:00 and 23:00-6:00) with the normal condition. Any observed changes in the data should be associated with stress or adaptation states based on theoretical knowledge.

This experiment is safe to conduct and can be carried out irrespective of the participants' health conditions. However, it is advisable to have teacher or adult supervision. The results can be used to explore the concepts of adaptation, human comfort zones, and stress conditions.

Topic: Differentiating muscle, fat, and bone composition between males and females (figure 5).

Objective: This experiment aims to illustrate to students the differences in muscle, fat, and bone composition between males and females, as well as to explain the underlying reasons for



(a) (b)

Figure 4: User interface of a smartwatch application for sleep tracking (Amazfit Zepp) (a) and the analysis results (b).

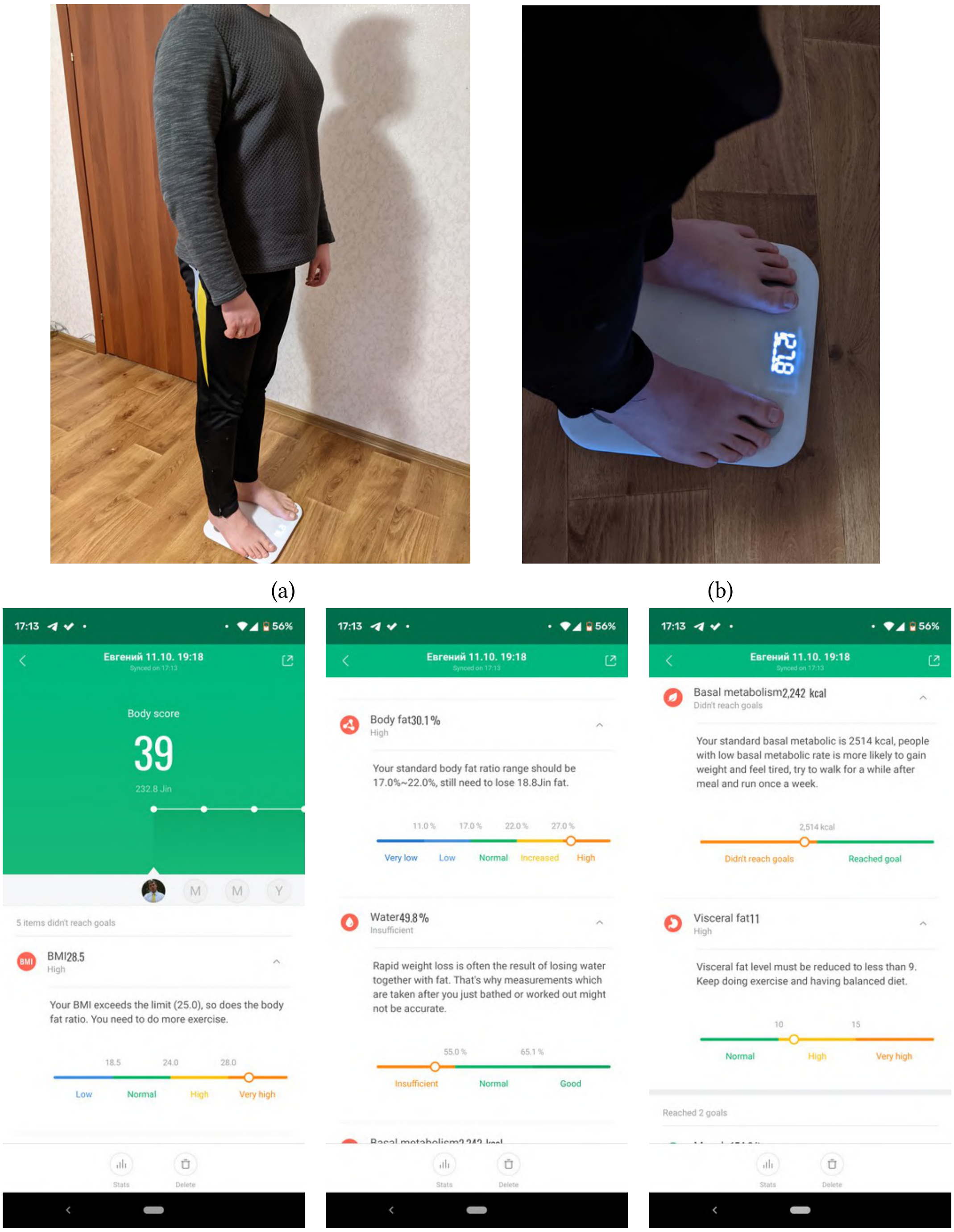
these differences.

Experimental procedure: The experimental procedure involves selecting 10 participants of each gender. Each student measures their muscle, fat, and bone tissue composition. The collected data can be presented in personalized graphs on the participants' smartphones and as a table on a blackboard. The teacher can analyze the data, identify patterns, and explain them to the class.

Data analysis: The analysis focuses on identifying patterns in the amount of muscle, fat, and bone tissue, as well as comparing the actual and relative rates of change in these measures between boys and girls.

It is worth noting that this method is simple and can be implemented in any school without the need for sophisticated or expensive smart equipment. Moreover, it is beneficial as it allows students to obtain real-time measurements compared to the traditional approach, and it facilitates data analysis using smartphones. The hands-on nature of the experiment enhances student motivation for research beyond the classroom. The data analysis involves identifying patterns in the amount of muscle, fat, and bone tissue and comparing the actual and relative rates of change in these measures between boys and girls.

Topic: Assessing blood oxygen saturation in suspected COVID-19 cases (figure 6).



(a) (b)

(c) (d) (e)

Figure 5: Procedure for measuring weight (a), weight display example (b), interface for integral automatic body composition assessment (c), detailed body composition information (d, e).

Figure 6: Result of blood oxygen content determination.

Objective: This experiment aims to teach students how to measure blood oxygen saturation, which is particularly relevant during the COVID-19 pandemic.

Equipment: IoT devices, smartwatches, or fitness trackers with oxygen concentration (saturation) monitoring capabilities.

Experimental procedure: Students measure their blood oxygen concentration using smartwatches or fitness trackers. If the measured value is below 95%, immediate medical consultation is recommended.

Data analysis: This experiment can be performed once, with the data recorded daily and exported to a spreadsheet program like Excel. In a healthy individual, the level of blood oxygen saturation remains consistent and does not vary significantly based on external factors.

By conducting these experiments, students gain valuable insights into the application of smart tools in educational settings, fostering their scientific understanding and enhancing their technological literacy. The hands-on nature of these experiments enables students to engage actively with the data and encourages further exploration and research beyond the classroom.

4.4.2. Long-standing methods in educational research

Topic: Impact of diet on body composition, specifically muscle, fat, and bone tissue (figure 7).

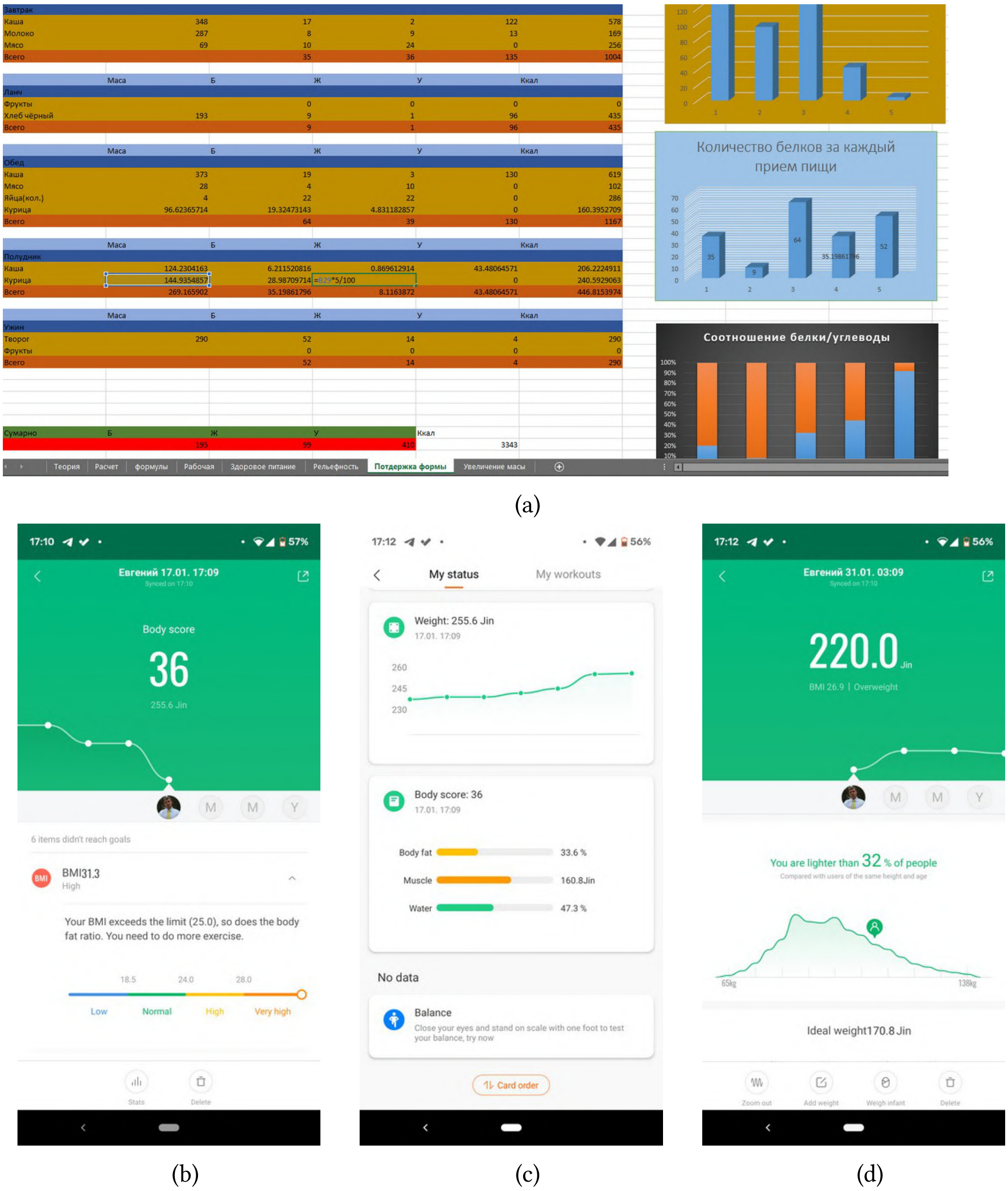


Figure 7: Screenshot of the mathematical modeling method for assessing student nutrition (a), dynamic estimation of body composition (b), current body state (fats, muscles, water content) (c), and weight dynamics compared to other users (d).

Objective: This study aims to elucidate the relationship between diet and body composition, focusing on muscle, fat, and bone tissue, to foster students' understanding of healthy nutrition.

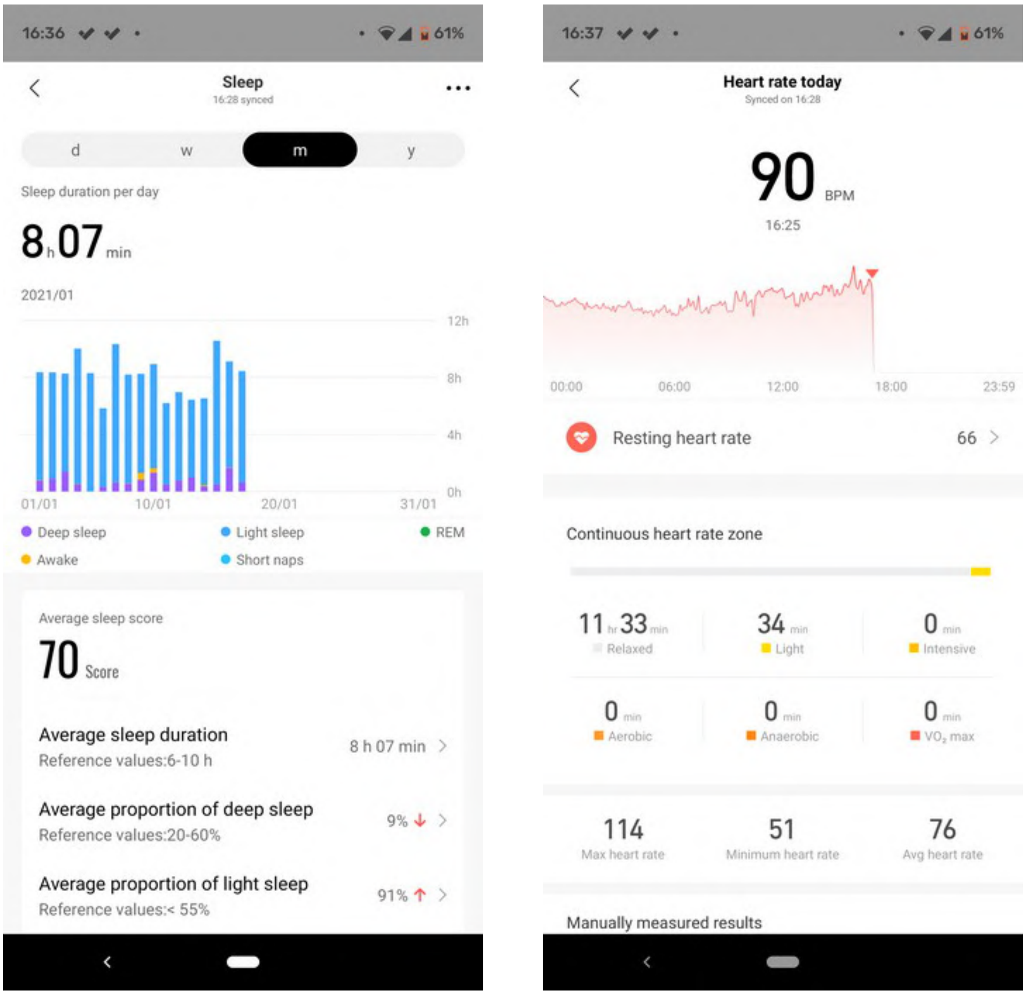
Equipment: Smart scales.

Experimental procedure: Initially, students measure their muscle tissue, fat tissue, and bone tissue using smart scales. Based on the results, students consult with a teacher to set personal goals (e.g., reducing fat tissue) and select an appropriate diet. Over a period of six months, students regularly measure their muscle, fat, and bone tissue, preferably in the morning before meals. The collected data can be analyzed using smartphones or exported to an Excel table.

Data analysis: Students analyze the effectiveness of their chosen diet and draw conclusions about its suitability for their individual needs. They identify trends in the data, including periods of stress and adaptation within the body.

This method can be implemented in various educational settings, and while it is time-consuming, it is highly beneficial for students' research work and participation in contests. It is advisable to conduct the research under the supervision of a teacher or adult.

Topic: The influence of physical activity on sleep duration and heart rate (figure 8).



(a) (b)

Figure 8: Sleep duration dynamics of long and short phases (a) and heart rate dynamics (b).

Objective: This study aims to demonstrate the effects of physical activity on sleep duration and heart rate.

Equipment: Smartwatches or fitness trackers with heart rate monitoring functions; blood pressure and oxygen concentration measurements (optional).

Experimental procedure: Students measure their sleep duration, heart rate, and optionally, blood pressure and oxygen concentration (before physical exertion) for a week. Subsequently, students engage in one of two activities three hours before sleep:

1. Perform three sets of thirty squats and three sets of ten push-ups, repeating the exercise cycle four times a week with three rest days.
2. Run 2-4 kilometers each day for six days a week, with one rest day.

Each day, students record their sleep duration, heart rate, blood pressure, and blood oxygen levels. The data is recorded in an Excel table or using the interface of a smartwatch or fitness tracker.

Data analysis: Students compare the measured parameters before and during the "active" week to assess the impact of physical activity. They evaluate the quality of the long phase of sleep and changes in heart rate before sleep, comparing the results to their overall well-being.

This method is straightforward and suitable for most educational institutions, especially considering the minimal requirement of a smartwatch or fitness tracker. It provides valuable data for student research works and contest participation.

Topic: Effect of physical activity on muscle and fat tissue composition

Objective: This study aims to demonstrate to students that regular exercise increases muscle tissue mass.

Equipment: Smart scales.

Experimental procedure: Students measure their muscle tissue using smart scales. Starting the following day, students engage in one of two options:

1. Perform three sets of 30 squats and three sets of ten push-ups, repeating the exercise cycle four times a week with three rest days.
2. Run 2-4 kilometers every day. Students measure their muscle tissue daily using smart scales over a six-month period. The data can be captured through a smartwatch or fitness tracker interface or imported into Excel for analysis. At the end of the year, students analyze the data to evaluate their muscle tissue development.

Data analysis: Students analyze the weight changes and composition dynamics, focusing on fat and muscle tissue. They identify trends and changes over time, including periods of stress and adaptation. Additionally, students calculate the amount of fat and muscle lost during the research period and determine if the fat reduction process follows a linear pattern or exhibits distinct steps.

As this method involves exercises resembling sports activities, it is essential to undergo a preliminary medical examination and receive supervision from a teacher.

Topic: Influence of fitness zone training on resting heart rate

Objective: To teach students how to calculate their maximum heart rate and identify the target heart rate for the fitness zone. Additionally, students select a set of exercises that maintain the required heart rate during physical activity.

Equipment: IoT devices, smartwatches, fitness trackers with heart rate monitoring functions.

Experimental procedure: Students measure their heart rate using smartwatches or fitness trackers and calculate their maximum heart rate using the appropriate formula based on their gender and age. Next, students determine 70-80% of their maximum heart rate, which represents the optimal heart rate during exercise. Using this information, students design their own set of exercises that allow them to maintain the target heart rate. After three months of regular exercise, students measure their resting heart rate again.

Data analysis: Students evaluate the effectiveness of maintaining their heart rate within the fitness zone during physical activity. They compare the mean physical activity level within the group and examine individual results. Furthermore, students explore the relationship between optimal physical activity, sex, weight, and age.

Throughout the study, students learn to use smartwatches or fitness trackers to collect and process their data effectively.

5. Conclusions

The increasing availability and remarkable performance of smart tools have led to a significant rise in their adoption. With the anticipated shift from 4G to 5G technology, it is projected that by 2022, the global representation of individual smart instruments could reach a staggering 1.1 billion. This implies that approximately one out of every seven individuals on Earth will be utilizing smart tools. In light of this trend, our study focused on introducing concrete methods that can be employed for educational research in STEM-based processes.

For the first time, we proposed the “As is – To be” Business Process Model and Notation (BPMN) method to evaluate the impact of the proposed methods. Through the application of these methods, it was empirically demonstrated that incorporating personal smart tools into STEM education leads to enhanced automation and fosters the development of students’ critical thinking abilities. These tools facilitate graphing, calculations, and engagement in individual research endeavors.

The utilization of personal smart tools for educational research enables the attainment of various competences, including training, health monitoring, ergonomics, mathematical proficiency, natural sciences, engineering and technology, and social skills.

A range of methods have been developed and are now readily available for implementation. These include the “Heart rate measurement before and after physical activity using smartwatches / bands”, “The influence of sleep duration on heart rate”, “Differentiating muscle, fat, and bone composition between males and females”, “Assessing blood oxygen saturation in suspected COVID-19 cases”, “Impact of diet on body composition, specifically muscle, fat, and bone tissue”, “The influence of physical activity on sleep duration and heart rate”, “Effect of physical activity on muscle and fat tissue composition” and “Influence of fitness zone training on resting heart rate” methods.

The integration of smart tools into educational research holds immense potential for advancing STEM education and empowering students to explore and understand various phenomena in a more efficient and comprehensive manner. These findings contribute to the ever-growing body of knowledge in the field of educational technology and provide valuable insights for researchers, educators, and policymakers seeking to enhance learning experiences and outcomes in STEM education.

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