

Emotion Recognition and Continuous Mental Health Monitoring Using Intelligent E-Textiles

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Abstract

The growth in the number of anxiety, stress, and depression cases highlights the importance of consistently, objectively, and conveniently tracking emotions and monitoring them. E-textiles are fabrics that incorporate sensors and microelectronics which provide a comfortable and non-obtrusive structural framework of monitoring physiological and emotional conditions when performing everyday tasks. The paper describes an emotion-recognition system that is human-centric and is based on multimodal sensing, machine learning (ML), and real-time biofeedback in soft wearable textile layers. The suggested system will use textile-based electrodes, piezoresistive pressure sensors, capacitive touch sensors, and lightweight electronic modules to record the major indicators of emotions, including heart rate (HR), heart-rate variability (HRV), electrodermal activity (EDA), respiration rate (RR), EEG signals, and micro-pressure patterns. Experimental findings indicate that ensemble classifiers demonstrate the best performance with the highest precision of 99.15, recall of 99, and F1-score of 99.5 as well as textile-integrated EEG sensors can identify early emotion changes at a maximum of 72 percent accuracy. The system additionally offers subtle biofeedback vibration, breathing guided cues and light modulation to help in emotional self-regulation. A textile architecture with multiple layers and all modules is more comfortable, is more durable and can be replaced easily. In general, the present article shows that intelligent e-textile can be used in practice to deliver real-time, accurate, and individualized mental-health monitoring.

Keywords

Emotion Recognition, Mental Health Monitoring, Machine Learning, Wearable Sensors, Biofeedback

1. Introduction

Emotional health and mental health are very important elements of the health of a human being, and they directly affect productivity, social behavior, and the quality of life. As per the World Health Organization reports, depression, anxiety, and persistent stress are becoming alarming, especially in the cases of young adults and working citizens. Prevention, personalised treatment, and chronic mental health care management can be crucial in the case of early diagnosis and close monitoring of emotional conditions. Traditional mental health assessment techniques, such as clinical interviews, questionnaires, and episodic physiological measurements, have drawbacks in that they are

subjective, biased in recollection, and not real-time. Wearable technologies have become popular in recent years as an objective means of constant health monitoring. Of these, intelligent e-textiles are one of the major developments in which the sensing and computing powers are direct in the fabrics, which allows data collection in everyday life without any unobtrusive interruptions. Physiological signals that have been used in the recognition of emotion have shown promising results, this includes electrocardiography (ECG), electrodermal activity (EDA), electromyography (EMG), respiration rate, and skin temperature. These signals can be used in the application of continuous mental health monitoring when used in combination with intelligent e-textile platforms and advanced data analytics. The purpose of this review is a systematic discussion of the state of the art in emotion-sensitive e-textile systems and research gaps and opportunities for the future.

2. Literature Search Strategy

An electronic literature review was carried out in order to locate and examine the recent studies on emotion recognition and mental health monitoring with intelligent e-textiles. The major scientific databases were searched on combinations of the following keywords: emotion recognition, mental health monitoring, intelligent textiles, smart garments, ECG, EDA, wearable sensors, and machine learning. PubMed, Scopus, Web of Science, and Google Scholar were major scientific databases used. To be relevant and technically mature, the review was narrowed down to peer-reviewed journal articles and conference papers released between 2013 and 2025. A literature search of the chosen articles was also done to locate any other relevant studies. This strategy guaranteed a broad scope of sensing technologies, signal processing techniques, and applications (Figure 1).

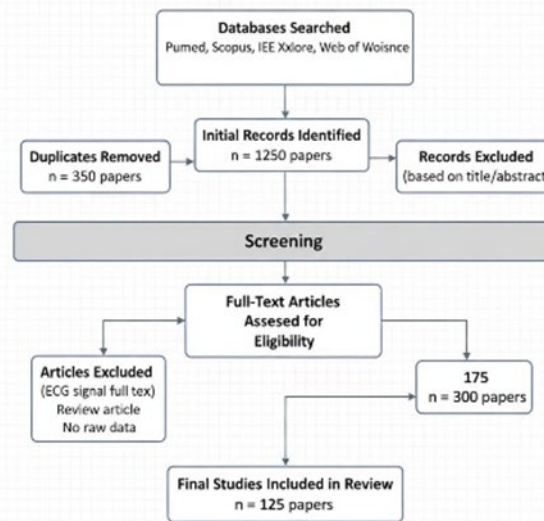


Figure 1. Literature Search Strategy

3. Background and Concept of Intelligent E-Textiles

Also referred to as smart textiles or intelligent e-textiles, smart textiles are textiles that incorporate electronic parts and sensing parts without losing the flexibility, comfort, and aesthetic properties of regular textiles. Depending on the capabilities of their functions, e-textiles are typically divided into three groupings: passive smart textiles, able to detect environmental or physiological parameters; active smart textiles, able to detect and respond to stimuli as well as actuate them; and ultra-smart textiles, able to sense, respond, and autonomously adapt to changes in the environment using built-in intelligence. When applied to mental health monitoring, the use of e-textiles usually involves conductive yarns, electrodes made of textile materials, flexible sensors, and miniaturized processing units so that their regular operation may allow these devices to continuously collect and examine data (Ahsan et al. 2022). E-textiles afford better wearability, fewer motion artifacts, and better compliance by users, which is why they are especially useful in the context of long-term and unobtrusive emotional and mental health measurement.

3.1 Electrocardiography (ECG)

Mental and emotional states are commonly measured using one of the most common physiological signals, electrocardiography (ECG). The major indicators that can be derived based on the ECG signals are heart rate (HR) and heart rate variability (HRV), which are closely linked to stress, anxiety, emotional arousal, and activity of the

autonomic nervous system (Burnstine 2025). The change in HRV especially indicates the sympathetic to parasympathetic tone, which is why the alteration is a powerful biomarker of mental health. Intelligent e-textile. In intelligent e-textiles, textile-based ECG electrodes made of conductive yarns, conductive coatings, or patterned embroideries are inbuilt into clothing, e.g. shirt, a breast, or a chest band (Azeem et al. 2025). These are textile electrodes that allow monitoring the heart in a continuous and unimposing fashion throughout the day without negatively affecting the user in terms of comfort and adherence. In comparison with traditional gel-based electrodes, textile ECG sensors are better at causing skin irritation and can be used more effectively in mental health monitoring and long-term applications, though other issues like motion artifact and variable electrode-skin contact are also still under study.

3.2 Electrodermal Activity (EDA)

Electrodermal activity (EDA) is an instrument for measuring the presence of changes in skin conductance due to the activity of the skin glands, which are directly controlled by the sympathetic nervous system (Carlson, n.d.). Consequently, EDA is a very sensitive measure of emotional excitement and anxiety, mental stress, and anxiety. The EDA sensors are commonly applied to the regions of high concentration of sweat glands, like the cuff, palm, or inner garment surface, that are maintained in a fixed contact with the skin in the smart textile systems. Sensors based on textile EDA usually utilize conductive fabrics or yarns to create electrodes that have the capability of recording tonic (skin conductance level) and phasic (skin conductance response) elements. These aspects can give essential information about not only short-term emotional responses but also stress patterns in the long term. Although textile-based EDA sensors can be more comfortable and wearable than the rigid ones, the stability in electrode contact and reduction of noise by movement and other environmental factors are still relevant design issues.

3.3 Electromyography (EMG)

EMG signals are electrical activities recorded as a result of muscle contractions and are especially useful in identifying minor muscle movements that can be linked to facial expressions during stress or anxiety, e.g., facial tension. It has been demonstrated that ECG-based emotion recognition supplements cardiovascular and electrodermal responses with expressive and behavioral responses of the body. Compared to ECG or EDA, inclusion of EMG sensors in textiles is harder because of the requirement of accurate positioning of electrodes and high contact between the skin and electrodes (Dejene 2025). But recent developments of flexible and stretchable conductive materials, embroidered electrodes, and soft textile interfaces have enhanced the practicability of textile-based EMG systems.

3.4 Respiration and Skin Temperatures

The respiration rate and skin temperature are the two physiological variables that give precious information about mental and emotional conditions, especially when it comes to relaxation, stress, and anxiety. The alterations in breathing patterns, including higher breathing rate or abnormal breathing, are generally accompanied by the growth of stress and emotional arousal. Equally, the changes in skin temperature indicate blood flow changes in the periphery, which are regulated by the autonomic nervous system. Textile-based piezoresistive, piezoelectric, or strain sensors built in the chest or abdominal locales commonly measure respiration, whilst thermoresistive or thermocouple-based textile sensors measure skin temperature in e-textile systems. With these sensors, the monitoring process is continuous and unobtrusive and does not limit the movement of users. Respiration and skin temperature measurements, together with ECG, EDA, and EMG data, increase the strength and precision of multimodal mental health monitoring in intelligent e-textiles (Hooda 2023).

4. Physiological Cues of Emotional Recognition

The basis of emotion recognition systems lies in the correlation of emotional states and autonomic nervous system (ANS) governed physiologies. Emotions arouse differences in sympathetic and parasympathetic activity that can be detected as changes in cardiovascular and electrodermal activities, muscular activity, respiratory and thermal activity. Smart e-textiles offer a special medium to receive such signals at all times and without being invasive by embedding sensors in their daily clothes (Islam et al. 2024). This is a smooth connection that allows the long-term data collection under natural conditions, which is essential to effective emotion recognition and mental health evaluation. The most common physiological cues that have been employed in e-textile-based emotion recognition systems are electrocardiography (ECG), electrodermal activity (EDA), electromyography (EMG), breathing, and skin temperature. The signals correspond to the various elements of emotional processing: ECG-derived values, including heart rate and heart rate variability, reflect the level of stress and emotional arousal, EDA response will reflect the rapid sympathetic response to excitement, anxiety, or fear, EMG will provide the data about muscle tension and

expressive behavior, respiration patterns will reflect the state of relaxation or stress, and changes in skin temperature will indicate the peripheral vasoconstriction or vasodilation related to emotional changes. Using such multimodal physiological cues, e-textile-based emotion recognition systems can be more robust and accurate than single-sensor systems. The combination of various signals can counter the noise, motion artifacts, and personal differences, which are typical pitfalls in real-world monitoring. (Figure 2).

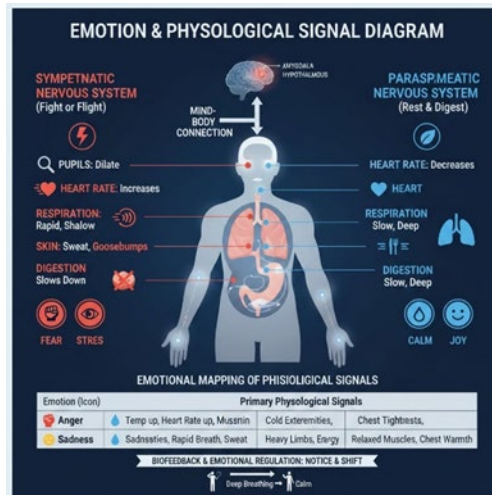


Figure 2. Emotional and Physiological Diagram

5. Emotion-Aware E-Textiles System Architecture

The general intelligence e-textile system used in mental health monitoring has a layered architecture, which guarantees orderly data flow, modular design, and integration with digital healthcare systems. The sensing layer forms the basis of the system, which comprises textile-based physiological sensors that are able to continuously record bio-signals, which include electrocardiography (ECG), electrodermal activity (EDA), respiration, body temperature, and motion. These sensors are made in the form of conductive yarns, embroidered electrodes, or printed flexible circuits so that they can be unobtrusively monitored over a long period of time without compromising the comfort and compliance of the wearer- a crucial feature in mental health applications (Jiang et al. 2024). The data acquisition layer involves the transformation of raw physiological data into a useful digital data format (Figure 3). This layer comprises signal conditioning devices like instrumentation amplifiers, filters, and noise-reduction modules that help to reduce motion artifacts, electromagnetic interference, and baseline drift that are often experienced when using wearable devices. The conditioned signals are then digitized by analog-to-digital converters (ADCs) at the right sampling rates and resolution in such a way that data fidelity is preserved to allow further data analysis. At this stage, such strategies as efficient power management are frequently incorporated to enable low-power and long-duration operation.

The processing layer will be used to extract features and classify them as emotion or mental-state using embedded processors or edge-computing platforms. Time-domain, frequency-domain, and nonlinear variables, including heart rate variability (HRV), skin conductance responses, and breathing patterns, are derived and input into machine learning or deep learning algorithms to determine stress, anxiety, depression, or emotional arousal. The edge-based processing has lower latency, maintains user privacy, and the system does not rely on constant cloud connectivity, which is more dependable in real-time applications of mental health monitoring. The communication layer allows safe and energy-efficient conveyance of processed or raw data to external devices. Bluetooth Low Energy (BLE), Wi-Fi, and Near Field Communication (NFC) wireless protocols are usually used, depending on the data rate, range, and power limitations needed (Jiang et al. 2024). This layer guarantees a connection with smartphones, gateways, and healthcare infrastructure, as well as providing encrypted data transfer to secure sensitive mental health data. Lastly, the application layer offers a visualization, feedback, and decision support via mobile applications or cloud-based applications. It is a user-friendly layer that converts complicated physiological and emotional information into user-friendly dashboards, alerts, and user-specific recommendations to users, caregivers, or clinicians (Liu et al. 2025).

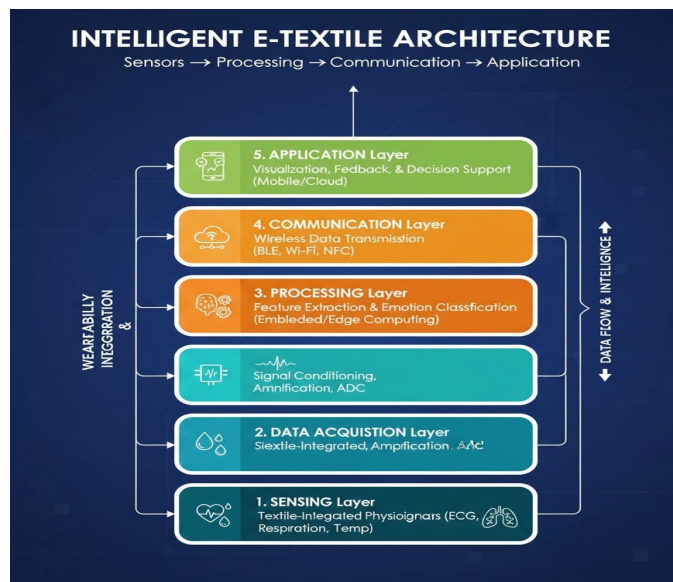


Figure 3. System Architecture of Emotion-Aware E-Textiles

6. Data Processing and Machine Learning Techniques

Raw physiological signals obtained through intelligent e-textiles are by nature vulnerable to noise, motion artifacts, and signal variability due to body movement, cloth deformation, and interference with the environment. Consequently, signal preprocessing is an important process to guarantee the data reliability and enhance the wellness of the downstream analysis. Digital filtering (e.g., low-pass, high-pass, band-pass, and notch filters) to minimize power-line interference and high-frequency noise, and baseline correction techniques to eliminate slow signal drifts are common examples of preprocessing (Liu et al. 2025). Also, normalization and standardization are used to minimize inter-subject and intra-subject variability and allow predictable feature representation inter-subject and across recording sessions. After preprocessing, feature extraction takes center stage, whereby physiological signals are converted to informative features used to reflect underlying emotional and mental conditions. Short-term physiological fluctuations are embodied in time-domain features like mean, variance, peak-to-peak amplitude, and heart rate variability (HRV) indices (Sharma et al. 2025).

The frequency-domain features, derived as a result of Fourier or wavelet transforms, offer information about the activity of the autonomic nervous system based on the analysis of power spectral density in various frequency bands. Moreover, nonlinear characteristics such as entropy counts, fractional dimensions, and recurrence quantification analysis are becoming more widely used to describe the nonlinear and non-stationary characteristics of physiological signals related to emotional reactions. A large variety of machine learning algorithms have been used in emotion recognition and mental health classification. Support Vector Machines (SVM), k-Nearest Neighbors (k-NN), Random Forests (RF), and Artificial Neural Networks (ANN) are some of the traditional classifiers that are still popular because they are easy to interpret, computationally efficient, and they perform well in structured feature sets (Shuvo et al. 2022). But, as multimodal physiological data becomes increasingly accessible, deep learning methods have received a lot of interest. Convolutional Neural Networks (CNN) are good at the automatic feature learning of raw (or minimally processed) signals, and Long Short-Term Memory (LSTM) networks are good at the temporal dependence of sequential physiological data (Veske-Lepp et al. 2024) (Figure 4).

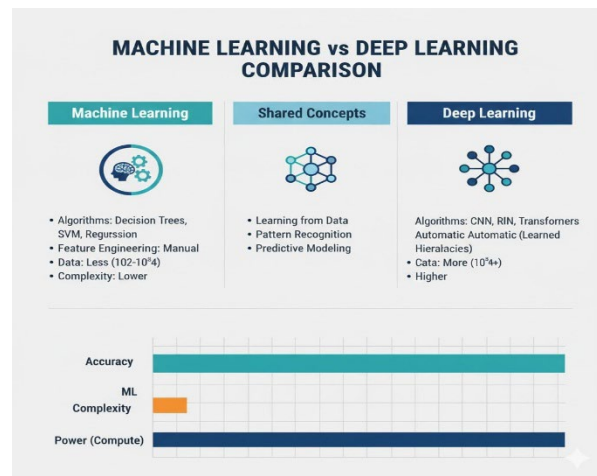


Figure 4. Contrast of Machine Learning and Deep Learning

7. Challenges and Limitations

Despite the progress made, a number of factors, specifically related to the technical, functional, and ethical domains, continue to limit the applicability and effectiveness of emotion-aware e-textile systems. Firstly, the volatility of signals is one of the most serious factors that limit the applicability of physiological signals, such as ECG, EDA, and EMG, due to their extreme susceptibility to movement, posture, and environmental factors, thus being adversely affected by noise and subsequently classified into incorrect emotional states (Shuvo et al. 2022). Secondly, the power and energy aspects also remain a serious limitation, specifically due to restricted battery lifetimes that accentuate the need for recharging, thus further adversely affecting applicability, while energy harvesting techniques are also very much in the early development stage. Lastly, wearability, with respect to durability and washability, also constitutes a serious limitation due to restricted testing standards, thus making it extremely problematic regarding evaluation, applicability, and comparison among research works, while also accentuating adverse effects due to repeated stress, bending, and washing efforts, especially concerning textile-based sensors. Finally, the ethical aspects related to user data, especially regarding emotion, also constitute a very serious limitation due to the extreme sensitivity of data, thus accentuating complications regarding security, consent, and misuse, especially concerning clinical, work, and commercial aspects.

8. Future Research Directions

Future studies on emotion-aware e-textiles should focus on the following key research thrusts. First, multimodal sensor fusion is a must, whereby the combination of multiple physiological and environmental measures, such as ECG, EDA, respiration, movement, and environmental variables, has been found in various studies to improve the accuracy of emotion recognition. Hardware-related studies should also focus on the development of energy harvesting e-textiles that are free from battery recharging limitations and continuous usage. Methods that should be pursued include textile triboelectric, piezoelectric, or thermoelectric energy converters. On the analytics side, there is also a need to incorporate the principles and techniques of explainable artificial intelligence or XAI (Ahsan et al. 2022). There are potential benefits in terms of increased trust and confidence in the emotion recognition results by healthcare professionals. Moreover, the output of the analysis can also facilitate acceptance by regulatory bodies because it gives the freedom to professionals or clinicians to decide on the automated analysis method. In particular, there should also be an emphasis on integrating emotion recognition in e-textiles with Industry 4.0 concepts and smart health infrastructures. This allows the integration of various IoT frameworks, cloud computing platforms, and digital twins that facilitate innovations in healthcare informatics and smart health infrastructures. Finally, there should also be an emphasis on doing comprehensive studies that are representative of long-term system reliability and effectiveness in different environments (Veske-Lepp et al. 2024).

9. Conclusion

Intelligent e-textiles have recently emerged as a useful and human-centric technology for emotion recognition and real-time mental health monitoring, effectively closing the gap between wearable technology and AI. The integration of biological sensors directly into wearable clothes has recently enabled the unobtrusive, real-time, and long-term

evaluation of emotional and mental conditions, solving several limitations pertinent to traditional clinical and wearables-based monitoring methods. Additionally, the integration of multimodal sensing, edge intelligence, and mobile health platforms has further improved the effectiveness of these technologies for providing individualized, context-aware, and scalable mental health care. Notwithstanding the considerable advances, challenges pertinent to reliability, energy efficiency, ease of use, data security, and the lack of standards are currently hampering the widespread use and clinical adoption. However, with the current advances in textile materials science, low-energy electronics, multimodal sensor fusion, and Explainable AI, these challenges are being effectively mitigated. Furthermore, the integration of Industry 4.0 technologies with emotion-aware e-textiles and the underlying IoT infrastructure has recently opened new horizons for the development of predictive mental health care, workplace well-being, and assistive living technologies. In summary, intelligent e-textiles are poised to become the next-generation solution for real-time mental health monitoring. Given the necessary interdisciplinary advances, design guides, and large-scale clinical adoption, these technologies are poised to play an integral role in shaping the future of mental health care and human-centric technology, henceforth paving the way for improved emotional well-being.

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Biographies

Kathika Majumder has completed her BSc (Hons) in Mechatronics Engineering from the World University of Bangladesh. Her research interests include robotics, Robot Operating System (ROS), SLAM, computer vision, autonomous navigation, embedded systems, and IoT-based intelligent solutions. She completed her undergraduate thesis titled "AI-Enhanced Visual SLAM for Robust Autonomous Navigation in Dynamic Rescue Missions," focusing on perception-driven mapping and localization using ROS Noetic, OpenCV, and TurtleBot3 simulations. Kathika has participated in several technical workshops on research paper writing, publication, and scientific poster presentation, along with hands-on projects in Arduino, sensors, Python, MATLAB, Proteus, AutoCAD, and embedded system prototyping. She has experience mentoring students through workshops on obstacle-avoiding line follower robots and has presented projects on smart city solutions and energy-efficient systems. She served as Senior Executive of Archive

at the WUB Robotics Club, Assistant Treasurer at the WUB Mechatronics Club, and a General Member of Prothom Alo Bondhushava. She also volunteered as a teacher at Zoom Bangladesh, contributing to the education of underprivileged children and supporting low-income communities.

Md. Sharif Uddin Shajib is a Lecturer in the Department of Electrical and Electronic Engineering (EEE) at the World University of Bangladesh (WUB). He holds an M.Engg. in Telecommunication Engineering and a B.Sc. in Electrical and Electronic Engineering, both from WUB. His academic career reflects a strong foundation in telecommunication, signal processing, and next-generation wireless networks. With progressive roles ranging from Senior Lab Assistant (2016–2020) and Teaching Assistant (2020–2023) to his current lecturing position, he has developed deep expertise in teaching, research, and lab modernization. His current research centers on resource allocation in photonic systems, wireless communication, and the evolution of 5G/6G networks, with an emphasis on simulation-driven design and performance analysis.

Tanzim Hossain Oyshi is a 4th-year undergraduate student in the Department of Textile Engineering at the World University of Bangladesh (WUB), where she maintains an excellent academic record. Her primary research interests include functional textiles, sustainable materials, natural fiber composites, and the environmental impacts of textile processing. She previously served as a Research Fellow under the Ministry of Science and Technology, contributing to the project titled “Development and Characterization of Locally Available Natural Fiber Reinforced Polypropylene (PP) Matrix Based Partially Degradable Composites for Civil Construction.” In this role, she was actively involved in experimental analysis, fiber–matrix characterization, mechanical testing, and material evaluation, supporting the development of eco-friendly composite materials. Oyshi has authored multiple publications covering diverse yet impactful areas, including taro fiber properties, eco-friendly material development, environmental consequences of textile dyes, and the psychological effects of the COVID-19 pandemic. Her work reflects a strong commitment to sustainability-driven innovation and interdisciplinary research. Beyond academics and research, she is deeply engaged in leadership and extracurricular activities. She currently serves as the President of the IEOM Society WUB Student Chapter and the Organizing Secretary of the WUB Textile Club, along with contributing as a Campus Ambassador for various textile and engineering platforms. Throughout her journey, she has also actively participated in volunteering initiatives, especially in projects supporting underprivileged street children. Passionate about research, sustainability, and community impact, Oyshi aims to continue advancing environmentally responsible textile solutions and contribute to research-driven innovations that address global challenges.

Moubassira Akter is a Mechanical Engineering student at the World University of Bangladesh, focusing on developing a strong foundation in core mechanical engineering subjects. She is building her skills in thermodynamics, fluid mechanics, manufacturing processes, machine design basics, and engineering materials. She is also learning essential engineering tools and techniques used in academic and industrial applications. At her university, she is involved in class projects, lab work, and research activities related to mechanical systems, energy technology, industrial operations, and sustainability. Her interest lies in understanding how machines work, how energy is used, and how engineering solutions can make everyday systems more efficient. Moubassira aims to grow as a dedicated mechanical engineer and contribute to fields such as energy systems, industrial engineering, and sustainable technology development. She is committed to continuous learning, practical problem-solving, and applying engineering principles to real-life challenges.

Sheak Nahian Islam Rakin is an engineering student in Bangladesh at World University Of Bangladesh, focused on building a strong academic and practical foundation in core engineering subjects, specially in Mechatronics Engineering Subjects. He is developing skills in areas such as electrical machines, automation, control systems, basic electronics, and engineering mathematics, along with an understanding of related mechanical and industrial concepts. Through his university studies, Sheak Nahian Islam Rakin actively participates in class projects, laboratory work, and technical assignments that enhance his problem-solving and analytical abilities. He is learning essential engineering tools, techniques, and methodologies used in both academic research and industrial applications. His interests lie in understanding how electrical and automated systems operate, how energy is converted and utilized, and how engineering solutions can improve efficiency, reliability, and sustainability in real-world systems. Sheak aims to grow as a dedicated engineer with a strong technical base and practical mindset, contributing to fields such as automation, energy systems, and industrial technology. He is committed to continuous learning, hands-on experience, and applying engineering principles to solve real-life challenges effectively.

Tanjid Alam Khan is a mechanical engineering student at the World University of Bangladesh, dedicated to building a strong foundation in core mechanical engineering disciplines. He is currently expanding his knowledge and skills in

the areas of thermodynamics, fluid mechanics, manufacturing processes, introductory machine design, and engineering materials. Alongside his academic studies, he is actively working on skill development, practical learning, and creative problem-solving. At his university, He is engaged in class projects, laboratory work, and technical activities related to mechanical systems and industrial applications. His interests focus on understanding how machines operate, how energy is utilized, and how engineering principles can be applied to improve efficiency and performance. He aspires to do impactful work, build meaningful engineering solutions, and contribute to innovative and sustainable developments in the field. Tanjid's professional goals include becoming a proficient mechanical engineer, leading innovative engineering projects with significant impact, and joining a well-regarded company to apply his skills to real-world issues, thus generating a lasting positive effect through engineering endeavors.