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AN INTERDISCIPLINARY EDUCATIONAL MODULE INTEGRATING ELECTRONICS, MATHEMATICS, PROGRAMMING LANGUAGE AND PHYSIOLOGY TO CULTIVATE CREATIVITY AND ENTREPRENEURSHIP

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Abstract

Incorporating creativity, innovation, and entrepreneurship education in the curriculum of university level programs of health sciences will enable the graduates to tackle complex healthcare and biomedical problems. However, the traditional educational models are insufficient to address these needs. For effective problem solving and innovation, educational systems with integrative and interdisciplinary components are necessary. This paper introduces an interdisciplinary education module tailored for graduate students of health sciences students. The module combines four disciplines - physiology, electronics, programming, and mathematics, to impart education through a problem-based, hands-on approach. The interdisciplinary module will enable students from diverse academic backgrounds to collaboratively work to design and develop an electrocardiogram (ECG) signal acquisition system and interpret ECG data. We have also provided methods to evaluate the learning outcomes by assessing creativity, innovation, problem-solving, and entrepreneurship through methods such as creating open-ended designs, real-world problem-solving challenges, entrepreneurship pitches, collaborative peer reviews, and writing reflective reports. This integrated hands-on learning framework inspires interdisciplinary collaboration and

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entrepreneurial thinking among graduate level students of health sciences to develop practical and novel solutions to healthcare challenges. By imparting foundational theoretical knowledge along with the necessary skills and competencies, this module will contribute to the advancement of education and entrepreneurship in health sciences.

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KEYWORDS: Fourier Transform, Signal processing, Arduino, Electrocardiogram, Entrepreneurship

1. INTRODUCTION

In health sciences, creativity and entrepreneurial mindsets are necessary for creating professionals that can tackle complex real-world biomedical problems. Evidence suggests that traditional teaching models do not sufficiently address the integrative skills necessary for interdisciplinary innovation [1]. Integrative teaching approaches such as collaborative problem-based learning (PBL), cross-disciplinary curricula, and experiential training are better in preparing the students for solving real world problems by integrating knowledge from basic science, clinical practice, technical streams, and entrepreneurial thinking [2] [3]. For example, PBL models encourage collaboration, contextual learning, and self-regulation, which are important for creative and innovative approaches to healthcare challenges [4] and promoting the entrepreneurial mindset.

An entrepreneurial mindset incorporates adaptability, problem-solving, creative ideation and novel solutions for multifaceted problems [5]. The program curriculum, especially the one that provides exposure in entrepreneurship education, plays a key role in shaping entrepreneurial mindset and intention among students of graduate level programs [6] [7]. Since real-world healthcare challenges are not just limited to a single discipline, students must learn to integrate knowledge and skills across multiple STEM fields, as well as fields outside of STEM, such as sociology, economics, etc. Students should participate in design-based assignments, which encourage them to research and actively resolve real-world challenges [8].

This research work presents the design and implementation of an interdisciplinary education module for the graduate level students of health science programs by combining mathematics, electronics, programming, and physiology in a problem-based, hands-on format to promote innovation, creativity, and entrepreneurship. The module focuses on imparting both theoretical knowledge and the practical experience, regardless of the educational background of the students, through the process of building an electrocardiogram (ECG) signal acquisition system using multi-disciplinary and integrated approaches.

2. Methodology

This multidisciplinary educational module is designed for the undergraduate and graduate level students of diverse health science programs. The module integrates knlwledge and skill levels from multiple disciplines, including electronics, programming, mathematical applications, and

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physiology, to detect, visualize and analyze electrocardiogram (ECG) signals using a device. The various components of the device are illustrated in Figure 1.

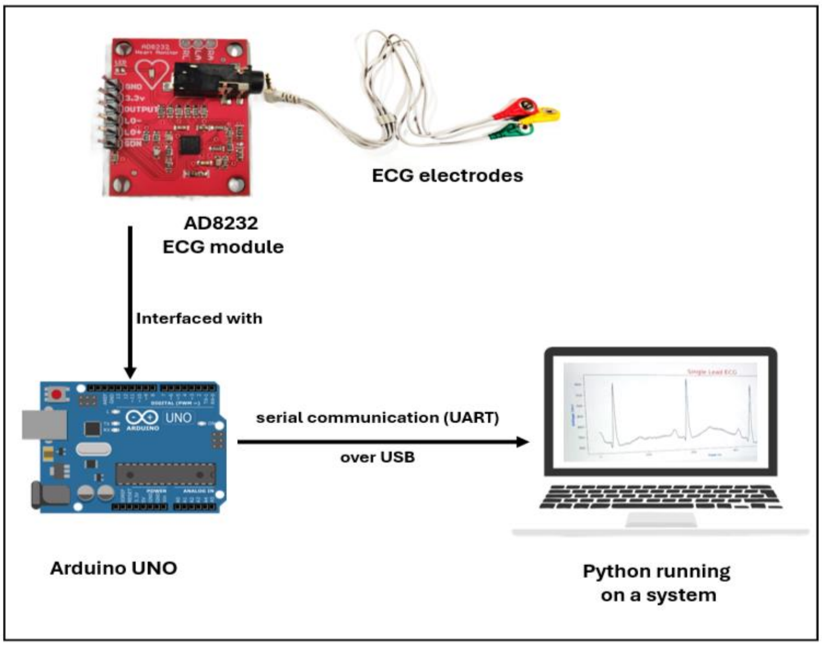

FIGURE 1. An illustration of the components and devices used in capturing ECG signals. The components include- AD8232 ECG sensor module to capture and amplify the signals, Arduino uno for analog-to-digital conversion and python program to visualize and analyse the ECG.

The educational module consists of four interconnected components, as given below:

A. Physiology Module:

This module provides a comprehensive theoretical foundation on the cardiac conduction system. The cardiac conduction system involves the generation of impulse and its conduction via sinoatrial node, atrioventricular node, bundle of His, and Purkinje fibers. Emphasis is placed on understanding the generation of action potentials, cardiac electrical impulses and the corresponding ECG waveform components such as the P wave, the QRS complex, and the T wave [9].

B. Electronics Module:

The electronics module involves theoretical foundations in analog signal acquisition and amplification, analog to digital conversion, signal filtering and its transmission modes. The signal acquisition and filtering are done using the following hardware components

B1. The AD8232 ECG sensor module

The AD8232 ECG Module consists of the AD8232 integrated circuit from *Analog Devices*. It is a widely used compact single-lead ECG device designed to extract, amplify, and filter small

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bio-signals such as cardiac electrical activity [10] for hobby electronics and educational purposes. It can be interfaced with the human body through three limb electrodes, to detect the cardiac electrical signals, which can then be amplified and processed. It has additional features such as common-mode rejection to minimize interference, limb leads off detection to ensure electrode connection status, and single-supply operation, which makes it suitable for portable and wearable ECG monitoring applications.

B2. Electrodes for Signal Acquisition

Commercially available electrodes can be used as limb electrodes to capture the cardiac electrical signals. Three limb electrodes [right arm, left arm, and right leg (as ground)] help capture the signals, which are then amplified by the AD8232 ECG module.

B3. Microcontroller

The AD8232 ECG sensor module is integrated with the microcontroller- Arduino Uno, which acts as the analog-to-digital converter (ADC) to digitize the amplified analog signal. The analog signals are converted into digital values which are then sent to a computer via a USB connection, to further process and plot them.

B4. Serial Communication Setup

The Arduino transmits the digitized ECG data via serial communication (UART) over USB to a computer. Students learn to configure and monitor this communication channel, capture the signal and plot them using a program developed using the Python programming language.

C. Programming Module:

Students learn to code and develop an ECG acquisition program using the Python programming language. The application receives the ECG data transmitted via serial communication from the Arduino [11]. The application is built using libraries such as pySerial to receive the amplified and digitized ECG signals from the microcontroller, numpy to process the data, and matplotlib to plot the real-time ECG waveform on a laptop. A sample ECG obtained using this setup is given in Figure 2.

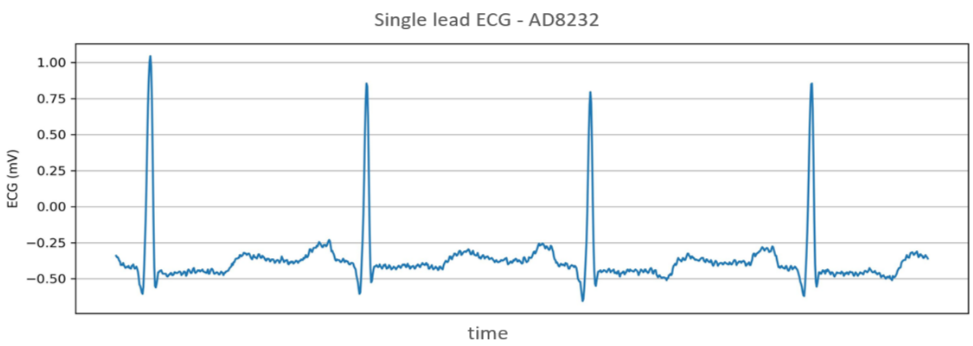

FIGURE 2. A representative ECG graph obtained from the developed ECG acquisition system

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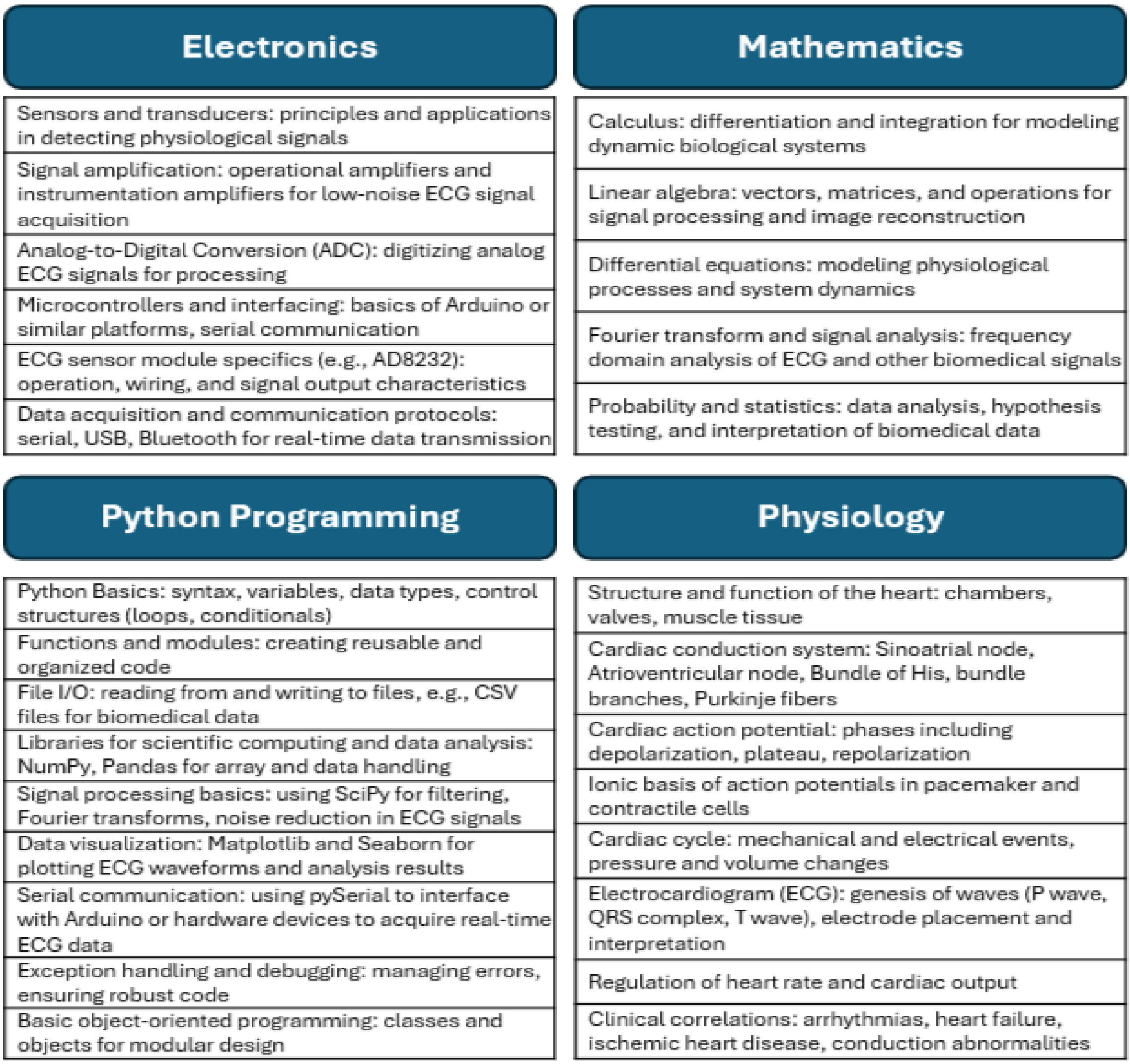

FIGURE 3. The components of the interdisciplinary educational module and the list of topics covered under each discipline

D. Mathematics Module:

Several mathematical applications can be used to filter and clean the ECG signal. The Fourier Transform is a widely used technique to filter noise from the raw ECG signal [12]. The Fourier Transform can be employed on digitized ECG data to filter out noise and enhance signal clarity by isolating certain frequency components corresponding to physiological phenomena (like the ECG). Additionally, the wavelet transforms are also useful for bio-signal filtering.

A comprehensive list of topics to be covered in each module is provided in Figure 3.

3. ASSESSMENT AND EVALUATION

One of the important aspects of pedagogy is to assess the impact of the teaching methodology on the learning outcomes using relevant assessment criteria. To create assessment modules that

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align with the objectives of creativity, innovation, problem-solving, and entrepreneurship using the interdisciplinary ECG education module, the following strategies can be considered.

3A. Open-ended design projects

The students can be assigned to innovate or improve aspects of the ECG acquisition and analysis system. This can include enhancements to electrode placement, signal amplification, noise reduction, data visualization, device ergonomics etc. The students can be assessed based on their creativity by uniqueness, feasibility of ideas, and innovation [13].

3B. Real world problem-solving scenarios

The students can be encouraged to present clinical, technical and patient-related problems, such as designing a low-cost portable ECG for remote areas or developing algorithms to detect arrhythmias. This helps to evaluate students' problem-solving approach, technical soundness, and innovative solutions [14].

3C. Entrepreneurship pitch and business plan

The main objective of developing this module is to foster entrepreneurial mindset. Students can be encouraged to create and present a business pitch for their ECG device. The presentation should include the target market, value proposition, competitive advantage, and commercialization strategy for the device or any related services. This process will help to assesses their entrepreneurial mindset [15].

3D. Collaborative peer reviews

Peer review is a process where the students critique each other's designs and solutions. The critical suggestions provided by the peers will encourage collaborative creativity, an essential component of entrepreneurship [16].

3E. Reflective report writing

In this assessment method, the reflective reports prepared by the students can be evaluated. Reflective reports encourage the students to journal their creative process and the entrepreneurial insights they have gained by participating in this educational module. This improves the self-awareness about the process and entrepreneurship [17].

To ensure transparent and actionable feedback that aligns with the learning objectives, we have also provided detailed rubric with specific questions for each of the criteria (Figure 4). The students can be scored based on their responses and performances. This rubric and assessment chart can be used to provide qualitative feedback based on their performance.

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Criteria	Scoring			
	Exemplary (4)	Proficient (3)	Developing (2)	Beginning (1)
Originality	Ideas are highly original, novel, and show unique insight into the problem.	Ideas are mostly original with some novel approaches.	Ideas are somewhat original but mostly derivative.	Ideas lack originality or are copied.
Problem Solving	Identifies key problems clearly, proposes effective and innovative solutions with logical reasoning.	Identifies problems adequately and proposes plausible solutions.	Identifies some problems but solutions lack depth.	Fails to identify relevant problems or solutions.
Integration of Disciplines	Seamlessly integrates physiology, electronics, programming, and mathematics to create innovative solutions.	Integrates most disciplines with minor gaps in coherence.	Shows limited interdisciplinary integration.	Lacks integration of disciplines.
Entrepreneurial Thinking	Presents a clear value proposition with market potential, demonstrates understanding of commercialization and feasibility.	Shows awareness of practical application and feasibility.	Shows limited understanding of entrepreneurial aspects.	Lacks consideration of market or feasibility.
Creativity in Execution	Demonstrates creativity in design, experimentation, iteration, and refinement of the product/solution.	Shows some creativity in design and improvements.	Attempts creativity but limited scope or impact.	Minimal or no creativity in execution.
Communication and Reflection	Communicates ideas clearly and persuasively; provides insightful reflection on creative process and learning.	Communicates effectively with adequate reflection.	Communication or reflection is partial or unclear.	Poor communication or lacks reflection.

FIGURE 4. The assessment criteria and the rubrics for evaluating the performance of the students.

This interdisciplinary education module aligns with several Sustainable Development Goals (SDGs) of the United Nations. These include- SDG 3 (Good Health and Well-being) by improving knowledge and technologies for improved healthcare outcomes, SDG 4 (Quality Education) by imparting interdisciplinary education, and SDG 9 (Industry, Innovation, and Infrastructure) by promoting innovation and entrepreneurial competencies among students of health science programs.

4. CONCLUSION

We have designed and presented an interdisciplinary educational module that offers a novel and integrative approach to train the graduate level students of health science programs. This module combines diverse disciplines such as- physiology, electronics, programming and mathematics using a problem-based, hands-on approach to impart education to promote creativity and innovation. The module not only imparts foundational theoretical knowledge but also helps to acquire the necessary competencies for creativity, innovation, problem solving, and entrepreneurship. This framework integrates health sciences, technical knowledge and skills to promote cross disciplinary collaboration to prepare students for complex biomedical challenges.

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