

CHAPTER I

THE PROBLEM AND ITS BACKGROUND

Introduction

Mobility impairment remains one of the most persistent barriers to independence, productivity, and social participation among individuals with physical disabilities globally. According to global disability reports, millions of people rely on wheelchairs as their primary mode of mobility, yet many still struggle due to the limitations of conventional manually operated wheelchairs. Traditional wheelchairs demand continuous physical exertion, upper-body strength, and coordinated arm movement—requirements that many users, especially those with neuromuscular disorders, cardiovascular limitations, or age-related weakness, may not be able to meet consistently. As a result, users frequently encounter reduced mobility, dependence on caregivers, and decreased quality of life. The challenge becomes even more critical in countries where access to specialized assistive devices remains financially and technologically limited.

According to Sathananthan et al., it reveals that Manual Wheelchair users experience psychological impacts, such as hesitation to be seen in a wheelchair and concerns about self-image, leading to reluctance to go outside. Additionally, users face difficulties with basic propulsion skills, physical demands, learning curves, and navigational challenges, often requiring significant effort, especially when dealing with uneven surfaces or inclines. These problems and concerns often restrain the individual's freedom.

Over the years, technological advancement in terms of assistance in different fields have undergone a massive transformation over the past decades playing a vital role in the fields of medical care, recovery and rehabilitation. The development of advanced assistive devices has been driven by the global movement towards human accessibility, inclusivity, and independence for individuals with mobility issues. Despite technological advancements, various traditional mobility aids, especially manual and electric wheelchairs, often lack advanced systems that address multiple measurements of patient assistance. According to global disability reports, millions of people rely on wheelchairs as their primary mode of mobility, yet many still struggle due to the limitations of conventional manually operated wheelchairs. Traditional wheelchairs demand continuous physical exertion, upper-body strength, and coordinated arm movement—requirements that many users, especially those with neuromuscular disorders, cardiovascular limitations, or age-related weakness, may not be able to meet consistently. As a result, users frequently encounter reduced mobility, dependence on caregivers, and decreased quality of life. The challenge becomes even more critical in countries where access to specialized assistive devices remains financially and technologically limited.

People with needs in terms of mobility, to those individuals with conditions such as neuromuscular disorders, spinal cord injuries, stroke-related impairments, and limb disabilities, often experience challenges not only in mobility but also with continuous health monitoring and medication needs. The insufficient component of built-in monitoring systems in traditional wheelchairs created gaps in safety and increased the risk of unnoticed health fluctuations. An example of this is that heart-related irregularities can go undetected without the presence of proper monitoring tools that can potentially lead to serious situations. Additionally, management in medication

schedules can serve as difficulties for patients with cognitive challenges, memory issues, or limited caregiver supervision.

Because of this problem, the emergence of factors that affect humanity's technological advancement has been largely focused on the component's practicality. One of this is the increasing accessibility of microcontrollers, open-source systems, and modular sensors—in particular to Arduino-based software—has strengthened innovations of new opportunities in redesigning robotic—centered devices for assistance, and care. Arduino enables the development of low-cost, customizable, adaptable, and multifunctional components, presenting it as a preferred platform for software developers, engineers, and researchers aiming to address specific user needs. Components such as voice recognition modules, ECG (electrocardiogram) sensors, servo motors, and automated dispensing systems can be integrated into various designs (simple - complex), developing multifunctional assistive technologies that improve both the mobility and health management.

Additionally, the emergence of voice-based technologies has been an essential innovation for individuals with limited hand mobility. Through the usage of speech recognition, commands for devices to perform specific movements have been made possible. This capability is especially beneficial for patients who struggle to operate joystick-controlled and touch-controlled wheelchairs due to muscle weakness or motor impairment. By integrating voice control into wheelchairs, mobility becomes more open and accessible, reducing reliance on caregivers and improving the user's autonomy.

Equally important is the incorporation of biomedical sensors, such as ECG devices, directly into mobility aids. ECG sensors provide real-time monitoring of heart activity, allowing for early detection of unusual patterns such as arrhythmias or abnormal heart rates. When integrated into a wheelchair, ECG systems offer continuous health surveillance, thereby reducing the risks associated with undetected cardiovascular issues. This feature is particularly significant for elderly users and individuals with pre-existing heart conditions.

Medication management is another critical aspect of daily care for individuals with chronic illnesses or mobility limitations. A medicine sorter integrated into a wheelchair can automate the process of organizing and dispensing medicine doses at predetermined intervals. This minimizes the possibility of missed doses, incorrect medicine intake, or medication confusion—issues commonly faced by vulnerable populations. The combination of automation and mobility integration enables users to maintain independence while ensuring safety.

According to Rani et al. (2024), many conventional wheelchairs are expensive and lack enhanced medical features, which led to the creation of an Arduino-based prototype that operates through Bluetooth-enabled, voice-activated, hand gesture, and eye-blink controlled wheelchair that support users with mobility impairment. This highlights the limited health feature of traditional wheelchairs and directly connects to our study, which aims to develop an Arduino-based multipurpose wheelchair that enhances innovative health-focused components by incorporating Voice Motion Commands, ECG Monitoring, and a Smart Medication Sorting System.

By merging these three essential functions—voice-controlled movement, ECG monitoring, and automated medicine sorting—an Arduino-based intelligent wheelchair presents a comprehensive solution to multiple everyday challenges faced by persons with disabilities. Such a system demonstrates the potential of assistive technology not only to enhance mobility but also to support holistic healthcare needs. More importantly, it underscores the idea that assistive devices should not be limited to basic function but should evolve toward multifunctional systems capable of addressing physical, medical, and cognitive dimensions of disability

The present study explores the development and evaluation of such an innovative prototype. Recognizing the limitations of traditional wheelchairs and the growing scope of embedded medical technologies, this research aims to create a fully integrated, cost-effective, and user-friendly assistive device that enhances mobility and patient care. Through continuous monitoring, automated medicine management, and handsfree navigation, the proposed system seeks to improve quality of life, reduce caregiver burden, and promote technological inclusivity.

Statement of the Problem

This study aims to evaluate the impact of creating an Arduino-based Wheelchair, featuring Voice Motion Commands, ECG Monitoring, and Smart Medication Sorting System in the demand of assistance of immobilized patients. The researchers will aim to benefit the assistive needs of immobilized patients and raise inclusivity and accessibility throughout everyday living by answering the following questions:

1. How accurate and responsive is the voice-controlled motion system in terms of:

1.1. Voice Command Recognition Accuracy

1.2. Response time

2. What is the reliability of the ECG monitoring module in terms of:

2.1. Accuracy of heart-rate readings

2.2. Stability of ECG signal/wave data during movement

3. In what ways are the fundamental mobility functions of the Arduino-based wheelchair, like those of a conventional wheelchair in terms of structure, user control, and basic operation?

4. How does the integration of the three subsystem highlights the accessibility as the overall performance of the smart wheelchair?

5. Design and Development of improved Arduino-based wheelchair prototype in assisting the medical, physical and safety needs of immobilized and disabled patients.

Hypothesis

The Arduino-based intelligent wheelchair with voice control, ECG monitoring, and an automated medicine sorter provides a significant improvement in user mobility, health monitoring, and medication management compared to a standard, non-automated wheelchair.

Significance of the Study

This study will aim to benefit different sectors of society. Assistive devices and equipment have become an essential factor in raising mobility support. The development of an Arduino-based wheelchair with an automated medicine-sorting mechanism and ECG monitoring will provide users with a safer, more efficient and supportive mobility system. This study highlights the advantages of implementing automation and health-monitoring technologies into assistive devices, especially for those individuals who require continuous support and assistance. The system enhances independence, reduces the requirement of excessive movements, and promotes safety during emergencies. Through the integration of medicine-sorting and ECG-reading features, the device contributes to improving health management while reducing the burden placed on caregivers and medical staff. The following groups are expected to find this study beneficial:

Persons With Disabilities (PWDs). The study will provide users with a mobility device which enhances independence through automated management of medicines and immediate ECG monitoring, ensuring safety, convenience, and improved daily functioning.

Caregivers. The device reduces caregiver workload by automating medicine organizations and lowering the need for constant manual monitoring. This allows caregivers to allocate their time more efficiently and minimizes risks of medication errors.

Students. This study will provide the students with a deeper understanding of how assistive technologies can be designed to improve a patient's healthcare and mobility. It will also help them grasp the combination of voice commands, ECG monitoring, and innovative systems into practical innovations that address real-world needs.

Healthcare Personnel and Facilities. Clinics, rehabilitation centers, and community health programs can benefit from improved patient monitoring, timely detection of irregular ECG readings, and easier medicine management—leading to a faster response to patient needs.

School Administrators and Educators. This study may serve as a useful reference for schools, particularly those offering STEM, robotics, or healthcare-related curricula, as it showcases practical applications of engineering and technology in solving real-world problems.

Society. The invention provides a more reliable and accessible assistive mobility device, potentially improving the quality of life of vulnerable groups and reducing public healthcare strain by promoting early detection of health abnormalities.

Environment. Although not directly related to ecological conservation, the system still encourages sustainable innovation by promoting smart technologies that

reduce waste in medicine handling and contribute to more organized healthcare routines.

Future Researchers. This study will aid future researchers in improving automated assistive devices. It may serve as a foundation for developing more advanced, AI-driven mobility systems and health-monitoring equipment.

Scope and Delimitations of the Study

This study focuses on the design, development, and basic evaluation of an Arduino-based wheelchair featuring Voice Motion Commands, ECG Monitoring, and a Smart Medication Sorting System. The research is limited to determining the functionality, responsiveness, and overall performance of the developed prototype under controlled, school-based conditions.

The scope of the study includes testing the basic operation of the wheelchair's main features, such as the ability of the system to respond to voice commands, display heart activity using an ECG sensor, and sort and dispense medicine automatically at scheduled times. The study aims to determine whether these integrated systems can support mobility and basic health-related assistance at a prototype level.

The respondents of the study are limited to Grade 10 and Grade 11 students from Marian Learning Center and Science High School, Inc. These respondents participated as evaluators of the prototype's performance and usability, not as patients or actual wheelchair users. Their feedback was used to assess the perceived effectiveness, ease of use, and integration of the system, rather than medical or clinical outcomes.

This study does not include medical diagnosis, clinical testing, or professional health evaluation. The ECG monitoring feature is intended only for basic observation of heart activity and does not replace hospital-grade ECG machines or medical consultation. Interpretation of ECG results and treatment decisions are not included in this research.

The study is also limited to short-term testing of the prototype. Factors such as long-term durability, extended battery life, real-world outdoor use, commercial production, and compliance with medical or pharmaceutical regulations are beyond the scope of this research. The automated medicine sorting system is evaluated only for sorting accuracy and functionality and does not include drug safety validation or advanced security features.

Furthermore, the study does not involve people with disabilities, elderly patients, or individuals with serious medical conditions due to ethical, time, and resource limitations. Testing was conducted in a controlled environment and did not include varied terrain, environmental noise, or long-term daily use. Despite these limitations, the study aims to provide a foundational understanding of how Arduino-based systems can be used to integrate mobility assistance, basic health monitoring, and medication management into a single assistive device. The findings of this research may serve as a reference for future studies that may involve actual users, healthcare professionals, and more advanced testing.

Conceptual Framework

The process of the study and the methods used are illustrated through the conceptual paradigm presented in Figure 1. The input of the study includes the essential components of the Arduino-based intelligent wheelchair, such as the voice recognition module, ECG sensor, automated medicine sorter, Arduino Board, power source, and the wheelchair frame.

At the initial stage, each component is prepared and tested according to its specific function. The voice control module is programmed to recognize the set of verbal commands, while the ECG sensor is calibrated to ensure accurate monitoring of the user's heart activity. Simultaneously, the automated medicine sorter is assembled and programmed to dispense medications at scheduled intervals. All components are controlled and coordinated through the Arduino Board and Arduino Nano, which serves as the central processing unit of the system.

After preparation, the components are integrated into the wheelchair system. The mobility mechanism is configured to respond to voice commands, while the ECG monitoring and medicine sorting functions are synchronized with the movement system. The entire setup is then subjected to a series of tests and adjustments to verify proper operation, improve accuracy, and ensure user safety.

Once system integration and testing are completed, the intelligent wheelchair is utilized for evaluation purposes. During this phase, the user operates the wheelchair using voice commands; heart activity is continuously monitored through the ECG sensor, and medications are dispensed automatically as programmed. Performance data and user feedback are gathered to assess the effectiveness of the system.

The output of the study is a functional Arduino-based intelligent wheelchair that combines voice-controlled navigation, real-time ECG monitoring, and automated medicine dispensing. This system is designed to enhance mobility, support health monitoring, improve medication management, and promote greater independence and safety for individuals with mobility limitations.

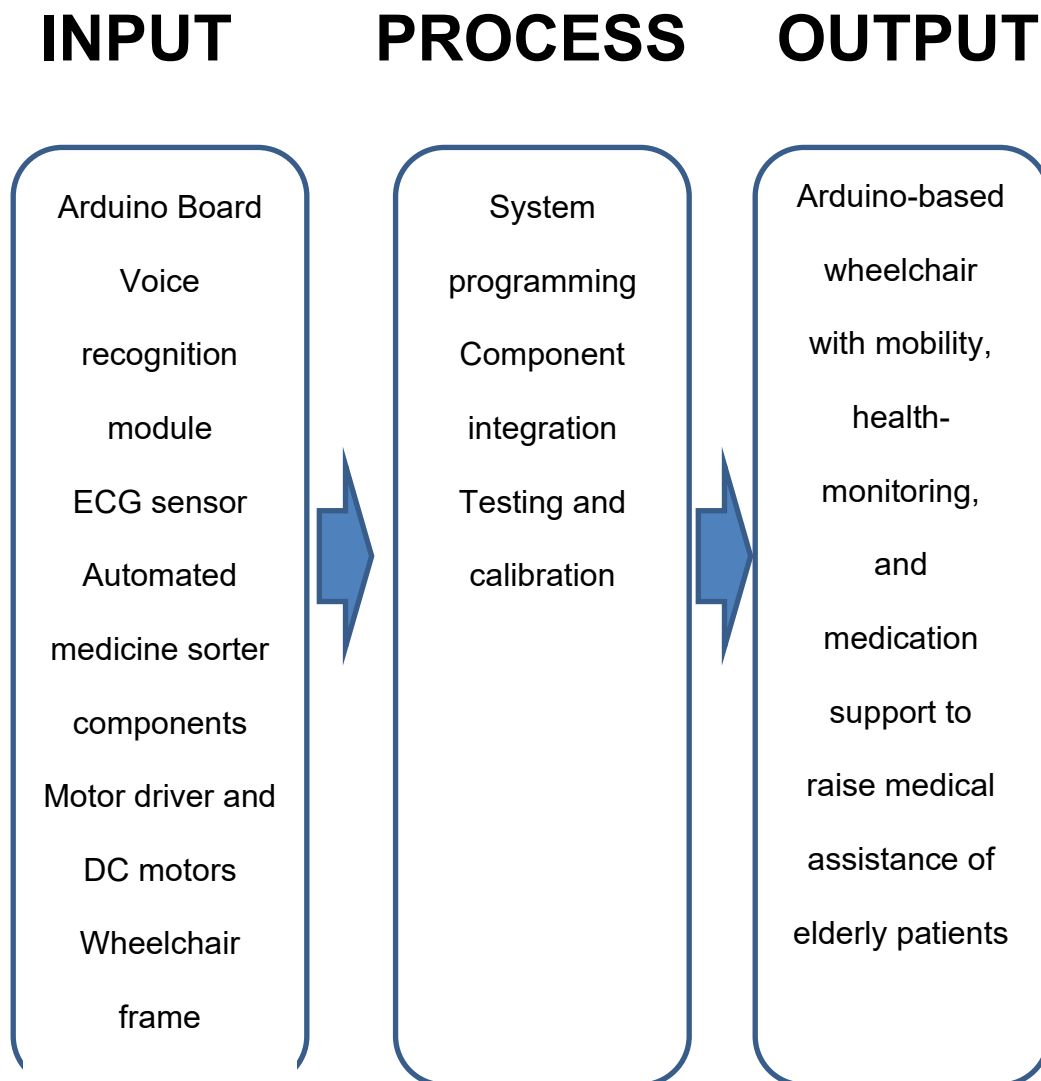


Figure 1: Conceptual Paradigm of the Prototype Creation of an Arduino-Based Wheelchair Featuring Voice Motion Commands, ECG Monitoring, and a Smart Medication Sorting System.

Definition of Terms

Accessibility - The ability to be reached or acquired without difficulty (Cambridge Dictionary, n.d.). In this study, this refers to making the Arduino-based wheelchair easy to reach, use, and benefit from, by ensuring that its features, such as voice commands, ECG monitoring, and medication sorting, are accessible to all users.

Arduino-Based Wheelchair – It is an assistive mobility device enhanced with Arduino technology to automate or control wheelchair functions (Arduino, 2024). In this study, this refers to a manual wheelchair integrated with Arduino components to improve specific features such as ECG sensors, voice or motion commands, and a smart medication-sorting system.

Assistive Technology - Adaptive tools, such as prosthetics or computer programs, designed for and used by people living with a disability to engage in everyday activities (Dictionary.com). In this study, this refers to technology specifically designed to support people with disabilities.

Cardiovascular Limitations - The qualities and abilities of the heart and blood vessels being limited (Merriam Webster Dictionary). In this study, this means that the blood flow and heart rate are at high risk and needs to be observed regularly via the ECG sensor.

Inclusivity – The act of welcoming all kinds of people, things, or ideas and treating them equally and fairly (Cambridge Dictionary, n.d.). In this study, this refers to the ability of the Arduino-based wheelchair to accommodate users with varying needs by providing inclusive access to its functions.

Manual Wheelchair – It is an assistive device propelled by the user or pushed by a caregiver (World Health Organization). In this study, this refers to a hand-operated wheelchair that functions without the use of motors.

Microcontroller – An integrated circuit that contains a microprocessor, memory, and essential electronic components used to control the functions of a device or system (Merriam Webster Dictionary). In this study, this refers to the central unit that processes voice commands, interprets ECG data, and manages the intelligent medication-sorting mechanism.

Mobility Impairment - is a physical condition that limits an individual's capacity to walk or move freely (World Health Organization). In this study, this refers to individuals who cannot walk independently without the use of a standard wheelchair.

Monitoring - A device for observing a biological condition or function (Merriam Webster Dictionary). In this study, this refers to devices that continuously observe physiological conditions, such as an Electrocardiogram (ECG) that monitors the heart's electrical activity.

Neuromuscular Disorders - These are abnormal conditions related to nerves and muscles (Merriam Webster Dictionary). In this study, this refers to the problems regarding to body movements that might require the use of voice control on the Arduino based Wheelchair.

Sensor - A device that responds to physical stimulus (such as heat, light, sound, pressure, magnetism, or a particular motion) and transmits a resulting impulse (as for measurement or operating a control) (Merriam Webster Dictionary). In this study, this refers to devices that detect physiological signals and convert them into

measurable data, such as the sensors used in an Electrocardiogram (ECG) that capture the heart's electrical activity.

ServoMotor - A power-driven mechanism that supplements a main control operated by a comparatively feeble force like in a servo mechanism (Merriam Dictionary). In this study, this refers to a device that amplifies weak input signals into regulated mechanical motion, ensuring precision and reliability in automated systems.

Sorting System - A regularly interacting or interdependent group of items forming a unified whole to perform specific functions or set up the basis of any characteristics in common (Merriam Webster Dictionary). In this study, this refers to the Assistive Arduino Wheelchair; the system operates as one unified assistive through its integrated features.

Voice Motion Commands - Verbal instructions to control or direct actions. (Dictionary.com). In this study, this refers to spoken instructions that are used to control or direct the movements of the wheelchair, especially its robotic components.

Voice Recognition Module - Voice Recognition Module is a compact and easy to use speech recognition board that can be easily interface easily with Arduino (Makerlab Electronics). In this study, this refers to a system that analyzes the human voice to recognize spoken input and respond accordingly.

CHAPTER II

REVIEW OF RELATED LITERATURE AND STUDIES

This chapter presents the various concepts, studies, and data relevant to the research, providing a foundation for further discussion. It also includes a synthesis of these concepts and studies, highlighting notable similarities that can guide the researchers in carrying out their study.

Conceptual Literature

Wheel Chair

Nowadays, wheelchairs significantly influence social participation and quality of life (QoL) among adults who rely on the assistive influence of this equipment as their primary mobility device. A systematic review of 18 studies highlighted that mobility's impact on participation is more frequently studied than its effect on QoL. Key determinants of participation include wheelchair quality, ease of maintenance and repairs, user confidence, and WC skills. Proper provision of wheelchairs following the World Health Organization's eight-step service model was associated with improved physical health, satisfaction with the device, increased usage, and overall QoL enhancement. These findings emphasize the importance of continuous support in wheelchair services and ongoing professional education to optimize WC functionality, facilitate participation, and enhance rehabilitation outcomes. Consequently, clinical interventions targeting wheelchair skills are vital to promoting social engagement and overall well-being in wheelchair users. (Andrade, et al.)

Assistive products, particularly wheelchairs, play a critical role in enhancing the health, well-being, participation, and social inclusion of people with disabilities by promoting independence and access to education, employment, and social engagement. With approximately 240 million children worldwide living with disabilities and many more experiencing temporary or permanent mobility impairments due to illness or accidents, wheelchairs have become essential for daily functioning and autonomy. However, some users face challenges operating wheelchairs independently, increasing reliance on caregivers and perpetuating inequalities. Globally, over 2.5 billion people currently require assistive technologies, and this number is projected to reach 3.5 billion by 2050 due to population aging and the rise of noncommunicable diseases. While innovations such as smart wheelchairs offer potential solutions, limitations exist for certain populations, including individuals who are mute, blind, or amputees, highlighting the need for adaptable and inclusive wheelchair designs to meet diverse user needs. (Jayasekera, 2024)

Sahoo and Choudhury (2023) stated that wheelchair accessibility is a critical factor in promoting equality, inclusion, and well-being for individuals with mobility limitations. Accessible environments, encompassing public spaces, transportation, educational institutions, workplaces, and recreational facilities, enable wheelchair users to participate fully in society on an equal basis with others. Beyond physical infrastructure, accessibility also involves inclusive attitudes, policies, and practices that foster social integration and reduce discrimination. Limited accessibility restricts independence, social participation, education, employment, and overall quality of life, highlighting the importance of addressing both physical and attitudinal barriers. Moreover, wheelchair accessibility is grounded in human rights, as recognized by

the United Nations Convention on the Rights of Persons with Disabilities (UNCRPD), ensuring that individuals with disabilities can exercise their rights and live with dignity. By promoting independence, empowerment, social engagement, education, and health, comprehensive wheelchair accessibility is essential for creating inclusive societies that value diversity and provide equal opportunities for all.

Individuals with mobility impairments often face challenges in performing daily activities and participating fully in society, and while traditional wheelchairs provide essential support, they may not offer sufficient independence or ease of movement. Robotic wheelchairs, controlled by computerized systems, can enhance mobility, autonomy, and overall quality of life for users; however, their high-cost limits accessibility, particularly in developing countries. Advances in technology, including voice-activated and Raspberry Pi-based systems, have made it possible to design affordable, user-friendly, and customizable robotic wheelchairs that can meet individual needs. International organizations, such as the World Health Organization (WHO) and the Rehabilitation Engineering and Assistive Technology Society of North America (RESNA), emphasize the importance of accessible and affordable assistive technologies, advocating for inclusive design processes that involve users and communities to ensure these devices are effective and equitable. By providing advanced mobility assistance at lower costs, affordable robotic wheelchairs have the potential to significantly improve independence, social participation, and inclusion for people with disabilities worldwide. (Sahoo and Choudhury, 2023)

According to Griggs (2025), manual wheelchair users require a range of skills to navigate physical barriers in daily life, as the built environment is often designed

primarily for ambulatory individuals, creating challenges for independent mobility. The wheelchair itself can either facilitate or hinder mobility, depending on its design, fit, and functionality. As highly personalized devices, manual wheelchairs serve as an extension of the self, replacing lower-limb function and supporting independence, but ill-fitting or cumbersome wheelchairs can negatively impact health, mobility, and quality of life. Effective wheelchair prescription involves assessment, education, skills training, and follow-up, yet variations in service provision, commercial bias, and lack of intrinsic understanding by prescribers can result in suboptimal devices for users. User satisfaction, often assessed with tools like the Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST 2.0), is influenced by comfort, ease of use, and service-related factors such as maintenance and repairs, and is closely linked to quality of life and participation. Understanding and addressing the needs and satisfaction of wheelchair users are therefore crucial for improving wheelchair design, functionality, and long-term user outcomes.

Arduino Software

Arduino is an open-source electronics platform designed to simplify the use of microcontrollers for both beginners and experts, providing an accessible interface through its hardware and Arduino Programming Language, which is based on C++. Since its inception in 2005 at the Interaction Design Institute in Ivrea, Italy, and the release of the first widely marketed Diecimila board in 2007, Arduino has become a global tool for students, educators, hobbyists, and professionals to develop interactive devices using sensors and actuators. Its affordability, ease of use, and cross-platform compatibility with Windows, Mac, and Linux make it particularly suitable for educational purposes, enabling the creation of low-cost scientific

equipment and facilitating the teaching of programming, electronics, and robotics concepts. Compared to other microcontroller platforms, Arduino provides a versatile, user-friendly environment that supports experimentation and innovation across a wide range of applications, from simple projects to complex scientific systems, making it an effective tool for developing technical competencies in students and fostering a global community of creators. (Kumar, 2022)

According to Tsesebe et al., (2025), recent increases in diseases and pandemics have accelerated the demand for affordable and accessible biosensing devices, particularly in low-resource regions, leading to the growing use of open-source platforms such as Arduino in point-of-care (PoC) technologies. Studies highlight the Arduino platform—powered by Atmel microcontrollers—as a versatile and cost-effective foundation for developing health monitoring tools and integrating various biosensors for real-time diagnostics. Research further shows that combining Arduino-based systems with machine learning algorithms significantly enhances their accuracy, adaptability, and capability to analyze complex biosignals, improving the performance of user-defined prototypes. While Arduino offers clear advantages in accessibility, flexibility, and innovation, limitations still exist in processing power and sensor precision, indicating the need for continued refinement. Overall, current literature demonstrates that Arduino-driven biosensing systems hold strong potential to democratize medical diagnostics, expand PoC applications, and support broader uses in healthcare and environmental monitoring.

Programming education involves teaching students to develop algorithms and write programs to solve specific problems, fostering skills in analysis, design, and

problem-solving. Developing programming competencies is essential in computer science and engineering curricula, but students often face challenges with text-based programming languages, as high-level abstraction and syntax requirements can hinder the development of algorithmic reasoning. To address these challenges, educators have increasingly adopted low-cost, interactive platforms such as Arduino microcontrollers, which provide a hands-on, affordable, and accessible environment for students to develop programming, electronics, and system implementation skills. Studies have demonstrated that using Arduino in first-year courses enhances algorithmic thinking, programming competencies, and practical knowledge in digital systems while maintaining high student engagement and motivation. The integration of Arduino into introductory programming courses supports both theoretical learning and real-world application, highlighting its value as a tool for developing foundational competencies in computer science, information systems, and electrical engineering students. (Yupanqui et al., 2022)

Arduino microcontrollers are open-source, programmable devices introduced in 2005, designed to enable students, professionals, and hobbyists to create interactive systems that respond to environmental inputs using sensors and actuators. The platform consists of both hardware, such as Arduino development boards built on 8-bit Atmel AVR or 32-bit ARM microcontrollers, and software, including the Arduino IDE, which supports programming in C and C++ and provides a simplified, cross-platform development environment compatible with Windows, Mac, and Linux. Arduino boards support inputs and outputs, internet connectivity via HTTP requests, and wireless communication through shields such as Bluetooth, Ethernet, and motor driver modules, making them highly versatile for a wide range

of applications. Key advantages of Arduino include an active global user community, affordability, ease of use, and accessibility, which foster rapid learning and collaboration among users. These characteristics have made Arduino a popular choice in education, research, and DIY projects, allowing users to develop practical and innovative solutions while cultivating programming, electronics, and problem-solving skills. (Ismailov et al., 2022)

Research on educational robotics in programming instruction highlights its potential to enhance student engagement, particularly through the integration of microcontrollers such as Arduino in laboratory activities. A study conducted among second-year IT teacher candidates in Turkey investigated students' attitudes, self-efficacy, and perceptions toward robotic-based programming education using weekly Arduino applications embedded within a C programming course. Using programming attitude scales, self-efficacy measures, and semi-structured interviews, the findings revealed that Arduino-supported instruction positively influenced students' attitudes, with many describing the experience as engaging, exciting, and motivating. Despite these positive perceptions, the study showed no significant improvement in students' programming self-efficacy, suggesting that while Arduino increases interest and enjoyment, it may not immediately translate into higher confidence in programming skills. These results indicate that educational robotics can enrich the learning environment by increasing student motivation, yet consistent and long-term exposure may be necessary to produce measurable gains in programming competency. (Arslan and Tanel, 2021)

According to Viliam et al., (2022), improving the educational preparation of students in scientific, technical, and natural science disciplines has become a major focus of contemporary pedagogical research, particularly in the development of independent problem-solving and engineering design capabilities. Programming plays a central role in this process as both a universal modeling tool and a means of cultivating analytical and logical thinking. Recent studies emphasize the effectiveness of integrating the Arduino platform into programming instruction to strengthen these competencies. In this context, researchers examined the formation of programming skills among students in radio electronics and control systems, identifying inconsistencies between existing training practices and the requirements outlined in professional standards. A methodology for organizing programming instruction using Arduino was proposed, with clearly defined criteria and indicators for assessing competence development. An experimental implementation at I.N. Ulyanov Chuvash State University demonstrated significant improvement in students' programming proficiency, with statistical analysis using the chi-square test confirming that the majority of participants achieved high or advanced levels of programming skill. These findings support the growing body of evidence that Arduino-based instruction enhances both the effectiveness and practicality of programming education, making it a valuable approach for technical and engineering programs.

ECG Monitoring

Wearable consumer ECG devices—commonly integrated into smart watches, patches, and sensor plates—have expanded access to personal cardiac monitoring by enabling users to record heart rhythms outside clinical settings. Literature shows

that single-lead devices are effective for detecting atrial fibrillation, flutter, and ectopic beats, while newer six-lead models offer improved diagnostic information for monitoring QT intervals and arrhythmias. However, these devices remain limited in recording duration, usability for elderly individuals, and overall diagnostic capability, particularly for identifying myocardial infarction or ischemia, which still require a full 12-lead ECG, biomarker testing, and clinical evaluation. Additionally, the absence of a universal data exchange format restricts interoperability between device manufacturers and healthcare providers. Despite these limitations, consumer ECG wearables hold significant potential for early arrhythmia detection and preventive care, especially among high-risk populations. (Hilbel and Frey, 2023).

According to Hamad and Jasim (2021), real-time ECG monitoring using IoT has been increasingly developed in healthcare to enable faster and more efficient patient assessment by medical professionals. While many studies have focused on remotely observing ECG signals, few have integrated both monitoring and automated classification—an essential component for a fully functional health-monitoring system. The reviewed study addresses this gap by proposing an IoT-based ECG monitoring and classification system using the AD8232 sensor, Arduino NodeMCU, an ADC for signal precision, and cloud transmission via ESP8266 using MQTT. The ECG signal is pre-processed, denoised, and analyzed through QRS detection to obtain key features such as heart rate, after which it is classified using a convolutional neural network. Results from various test signals show high performance, with the model achieving 94.94% accuracy alongside strong sensitivity and specificity values, demonstrating that combining IoT monitoring with deep-learning classification can significantly enhance remote cardiac assessment.

Recent studies highlight the growing development of accessible ECG monitoring systems using low-cost sensors and microcontrollers, particularly the AD8232 module combined with Arduino platforms, to address the need for affordable cardiac assessment tools in both medical and home environments. Research emphasizes that traditional ECG devices, while highly accurate, are often expensive and complex, motivating the creation of portable alternatives featuring real-time monitoring, noise filtering, and user-friendly interfaces. Several works demonstrate the importance of integrating hardware and software components—such as custom PCBs, microcontroller-based signal acquisition, and GUI-driven data visualization—to ensure reliable detection of heart activity while minimizing interference. These systems have been shown to support educational settings as well, enabling biomedical students to understand ECG signal behavior and device functionality through hands-on experience. Validation experiments across different conditions consistently report stable signal performance, underscoring the potential of low-cost ECG technologies to provide accessible, practical, and efficient cardiac monitoring solutions for general users and learners alike. (Torres and Ferran, 2024)

According to Qtaish and Shrouf (2022), The growing global population, rising healthcare costs, and reduced medical accessibility during the COVID-19 pandemic have intensified the need for portable and low-cost ECG monitoring technologies. Traditional hospital-based 12-lead ECG systems, while accurate, are bulky, expensive, and restrictive, making frequent monitoring difficult for patients with cardiac risks. As a result, recent research increasingly focuses on developing smart, mobile ECG systems capable of long-term, real-time monitoring outside

clinical environments. Studies emphasize that ECG signals—composed of the P wave, QRS complex, and T wave—are vital for detecting cardiac abnormalities such as premature ventricular contractions, which can lead to sudden cardiac arrest, a leading cause of natural death worldwide. Early detection is therefore crucial, and portable ECG devices offer a practical solution by enabling continuous monitoring without requiring hospital visits. This growing trend highlights the importance of accessible, cost-efficient ECG technologies for timely diagnosis, patient safety, and improved management of heart-related conditions.

Electrocardiograms (ECGs) are essential diagnostic tools for identifying heart diseases, as they capture the heart's electrical activity and provide critical information on arrhythmias and other cardiac abnormalities. Traditional ECG systems, typically stationary and costly, limit patients' mobility and require frequent hospital visits, which can be burdensome, especially for individuals with chronic conditions. Recent advancements in portable ECG systems, including microcontroller-based and wearable devices, have enabled real-time cardiac monitoring at lower costs, facilitating early detection and management of heart disorders. Portable ECG solutions, often incorporating sensors like the AD8232 and microcontrollers such as Arduino Nano, allow continuous signal acquisition and real-time data processing, while leveraging machine learning algorithms, particularly Convolutional Neural Networks (CNNs), has demonstrated improved accuracy in classifying normal and abnormal heart rhythms. Studies indicate that these integrated systems enhance both the accessibility and precision of cardiac monitoring, making them suitable for home, clinical, and remote healthcare applications. Furthermore, understanding the fundamental ECG waveform

components—P wave, QRS complex, and T wave—and their pathological variations remains critical for accurate diagnosis and timely intervention. Overall, the literature highlights the growing potential of low-cost, portable ECG systems combined with machine learning for early arrhythmia detection, real-time monitoring, and improved cardiovascular health management. (Panwar et al., 2025)

Mobility Disabilities

According to Ginis et al., (2021), people living with disabilities (PLWD) face significant health disparities compared with the general population, being more susceptible to chronic diseases, injuries, and inactivity-related health issues. Globally, approximately 1.5 billion individuals live with some form of disability, the majority of whom reside in low- and middle-income countries, where data on physical activity are scarce. PLWD are significantly less likely to meet recommended physical activity guidelines, placing them at higher risk of poor cardiovascular, musculoskeletal, metabolic, and mental health outcomes. Evidence from meta-analyses indicates that even moderate levels of physical activity yield meaningful health benefits for PLWD, improving cardiovascular fitness, muscle strength, functional capacity, and psychosocial wellbeing. Despite these benefits, PLWD remain underserved in both research and policy, with physical activity monitoring often inconsistent due to the lack of standardized measures and inclusive surveillance systems. Furthermore, barriers such as limited school participation, inadequate access to resources, and insufficiently targeted interventions reduce physical activity engagement. Emerging policy initiatives and disability-inclusive guidelines aim to address these gaps, emphasizing the need for accessible, evidence-based programs that promote social inclusion, empowerment, and health

equity for PLWD. Collectively, the literature underscores the importance of promoting physical activity for PLWD to improve health outcomes, reduce disparities, and achieve broader public health and societal goals.

In the study conducted by Remilliard et al., (2022), it shows that participation in community and life activities is a critical determinant of health and quality of life for people with disabilities, with transportation playing a key role in enabling access to essential and recreational activities. Older adults with mobility disabilities, including those who are aging with disability (PAwMD), face substantial barriers in accessing transportation due to mobility limitations, inaccessible infrastructure, affordability issues, and limited availability of services, particularly in rural areas. These barriers contribute to reduced independence, social participation, increased risk of secondary health conditions and socioeconomic disadvantages. Federal policies in the U.S., such as the Rehabilitation Act, the Americans with Disabilities Act (ADA), and subsequent initiatives like the FAST Act, aim to enhance transportation accessibility for older adults and people with disabilities through funding, coordinated programs, and infrastructure development. Despite these legislative efforts, gaps remain in implementation, coordination, and equitable access, highlighting the need for continued research, policy development, and inclusive transportation solutions to support full participation and mobility for PAwMD.

According to MacEachern (2021), children and adolescents with disabilities experience numerous barriers to physical activity, resulting in lower fitness levels and higher rates of obesity compared to their peers. Studies indicate that the majority of this population fails to meet recommended physical activity guidelines, with

participation decreasing as age increases. Environmental factors and the lack of suitable programs capable of accommodating specific disabilities are frequently cited barriers, limiting access and engagement. Insufficient physical activity in this population may negatively affect both physical and mental health, and events such as the SARS-CoV-2 pandemic may exacerbate these challenges. Addressing these barriers through inclusive program design and accessible environments is critical to improving health outcomes and promoting equitable participation in physical activity for children and adolescents with disabilities.

In the study concluded by Hidayati et al., (2021) mobility inequality is a widespread issue influenced by individual, structural, and sociocultural factors, leading to unequal access to transportation and limiting participation in essential and desired activities. The COVID-19 pandemic has exacerbated mobility disparities, particularly for those without private vehicles, while long-term structural inequalities, such as segregated urban zones and gendered restrictions, continue to limit access for marginalized groups. Differences in mobility are shaped by physical capabilities, social norms, and institutional frameworks, resulting in reduced opportunities for older adults, women, people with disabilities, and low-income populations. While transport and planning literature often focus on technical measures of mobility, and sociological studies emphasize lived experiences, a comprehensive understanding requires integrating these perspectives to address accessibility and equity. Inequitable mobility not only constrains physical movement but also compounds socioeconomic disadvantage by restricting access to healthcare, education, employment, and social participation. Inclusive and people-centered planning

approaches, supported by policy and infrastructure, are essential to reduce mobility disparities and enhance social inclusion for marginalized populations.

Physical activity is a critical determinant of health, contributing to the prevention of non-communicable diseases and supporting overall well-being. Globally, a significant portion of adults fails to meet recommended physical activity levels, with approximately 27% of the population considered inactive, despite many expressing a desire to increase their activity. For people with physical disabilities, the challenge is compounded by social and environmental barriers, resulting in lower activity levels and earlier onset of health complications compared to the general population. Fitness centres represent a promising venue for promoting physical activity, offering flexible and individualized exercise opportunities that align with the preferences of people with disabilities. However, research on the experiences of both adults with physical disabilities (AwPD) and adults without physical disabilities (AwoPD) in fitness centres is limited. Barriers for AwPD include accessibility issues, negative social attitudes, and inadequate policies, whereas AwoPD experience barriers more related to time, motivation, and energy. Understanding these barriers and facilitators is essential to create inclusive fitness environments that enable all individuals to engage in regular physical activity, thereby promoting health equity and supporting WHO recommendations for safe, accessible, and appropriate exercise spaces. (Nikolajsen et al., 2021)

Arduino Voice-based Control

According to Subha et al., (2022), the integration of robotics in both business and domestic environments has increasingly focused on enhancing efficiency and reducing the physical and cognitive demands of tasks. Recent research emphasizes improving human-robot interaction, particularly through intuitive control mechanisms such as voice commands. Speech-controlled robots leverage microcontrollers, such as the Arduino Uno, in combination with smartphone-based voice recognition systems to facilitate real-time, responsive operations. In these systems, an Android application interprets spoken commands, converts them into text, and transmits the data via Bluetooth to the microcontroller, which then controls the robot's locomotion. The robot is also designed to provide auditory feedback by simulating human speech in response to user commands. Such developments demonstrate the potential of voice-operated robotic systems to enhance accessibility, user-friendliness, and task efficiency in everyday and professional applications, highlighting the growing role of embedded systems and microcontroller-based platforms in modern robotics.

The integration of Internet of Things (IoT) technologies into home environments has emerged as a significant solution to enhance autonomy for individuals with physical mobility disabilities. Voice-enabled IoT systems enable users to control appliances and perform daily tasks with minimal physical effort, overcoming challenges posed by conventional digital interfaces. Existing commercial solutions, however, are often costly and require specialized technical knowledge for proper operation, limiting their accessibility. Recent studies have demonstrated the potential of low-cost, voice-controlled systems using widely available platforms such as Google Assistant, combined with Arduino microcontrollers, ESP8266-based NodeMCU boards, and applications like Blynk for remote monitoring. These systems

allow users to operate lighting appliances through voice commands, with verification through voice pitch analysis, achieving effective control over distances up to 24.5 meters. Such developments highlight the potential for affordable, user-friendly smart home technologies to improve independence, accessibility, and quality of life for people with limited mobility, particularly those with lower-limb disabilities. (Aznilinda et al., 2021)

According to Ariza and Pearce (2022), voice-based assistive technologies have emerged as a crucial solution to enhance accessibility and independence for individuals with physical or mobility disabilities. These systems allow users to interact with devices, control appliances, and perform daily tasks through voice commands, significantly reducing reliance on physical interaction. Recent developments in low-cost, open-source hardware (OSHW) and open-source software (OSS) have facilitated the design and deployment of such technologies. Platforms like Arduino, ESP8266-based NodeMCU boards, and Google Assistant integration enable the creation of affordable and customizable voice-controlled systems, allowing users to operate lighting, household appliances, and other assistive devices remotely. Sensor integration, including microphones and voice pitch analyzers, ensures accurate recognition and execution of commands, while smartphone applications provide an intuitive interface for system monitoring and control. Studies demonstrate that these voice-enabled systems can function reliably over considerable distances, providing practical solutions for people with limited mobility. The use of OSHW and OSS not only reduces costs but also encourages collaborative development and adaptation, fostering wider accessibility and inclusion. These technologies have shown particular promise in low- and middle-

income countries, where commercial assistive devices are often financially prohibitive, highlighting the potential of voice-based open-source ATs to improve the quality of life and societal participation of people with disabilities.

Voice-controlled robotic systems have shown significant potential in enhancing autonomy for individuals with disabilities and older adults who face limitations in mobility. By integrating voice command recognition through smartphone applications with microcontrollers such as Arduino, these robots can perform essential tasks, including moving forward, backward, turning, and stopping upon detecting obstacles. Communication via Bluetooth ensures that commands are transmitted efficiently and executed accurately, enabling the robot to respond reliably to user instructions. Such systems offer practical benefits by reducing the need for human intervention in situations where direct assistance is difficult or unsafe. Beyond personal mobility, voice-controlled robots also demonstrate potential for broader applications, including home automation, security, and industrial tasks. The scalability of these prototypes highlights their adaptability, suggesting that future developments can further improve accessibility, independence, and safety for disabled individuals and the elderly, while also supporting diverse real-world applications. (Rajiv et al., 2021)

Based on the study conducted by Chumuang et al., (2024), voice-command technology has increasingly been applied to develop assistive systems for elderly individuals, aiming to enhance independence and convenience while reducing the need for human caregivers. By integrating speech recognition with Internet of Things (IoT) frameworks, these systems enable users to control household appliances,

make phone calls, and operate applications through natural language commands. Natural Language Processing (NLP) allows the system to interpret user commands accurately, while evaluation models such as the Confusion Matrix are used to assess the system's recognition performance. Studies testing such systems with elderly users have demonstrated promising results, achieving accuracy rates of approximately 85%, indicating effective command interpretation. This approach highlights the potential of voice-based assistive technology to improve quality of life for older adults, offering both practical convenience and reduced labor costs in caregiving.

Synthesis

People with mobility and physical disabilities often experience difficulties in moving independently, joining social activities, and managing their health. Wheelchairs are one of the most important assistive devices used to help with mobility. However, studies show that the benefits of wheelchairs depend on their quality, proper fit, maintenance, and the user's skills. Poorly designed or poorly maintained wheelchairs can limit movement and reduce quality of life. Because of this, researchers emphasize the importance of proper wheelchair services, training, and continuous support to help users move safely and confidently.

Aside from wheelchair design, many studies point out that accessibility in the environment is also important. Inaccessible transportation, buildings, and public spaces prevent people with disabilities from participating fully in school, work, exercise, and community activities. These barriers often lead to lower physical activity levels and poorer health outcomes. Inclusive environments, supportive policies, and

positive social attitudes are therefore necessary to promote independence, equality, and social inclusion for people with disabilities.

Recent studies show that technology can help reduce these challenges. Voice- controlled and robotic wheelchairs, as well as smart assistive systems, help users move and perform daily tasks with less help from caregivers. Many of these technologies use Arduino, an open-source and low-cost platform that allows devices to be customized based on user needs. Because Arduino systems are affordable and flexible, they are especially useful in areas where expensive assistive devices are not easily available.

Arduino technology is also widely used in health monitoring, especially in portable ECG devices that track heart activity. Research shows that low-cost ECG systems can help detect heart problems early and allow remote monitoring at home. These devices are useful for people with disabilities who may find it difficult to visit hospitals regularly. In addition, Arduino-based projects are commonly used in education, helping students learn programming, electronics, and problem-solving through hands-on activities.

However, many studies focus on only one aspect, such as mobility, voice control, or health monitoring. There is limited research that combines these technologies into one system designed specifically for people with mobility disabilities. This gap shows the need for further research on affordable, easy-to-use assistive systems that support both movement and health monitoring.

In conclusion, the reviewed studies show that combining accessible environments, proper wheelchair support, and low-cost technologies can greatly improve independence and quality of life for people with disabilities. Future research

can help develop simple, affordable, and inclusive assistive devices that benefit users, caregivers, and the community.

CHAPTER III

METHODOLOGY

Research Design

This study used a quasi-experimental developmental research design to design, build, and test an Arduino-based intelligent wheelchair with Voice Motion Commands, ECG Monitoring, and a Smart Medication Sorting System.

The developmental part of the study focused on creating wheelchair prototypes. The researchers assembled the Arduino board, voice recognition module, ECG sensor, motor drivers, and medicine-sorting components. Each part was programmed and tested individually before being combined into one complete system. Adjustments and calibrations were made to make sure the wheelchair functioned properly and safely.

The experimental part of the study focused on testing how effective the developed wheelchair was compared to a conventional manual wheelchair. The Arduino-based wheelchair served as an experimental setup, while the traditional wheelchair was used as a comparison basis. The researchers tested specific features such as the accuracy of voice commands, the speed of system response, the reliability of ECG readings, and the overall performance of the wheelchair during use.

The evaluation was conducted under controlled, school-based conditions. Selected respondents observed and interacted with the prototype and then provided feedback using structured questionnaires and observation guides. Performance results were recorded and analyzed to determine whether the integrated systems improved mobility assistance, basic health monitoring, and medication management.

This research design is considered quasi-experimental because the study tested the effects of a newly developed device but did not involve random assignment or clinical testing on patients. The design was appropriate for school-level prototype study, as it allowed the researchers to clearly compare the smart wheelchair with a conventional wheelchair and evaluate its effectiveness in a safe and controlled environment.

Participants and Respondents of the Study

The respondents of the study “Prototype Creation of an Arduino-based Wheelchair Featuring Voice Motion Commands, ECG Monitoring, and a Smart Medication Sorting System” were 60 students from the High School Department of Marian Learning Center and Science High School, Inc. for the school year 2026–2027. Probability sampling was done to ensure fairness and give everyone an equal chance of being chosen.

Of the 60 respondents, 45 were from the Senior High School's Grade 11 students, 16 students from Grade 11 - Silver (STEM), 16 from Grade 11 - Gold (STEM), and 2 from Grade 11 - Copper (HUMSS and ABM). The remaining 8 respondents were from Junior High School's Grades 10 students. The researchers expect that this study will help these students in implementing robotics to their research subject.

Data Gathering Instruments

This study followed an experimental quantitative design and used a structured survey questionnaire as its main tool for gathering data. The questionnaire was created to find out how participants feel about using an Arduino-based Wheelchair as an assistive device to raise solutions in mobility, accessibility, medical and safety aspects in correspond to the limitations present in conventional wheelchairs. It focuses on the acceptance of technology as a primary factor in innovating and providing advancement to such concerns. To make sure responses could be compared and analyzed fairly, the survey used a Likert scale, which provided consistent and measurable results for statistical interpretation.

Construction. A survey questionnaire was designed to correspond to the study's objectives and research problem. The items were formulated according to the relevancy of each literature concerning the practicality and accessibility of the Arduino-based wheelchair with voice-command movement, ECG Monitoring System, and Smart Medicine Sorter. The integration of this system will aim to assist in the mobility and accessibility needs of the patient. The questionnaire employed a 5-point Likert scale to assess respondents' levels of knowledge, envisioned effectiveness, medical and social impacts, safety concerns and willingness to implement Arduino-based wheelchair. The wording of each item was carefully crafted to ensure clarity, simplicity, and alignment with the goals of the study

Validation. The instrument's accuracy and suitability were verified through a validation process prior to its actual use. In order to ensure that the questionnaire effectively measured the intended variables, it was revised and improved based on

their input. To determine if each item adequately addressed the objectives of the study, a content validity index was also computed.

Administration. The questionnaire was ready for distribution after it had been validated. To run the survey, the researchers first got formal permission from the participants and received clearance from their research adviser. The questionnaire is provided in printed forms to respondents. The goal of the study, the voluntary nature of participation, and the confidentiality of their answers were all explained to participants along with clear instructions.

Retrieval. After the participants completed the survey, the researchers then gathered all complete questionnaires. The printed responses were manually retrieved by the researchers. After encoding, each item of data was ready for analysis. Descriptive analysis and statistical treatment were used to generate results aligned with the research objectives.

Scoring Responses

The items in the questionnaire were graded on a scale of one to five(5), with five being the highest and one (1) being the lowest. The scales to be utilized are as follows:

Option	Weighted Mean	Verbal Interpretation
5	4.21 – 5.00	Strongly Agree
4	3.41 – 4.20	Agree
3	2.61 – 3.40	Neutral
2	1.81 – 2.60	Disagree
1	1.00 – 1.80	Strongly Disagree

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