Physical Therapy and Rehabilitation Robotics: Engineering the Future of Recovery

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Abstract:

This interdisciplinary high school unit bridges physical science, biomedical engineering, and ethics to explore the essential question, "How can robotics enhance human mobility and recovery in physical therapy?" This fundamental question guides the unit, encouraging students to examine and investigate real-life examples of how human movement works and how assistive technologies, both wearable and non-wearable, are designed and utilized.

Forces and motion, the transfer of energy, and how levers and motor control systems function are the foundational physical science concepts that are explored in this unit. Students have the opportunity to design and test various assistive device prototypes through hands-on experiments, data analysis, and simulations.

The unit emphasizes ethical reflection alongside scientific inquiry. Students analyze how rehabilitation robotics impacts society and individuals, exploring fairness, accessibility, and personal autonomy through role-playing and ethical discussions. In the culminating project, students apply the engineering design process to design their own prototype of a robotic assistive device that addresses a real-world need, which they present at a school-wide, "Shark Tank-style" STEM showcase. Students will also critically examine the ethical and social implications of using robotics in physical therapy.

Designed to promote inquiry, critical thinking, and creative problem-solving, this unit empowers students to act as scientists, engineers, and socially conscious innovators capable of addressing human-centered challenges through creative design, engineering, and technology.

Keywords:

Robotics, engineering, rehabilitation robotics, assistive technology, assistive devices, wearable devices, prototypes, physical therapy, mobility, movement, injury, recovery, biomechanics, human anatomy, joints, forces and motion, levers, energy transfer, technology, coding, computer programming, 3-D printed design, simulation, CAD software, real-world application, role-playing, problem-solving, investigation, experimentation, experimental design, engineering design process, data analysis, project-based learning, hands-on learning, scientific inquiry, research, ethics, equity

Unit Content

Introduction and Background Context

To better understand the purpose and design of this unit plan—and to maximize its scope and impact—it is helpful to know a bit about my background as an educator. This context explains *the why, the how, and the heart* with which the unit was developed. The following paragraphs below include an abbreviated version of my background; however, a more detailed description of my early experiences that led to me becoming a TIP Fellow and the educator that I am today can be found in the following linked section here, titled **Author's Preface: Detailed Introduction and Background Context.**

For 15 years as a science educator and instructional leader in Philadelphia, I have been committed to providing my students with unique and meaningful STEM and real-world learning opportunities. I spent the first six years of my career teaching general science at Roberto Clemente Promise Academy, a middle school in a North Philadelphia neighborhood commonly referred to as the "Badlands." The school served a high-poverty, predominantly Hispanic and Black student population, with chronic absenteeism, housing insecurity, and trauma as persistent barriers to learning. With no science curriculum, outdated textbooks, and very limited supplies, I learned to be creative and resourceful—designing hands-on lessons and experiments for my students using dollar-store materials and household items.

By my third year, I was the only full-time science teacher in the whole school for grades 6–8, teaching nearly 450 students weekly across 14 large classes. I also had begun supervising and leading our after-school robotics and engineering team. Year after year, we competed against up to 35 public, private, and parochial schools from four different states—Pennsylvania, New Jersey, Maryland, and Delaware—at the Greater Philadelphia SeaPerch Competition. Each year, we got to know more of the teams and their coaches, and we learned that our team was operating at a large disadvantage compared to other schools that had their own pools on campus to practice in daily, and that taught SeaPerch as a full curriculum in yearlong STEM courses. We witnessed teams bring in fully 3-D printed SeaPerches, built with parts that we did not have access to. It was frustrating for my students to compete each year knowing that we did not have the same resources as our competitors.

In 2016, everything changed for our team. We were not rookies anymore, and we knew the types of schools we were up against. We embraced the fact that we were the true definition of
"underdogs," and we turned it into a calling that we knew we had to answer. We felt that we had to show the robotics community what we were made of and that the grit, determination, and pure love for the content we were learning were all enough to drive us forward and push us to the next level. We raised money to buy multiple SeaPerch robot

kits so we could have enough supplies to build and test several robots, allowing us to select the best one to complete that year's mission. We also used the money we raised to purchase more hours at our local YMCA so we could practice more in the pool and become one with our robot, and the mission and obstacle courses.

After years of persistence, our efforts paid in dividends that year in 2016. Our team from Roberto Clemente Promise Academy made history by becoming the first Philadelphia public school to ever win the Greater Philadelphia SeaPerch Regional Competition! We swept the entire competition—coming in 1st, 2nd, and 3rd in all categories—which averaged our scores to allow us to win 1st Place Overall Champions! Our 1st Place Overall ranking advanced us to the international competition in Baton Rouge, Louisiana, which made us the first Philadelphia public school to ever compete on the international level. We were elated—until we learned that we needed our own funds for our plane tickets, hotel, food, and transportation in Baton Rouge, as there were no funds available from the district or school level. We had spent all of our money on robotics supplies and pool time, and the international competition was only 2 weeks away. If we did not have enough money to send ourselves there, we were going to have to forfeit the right we had earned to compete.

Our team knew that this was not an option. We took on the "underdog" mindset once again and wore it as a badge of honor and pride as we immediately set to work raising money again, this time by crowdfunding on GoFundMe. In just 12 days, we successfully raised $6,000, sufficient to send three of my students, along with me as their coach, to represent our team. At internationals, my three students placed in the top 1.5% worldwide, securing 28th place among over 1,000 middle schools that won in their own regional competitions across the U.S. and countries like Australia, Scotland, and Ireland. Upon returning to Philadelphia, our team was interviewed by CBS Philly Channel 3, and we received the "Engineering Process Award" at the 2016 American Society of Naval Engineers (ASNE) Symposium at Villanova University.

That incredible journey—from an under-resourced lab in North Philadelphia to a national/international stage—reflected the true power of belief, resourcefulness, and community. Two of my students from that 2016 team learned from that program that engineering and robotics were their passion, and they went on to graduate this spring in 2025 with mechanical engineering degrees from Jefferson University. Another student from that same team also just graduated this spring with a degree in special education. They will now have the ability to inspire others just as they were once inspired. My former students will pursue mechanical engineering as a means to improve the world. My former student will inspire his future students to discover their untapped potential, igniting sparks in children that they do not yet realize are within them.

Since then, I have served as a STEM director, instructional coach, and most recently, a principal resident as I graduated from a principal residency and certification program this spring—which has fueled my fire and further deepened my commitment to educational equity and real-world learning. I know my experiences are not wholly unique. Countless educators across the city create powerful learning opportunities in the face of limited resources every single day. I joined the Teacher's Institute of Philadelphia to continue this work—to create units for teachers to implement that will inspire students to see themselves as innovators, engineers, and problem-solvers. Across all of the roles I have served in, my mission has remained the same: to ensure that every student—regardless of zip code—has access to rigorous, real-world STEM learning experiences that affirm their brilliance and build pathways to endless possibility.

Current Teaching Context

At Vaux Big Picture High School, my current school, we operate under a model that is unlike any other public high school in Philadelphia. Our school's mission and vision are deeply rooted in an educational philosophy that focuses on learning for and in the real world. Vaux is supported by a very unique partnership between the School District of Philadelphia (SDP), the Philadelphia Federation of Teachers (PFT), the Philadelphia Housing Authority (PHA)—who owns our building—and the nonprofit organization Big Picture Philadelphia (BPP). In addition to the mandated requirements of the Pennsylvania Department of Education (PDE) and School District of Philadelphia (SDP) to receive a high school diploma, our students engage in core programming provided by Big Picture that includes mandatory internships, externships, and community service learning for each student during all four years of their schooling. Two days a week, our students leave campus to work in professional settings and conduct community service in various areas of the city, receiving hands-on training in their chosen career paths. This means that our students need to not only show mastery of their core academic classes, but they must also be able to apply their knowledge to tasks in the real world and in professional social interactions well beyond the classroom.

Overview of STEM Content

Dr. Michelle Johnson, a bioengineering professor and the director of the Rehabilitation Robotics Lab at the University of Pennsylvania, led the TIP seminar series titled **"Robots and Smart Tech for Physical Therapy"** this spring, which immediately resonated with my professional interests and passions. It weaved together everything I value in a high-quality education: comprehensive science content, the combination of engineering and innovation, and its application in the real world that is relevant and beneficial to society. This topic of these seminars is both necessary and timely as "the interest in rehabilitation robotics and orthotics is increasing steadily, with marked growth in the last 10 years" (Krebs, H. I., & Volpe, B. T., 2013). The field of bioengineering has made rapid progress in developing robotic rehabilitation and assistive devices, which are rapidly transforming the field of medicine, particularly in physical therapy. In fact, "The global exoskeleton market is anticipated to reach a significant size of 3.340 billion USD, expanding at a growth rate of 46.2% by 2026" (MarketsandMarkets, 2025).

These new technologies are especially important for individuals who are dealing with or healing from a neuromuscular disorder or injury, such as a stroke, a spinal cord injury (SCI), Cerebral Palsy, Parkinson's Disease, Multiple Sclerosis (MS), or a traumatic brain injury (TBI). Other potential users who can benefit from these assistive devices can include those who require elderly or orthopedic care, those who are healing post-surgery, and those who are healing from injuries. Injuries to certain parts of the body can be more common than others, especially occurring in joints, as they play a much more critical role in aiding in our movement and flexibility. Common joint injuries can occur in the hands, wrists, neck, back, hips, knees, and ankles.

Robotic rehabilitation uses various types of robots and devices to help patients try to get back the functions they lost. These robots are designed to assist and guide limb movements during physical therapy sessions, making the rehabilitation process more controlled and effective for patients. Studies have shown that robotic devices can significantly improve recovery by "facilitating prolonged duration of training, increased number of repetitions of movements, improved patient safety, less strenuous operation by therapists, and eventually, to improve the therapeutic outcome" (Reiner, R., 2013). Users who require assistance with moving in a consistent and accurate manner may benefit from these devices greatly, as their human therapists may struggle to achieve the same motions. "Compared with traditional care, robotic rehabilitation can be better performed at high intensity and frequency, and can continuously monitor exercise performance so that the level of treatment can be better adapted to the patient's needs. It can also generate more appropriate movements and forces during training and therapy" (Payedimarri, A. B., et al., 2022).

The development of these devices is based on a deep understanding of how the body moves and how injuries affect the human body. As noted above, wearable robotic exoskeletons are becoming more widely used all around the world as global sales have skyrocketed, and they are only expected to keep climbing. These exoskeletons are truly remarkable and innovative robotic rehabilitation devices, as they help people with lower limb injuries walk by giving them the support they need. Patients utilizing these devices are given opportunities to walk that may have never been possible for them before.

While there are already several commercially available exoskeletons to assist the lower extremities, there are many more that are still being developed and tested. These devices can be separated into several overarching categories based on how they are best able to meet the specific needs of each individual, and each one is designed to change even further based on how the user moves, which makes the rehabilitation experience unique to each person. The three major categories of wearable exoskeletons include power overground exoskeleton devices, body weight-supported treadmill (BWST) exoskeleton devices or Driven Gait Orthoses (DGOs), and end-effector devices (Physiopedia, 2022).

Power overground exoskeleton devices are a category comprised of numerous models that allow patients to ambulate without an overhead support system, though they generally require patients to have some upper extremity strength to use an assistive device (e.g., forearm crutches) in collaboration with the lower extremity device. An example of these exoskeletons includes the Phoenix, which is a 23 lb exoskeleton that has motors that control hip and knee movements. Its average walking speed is 1.1 miles/hour, and its battery life allows for approximately 4 hours of continuous walking. It is meant for use in the clinic and community (Physiopedia, 2022).

Two other examples in this category are the Ekso GT and the Rewalk, which both include in their designs ways to specifically assist patients with spinal cord injuries. The Ekso GT is meant to be used in the clinic with the supervision and guidance of a physical therapist for SCI (C7 and below) or stroke. Two different models of the Rewalk can be used in the clinic or in the community, mainly for SCI patients with T7 to L5 SCI, as upper extremity strength is required to use it (Marinov, B., 2016). Rex is a model that is also designed for use in clinics, and can help patients who weigh up to 220 lbs. It supports/stabilizes the torso with abdominal straps and padding, hence less core activation is required by the patient to use it (Physiopedia, 2022).

The Keeogo is another power overground exoskeleton that allows for flat-ground ambulation, and it is also able to assist users to ascend and descend stairs. Another equally innovative device in this category is the Hybrid Assistive Limb (HAL), which is a lightweight power assistive device that uses technology that senses electrical signals sent from the brain to the muscles (through surface electromyography and ground reaction force sensors), and initiates the required movement for the patient (Narina, R., et al., 2022). "HAL devices are especially useful in early gait rehabilitation to establish stronger brain-muscle connections in patients. If no signals are detected (e.g. paraplegia), then the robot has an automated gait pattern that it assists the person through" (Narina, R., et al., 2022). There are different versions of HAL depending on the use, including full body, lower body, and one-legged versions. There is also a model called the Indego, which is a 26 lb exoskeleton that offers functional electrical stimulation (FES) to the lower extremity muscles. It is designed for clinic and community ambulation (Marinov, B., 2016).

The second category of exoskeletons consists of the body weight-supported treadmill (BWST) devices, or Driven Gait Orthoses (DGOs). BWST exoskeletons involve a harness that supports an adjusted percentage of the patient's body weight, while robotic orthoses control hip, knee, and/or ankle movement patterns during gait. Initial stages of rehabilitation may require the manual assistance of two therapists. The Lokomat is the most popular BWST exoskeleton, and it has been used for over 280 gait rehabilitation studies with various patient populations (Physiopedia, 2022).

The third category of exoskeletons includes end-effector devices, which also use a harness to provide body weight support for users. However, instead of orthoses, they strap the patient's feet and ankles to footplates that mimic the trajectory of gait (Physiopedia, 2022). The Gait-trainer GT 1 is a model that provides FES to up to 8 different muscle groups. Instead of orthoses, the patient's feet are strapped to footplates whose trajectories mimic on-ground walking. Patients experience increased freedom of movement in their knees and hips with this method. The G-EO System is another model that utilizes footplates, but with trajectories that mimic stair climbing, and it does not provide FES (Physiopedia, 2022). Lastly, the Lokohelp device is similar to the G-EO system, but it does not provide a stair-climbing option.

Smart technologies are also becoming more common in physical therapy, along with robotic devices. These technologies usually have sensors and software that keep track of a patient's progress, track performance, collect biometric data, and give feedback in real time. Wearable devices, for example, can keep track of muscle activity and joint movement. Immediate and consistent availability of this objective progress data helps therapists to personalize and change treatment plans based on what they learn during sessions (Porciuncula, F., 2018). Examples of wearable devices in healthcare and physical therapy include fitness trackers, smartwatches, glucose monitors, ECG monitors, blood pressure monitors, sleep monitors, smart clothing, pain management devices, posture-correcting devices, smart glasses, and sensor-embedded devices.

Fitness trackers, such as Fitbit and the Apple Watch, have the technology available to track the steps, heart rate, sleeping patterns, and activity levels of their users. Smart clothing provides a very innovative way to integrate sensors into clothing garments that can monitor movement, posture, and muscle activity. This enables therapists to have access to real-time feedback during therapy sessions, as well as through remote monitoring. Sensor-embedded devices use electromyography (EMG) sensors that measure muscle activity, as well as accelerometers and gyroscopes for motion analysis. They also improve patient safety as they use fall detection devices to send alerts to caregivers if the motion and impact of a fall are detected.

Devices such as smart orthopedic braces incorporate sensors to track the movement of joints, stability of the patient, and weight-bearing areas so therapists can identify areas to optimize support or that need improvement. Virtual reality (VR) systems have also become a very useful tool in rehabilitation settings. Therapists can create immersive, real-life situations that encourage movement and engagement by putting patients in a virtual world. Patients are able to practice movements in a safe environment that feels like a real scenario. This method has been shown to boost motivation and adherence to rehab programs, which leads to better overall results (Laver et al., 2017).

Patient motivation and disciplined adherence to their rehab programs are crucial in achieving their desired outcomes, especially when it comes to incorporating technology within therapy. Psychological considerations are important to take into account, as patients can often have varying mental perspectives on how they view themselves and their disability, and how they view the use of the rehabilitation technology itself. They are often very aware of society's perspective of their disabilities, as well. These pervasive and possibly conflicting perspectives can promote more diligent adherence to their rehab programs, or they can significantly reduce their use if the patient is not feeling motivated or emotionally and mentally safe enough to engage with them.

It is important to note the pivotal role that physical therapists play in introducing these devices to their patients. "A positive introduction to the robotic device can promote sustained use, whereas a negative experience may lead to decreased motivation and a reduced effect of utilizing the device on therapeutic outcomes. The physiotherapist plays a large part in this regard, through providing proper instructions and feedback while the patient is learning to use the device" (Physiopedia, 2022). The more rehabilitation resources are available and accessible to patients, the more likely it is for patients to experience an increase in their motivation and engagement, leading to enhanced rehabilitation outcomes and the improvement of their quality of life.

Ultimately, the field of robotic rehabilitation and assistive technologies continues to make rapid progress. By using robotics and smart technologies in physical therapy, therapists can help people who are recovering from injuries heal more fully and faster than ever before. Patients of all kinds, whether they are learning how to live their lives with a chronic illness or disability, or recovering from an injury, are experiencing massive improvements to their quality of life. Ongoing research in this area is likely to make many people's lives even better, allowing them to regain their independence and ability to function in ways that were never previously thought possible.

Overview of Unit

Designing a unit plan addressing robotics in rehabilitation and physical therapy provides students with ample opportunities to expand their knowledge about human anatomy and biomechanics, physics concepts, the implementation of the engineering design process, and various aspects of the lived experiences of people with disabilities, all within a multidisciplinary framework.

The unit I designed, "Physical Therapy and Rehabilitation Robotics: Engineering the Future of Recovery," is ideally suited for Vaux's context, as well as other schools and programs that emphasize the utilization of project-based and real-world-based learning, as it provides students with in-depth, content-rich instruction and hands-on problem-solving experiences while also requiring them to apply the skills they are already developing in their internships and externships. Skills such as inquiry, problem-solving, design thinking, and the clear presentation and justification of ideas are all highly transferable and essential to achieving success in almost any career that students may choose. This unit also creates connections to possible careers in health sciences, rehabilitation therapy, biomedical engineering, and robotics. These are all fields that the city of Philadelphia, and countless cities around the world, are currently focusing on developing their workforce in.

This 6-week interdisciplinary unit highlights how biology, physics, and engineering intersect in modern physical rehabilitation. The lessons focus on the practical applications of robotics and new technologies in physical therapy and rehabilitation science. The main goal of this unit is to give high school students in grades 9–12 a hands-on STEM experience that ignites their curiosity and challenges them to think outside of the box. Emphasis is put on making relevant connections between what students learn in school and what they will encounter in real-world situations and professional applications. This unit gives students ample opportunities to go beyond the typical classroom experiments and explore the complexities of biomechanical systems, engineering design, and problem-solving that puts people first as the center priority of these systems. This unit builds on insights that were learned in Dr. Michelle Johnson's TIP seminar classes, as well as through my own research. It also uses professional case studies, lab demonstrations, and the latest research in rehabilitation robotics. It teaches students how to look at scientific systems, suggest ways to improve them, and develop technological solutions with empathy and moral responsibility.

The unit begins with providing a strong and immersive foundation in biomechanics, which helps students learn about the structure and function of the musculoskeletal system. The main focuses that are explored here are anatomical terms, how joints work, different types of motion (such as flexion, extension, and rotation), and how muscles expand and contract. Students learn how soft tissues like tendons, ligaments, and cartilage interact with bones and how injuries affect normal body functions. Students look at patterns of injuries, such as ACL tears, shoulder dislocations, and wrist fractures, using models of the body, digital simulations, and videos. They research and explore how physical therapy can help these injuries heal, as well as the countless ways that robotic rehabilitation devices can help people get their lost function back and improve their overall quality of life. Students learn about how the body's systems work together by using materials like 3-D anatomical modeling tools and viewing professional rehabilitation videos.

The next part of the unit focuses on the physics of motion, force, and energy transfer in the context of human body movement. It builds on what students learned about anatomy in Lesson 1. Activities focus on Newton's laws of motion and how they influence how people move, such as when they lift something heavy or do a leg extension exercise. Key physics concepts such as inertia, acceleration, torque, and momentum are also addressed in depth. Students engage with simulations that are lab-based and use their problem-solving skills to calculate net force and how limb movements are affected by gravity. Students will also learn how to use devices like resistance bands, levers, and pulleys to increase mechanical advantage. Students conduct data collection exercises that mimic human movement by recording factors like joint angle, resistance, and load. They then plot this data using interdisciplinary mathematics skills to find patterns of function and movement.

This unit connects physics and engineering concepts by exploring numerous new technologies and robotic systems that are changing the way physical therapy treatments are conducted for patients. Students will study intriguing devices, such as exoskeletons, powered orthotic braces, soft robotic gloves, and smart gait trainers, and view them as they are utilized by humans. They will learn about the sensors, controllers, and mechanical parts that enable these tools to function effectively with the human body. These concepts will be presented through engaging videos, product demonstrations, and texts. The Lokomat, ReWalk, EksoNR, and MIT's soft robotic hand are all examples of cutting-edge technologies that show how robotic systems work together with human bodies to drive positive results in healing and function. Emphasis is placed on how robots use sensors to obtain feedback about the user's biometrics, change resistance levels, and change their movements to fit the needs of individual patients. Students learn how to use programmable microcontrollers, motion capture systems, force sensors, and pneumatic actuators to make smart rehabilitation tools work.

The next phase of the unit uses the engineering design process as a framework for inquiry, innovation, and problem-solving. Students learn about the five steps of design thinking: Empathize, Define, Ideate, Prototype, and Test. These steps form the educational core of the unit, pushing students to find a real-world problem in rehabilitation and try to solve it by designing a technological intervention or assistive device. Students find people who might use their devices, like stroke survivors, athletes who are recovering from surgery for a specific injury (like ACL or MCL surgery on the knee or ankle), and elderly people who have trouble with certain limb functions. They then collect qualitative data through interviews, testimonials from different patients, or short documentaries. This puts the users of these robotic devices at the center of the student's engineering design process, which helps them better understand the limitations and goals of the therapeutic interventions used by physical therapists. A user-centered approach also helps students develop empathy by putting them in situations that have a big impact on other people in the real world.

After this initial research, the students record the issues they discovered and develop many innovative ways to solve them. They make rough sketches of their ideas, add notes to their designs about how they will work mechanically and how users will interact with them, and build simple prototypes or simulations. Students can use digital tools and software like Tinkercad, SketchUp, or even paper and cardboard prototyping to make these ideas come to life. As students learn to test, get feedback, make changes, and test their designs again, the concept of iterative development becomes more important. They learn how to explain and also justify their scientific reasoning behind each design choice by using principles from biomechanics and physics as examples. Students also learn how to weigh the pros and cons of performance, usability, cost, and ethics.

Accessibility and ethics are important parts of the unit's content. Students are asked to think critically about who should have access to robotic therapy and who might not be able to because of things like cost, insurance, geographic location, or disability. Lessons examine case studies of robotic interventions that succeeded or failed due to human factors. Students learn about concepts like informed consent, the stigma around assistive technology, patient autonomy, and fair and equitable design. These discussions are based on current events and debates about healthcare policy. Students also look into how engineers can use universal design ideas to make technology that is more accessible to everyone.

At the end of the unit, student teams present their original ideas for rehabilitation technology to a panel of doctors, engineers, and patients. These final projects show how much the students have learned about anatomy, physics, engineering design, and ethics. A technical memo, annotated blueprints, a physical or digital prototype, and a reflective analysis are all instructional and evaluative tools that the students will engage with. Each presentation is graded and given a score using rubrics that align with national and state science standards, engineering criteria, and problem-solving indicators.

In summary, the “Physical Therapy and Rehabilitation Robotics: Engineering the Future of Recovery” unit provides interdisciplinary, hands-on, and intellectually rigorous lessons and activities that leverage students’ interests in science, engineering design, and real-world challenges. It promotes engagement through meaningful problem-solving and empowers students to realize that the next great idea that could change the world could come from them. They do not need to wait for another person to solve an issue; they can do it themselves. Additionally, it provides opportunities for students to connect school to the wider field of STEM by opening doors to careers in biomedical engineering, therapy, medical robotics, and design thinking.

This is not simply a science unit; it is a way to connect what students learn in school with real-world issues, such as innovation and ethics, the human impact on one another and the planet, and equity. An overwhelming majority of the students that I have taught come from communities in Philadelphia where receiving access to medical care and rehabilitation resources is extremely difficult, limited, and not at all equitable. Through their learning and experiences in this unit, my ultimate goal is for students to develop a mindset that allows them to see themselves as problem-solvers and future innovators capable of creating assistive technologies that have the potential to transform the worlds of those who rely on them.

Teaching Strategies

Delivering a unit that integrates biomechanics, robotics, physical therapy, and ethics requires an intentional and scaffolded teaching approach. This unit prioritizes evidence-based instructional strategies that are tailored to diverse learning needs and rooted in inquiry, project-based learning, and interdisciplinary connections. **The teaching plan draws upon multiple learning theories, including Vygotsky's Zone of Proximal Development (ZPD), Piaget's stages of cognitive development, Bloom's Taxonomy, Universal Design for Learning (UDL), and culturally responsive teaching pedagogy.**

To begin, the unit scaffolds instruction using a **gradual release of responsibility model**. Each week of the unit is anchored in a specific theme and learning objective, with lessons transitioning from teacher-led direct instruction to student-centered exploration and independent application. At the outset, students are introduced to fundamental anatomy and biomechanics through direct instruction that incorporates visual diagrams, interactive digital tools, and whole-class discussions. Concepts are introduced in small chunks—such as differentiating between ligaments and tendons, or defining contraction versus extension—to **prevent cognitive overload**. **Anchor charts, vocabulary word walls**, and **hand signals** are used to reinforce key terminology and concepts.

Students build models of joints using household and school-safe materials, such as paper towel tubes, cardboard, and rubber bands. **Kinesthetic learners** are accommodated by numerous **tactile activities and labs**, which provide ways for students to visualize complicated systems of human anatomy and biomechanics. The models also serve as **formative assessments**, allowing the teacher to assess students' comprehension of the content through their ability to explain joint functions and recreate them with their own prototypes.

As the unit transitions to the integration of physics principles, a combination of **flipped classroom methods** and **collaborative lab experiments** are employed. Students are assigned short video lectures to view as homework or in stations, allowing classroom time to be spent on group experiments and guided problem-solving. Key physics concepts like forces and motion, torque, and mechanical advantage are introduced through simulations (e.g., PhET), **peer teaching**, and **teacher modeling**.

Formative assessments are embedded in every stage, including pre-assessments at the beginning of each week, exit tickets, peer teaching opportunities, and lab journal prompts. For example, students write brief **"claim-evidence-reasoning" (CER)** paragraphs after each lab, helping them build scientific argumentation skills. These CERs can also be differentiated if needed by providing students with **sentence stems** or **guiding questions**, while others are encouraged to expand their writing with **data analysis** and **extension questions**.

The engineering portion of the unit engages students in the **design thinking framework**—empathize, define, ideate, prototype, test—which mirrors the process biomedical engineers use in real-world settings. To **scaffold** this process, the teacher provides **visual charts and posters** describing each stage and **models** how to complete each step using a sample classroom problem. Students complete **engineering design journals** throughout the unit, documenting their design journey, sketching ideas, and reflecting on iterations. For English Language Learners (ELLs) and students with IEPs, these journals are can be supported with **vocabulary banks, visual templates**, and opportunities to orally dictate entries using **speech-to-text software**.

During the design process, **group work** is carefully structured to foster collaboration and inclusion. Students are strategically grouped to balance strengths and ensure peer support, and roles such as researcher, engineer, writer, and presenter are rotated to give all students the **opportunity to lead**. Group norms are co-constructed at the beginning of the unit and revisited regularly. Teachers coach teams on conflict resolution, active listening, and equitable participation, drawing on **social-emotional learning competencies**.

Technology is embedded throughout the unit to enhance access, support differentiation, and provide real-time feedback. Tools like Google Classroom are used to post resources, collect assignments, and share feedback. Digital software like Tinkercad, SketchUp, and Canva are used for designing, modeling, and presenting prototypes and final projects. This also allows for **differentiation** by allowing students to choose the methods that they prefer or that align with their interests and strengths.

Assessment in this unit is multidimensional, authentic, and reflective of student growth over time. A blend of **formative and summative assessments**—including concept maps, scientific journals, engineering portfolios, Socratic discussions, and digital presentations—are used to measure understanding and application. **Rubrics** are co-developed with students to establish transparent criteria and support self-assessment. The engineering design rubric, for example, assesses creativity, feasibility, scientific accuracy, clarity of communication, and responsiveness to peer feedback. The group presentation rubric assesses content depth, delivery, visuals, and the integration of user-centered design principles.

Differentiation is thoughtfully built into all assessments. Students have multiple pathways to demonstrate mastery: traditional written assessments, oral presentations, physical prototypes, infographics, or multimedia submissions. Students who struggle with executive functioning can receive organizational supports, such as **checklists**, visual **timelines**, and **teacher conferencing**. **Extension tasks** are offered for students seeking additional challenges, such as analyzing the use of AI in physical therapy or conducting a cost-benefit analysis of a commercial rehabilitation robot.

Accommodations for **diverse learners** are provided through a **Universal Design for Learning (UDL) framework.** Lessons are designed to offer **multiple means of representation** (videos, diagrams, physical models), expression (written, spoken, visual), and engagement (group work, independent projects, real-world scenarios). Teachers must plan to meet regularly with special education staff and use student IEPs to modify materials, break down complex tasks, and provide **one-on-one or small group instruction** when needed.

In alignment with **Piaget's stages of cognitive development**, early lessons support students in the concrete operational stage by using physical models and simulations to explain abstract concepts. As students move into more abstract and hypothetical reasoning in the formal operational stage, instruction emphasizes analysis, ethical evaluation, and conceptual modeling. Lessons are sequenced to build cognitive complexity, gradually moving students from knowledge recall to evaluation and creation within **Bloom's Taxonomy**.

Culturally responsive teaching practices are embedded throughout the whole unit. Students are encouraged to connect content to their own lived experiences or communities. For instance, when discussing barriers to accessing physical therapy, students research disparities in healthcare based on race, socioeconomic status, or geography. Using this information, they are tasked with designing prototypes that consider people's cultural differences and that can be accessible to everyone, regardless of where they live in the world. In the culminating project, the schoolwide STEM showcase invites **guest speakers**, such as community health advocates, biomedical engineers, or local physical therapists, to share their expertise. Students' identities and future goals can be validated through interactions with experts in these fields.

In summary, the instructional approach of this unit is intended to be rigorous, equitable, and engaging for all students. It places a strong emphasis on skill development through teacher scaffolding, inclusive education through differentiation, and relevant and meaningful learning through real-world performance tasks. It also integrates content from multiple areas, including science, math, engineering, ethics, and social justice. "This approach may develop students' critical thinking and problem-solving skills through which they can transfer STEM-related skills and concepts to the 21st century STEM workplace." (Asunda, P., & Mativo, J., 2017). Through implementation of this unit, students will be prepared not just to understand how the body heals, but to design the future of that healing through thoughtful innovation.

Classroom Activities

Lesson 1: Anatomy in Action—Exploring Biomechanics Through Joint Models

Along with the first lesson described below, in the first week, students will take an educational trip! Students will attend the "Body Odyssey Exhibit" at the Franklin Institute at the very beginning of the unit to spark curiosity and inspiration to learn more about and participate in the unit.

The purpose of this introductory lesson is to provide students with a thorough understanding of the fundamentals of human biomechanics. A teacher-led investigation of the body's skeletal and muscular systems, with an emphasis on the composition and operation of joints, will open the class. Students will then use basic household and classroom materials, such as cardboard, paper towel rolls, rubber bands, and string, to build working models of various human joints. They will explore the movements and capabilities of hinge joints (knees, elbows) and ball-and-socket joints (shoulders, hips). They will also make predictions about how certain injuries might limit range of motion or cause stress on surrounding tissue, and even on other joints and body parts that might have to overcompensate for the injured area.

Students will exchange their ideas in small group discussions on topics such as what happens to the body during specific joint injuries, how muscles contract and extend by working in muscle pairs, and the types of physical therapies that exist to promote healing and recovery. Students will label their joint models and write a short explanation of how their model represents real anatomical structures. The lesson will culminate as they respond to a reflective prompt asking them to describe the importance of understanding joint structures and how this can help enhance the design of rehabilitation technologies.

This lesson addresses Pennsylvania state science standards on biological structure and function and aligns with NGSS HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems within multicellular organisms. Evaluation will include a completed labeled model, a short written reflection, and participation in group discussion.

Lesson Number: 1
Lesson Title: Anatomy in Action: Exploring Biomechanics Through Joint Models
Timeframe: 2 class periods (90–120 minutes total)

Objectives:

- Students will identify major joints in the human body and describe their structure and function.

- Students will construct a physical model of a human joint to demonstrate biomechanical principles.
- Students will explain how understanding joint biomechanics is essential to rehabilitation technologies.

PA STEELS Science Standards Addressed:

- **3.1.9-12.B:** Develop and use a model to illustrate the hierarchical organization of interacting systems within multicellular organisms.
- **3.2.9-12.B:** Develop and use models to illustrate relationships between systems.
- **3.5.9-12.C:** Design a solution to a complex real-world problem by breaking it down into smaller, manageable problems that can be solved through engineering.

Materials Needed:

- Cardboard (cut into strips and squares)
- Paper towel/toilet paper tubes
- Rubber bands
- String or twine
- Metal fasteners
- Hole punchers or scissors
- Labels/sticky notes
- Anatomy diagrams (digital or print)
- Laptops or tablets with internet access
- Student handout: "Joint Model Design Notes"
- Engineering Design Process visual aid

Instructional Strategy Connection:

This lesson incorporates a variety of integrated instructional methods, including visual, hands-on, and collaborative. These are combined with a design-thinking approach that emphasizes the use of modeling and exploration. Students start by learning foundational content, then deepen their understanding through real-world application.

Step-by-Step Lesson Narrative:

Day 1 (45–60 minutes):

1. **Engage (5 min):** Begin with a warm-up question on the board: "What parts of your body help you move, and how do they work together?" Students complete a quick-write.

2. **Introduce Concept (10 min):** Present a short lecture with visual aids on joint types (ex: hinge, ball-and-socket, pivot) and how muscles and tendons work together. Use 3-D anatomical software or a video walkthrough.

3. **Explore (20 min):** Provide students with anatomical diagrams. In pairs, students identify the names, types, and movement ranges of major joints (hand, wrist, elbow, knee, hip, shoulder, and ankle).

4. **Explain—Modeling Activity (10 min):** Introduce the design challenge: Create a working model of a human joint that shows how it moves and how an injury might affect it.

Day 2 (45–60 minutes):

5. **Model Building (30 min):** Students use craft materials to construct their models. They must choose a joint type, simulate muscle/tendon function, and label all important parts.

6. **Gallery Walk & Peer Feedback (10 min):** Students display their models and do a short gallery walk. Using sticky notes, they give peers feedback based on movement accuracy and anatomical labeling.

7. **Reflection & Application (15 min):** Students complete the "Joint Model Design Notes" handout. Prompt: "How could a robotic device be designed to restore function to this joint after injury?"

Evaluation Tools:

- Completed and labeled joint model
- Student reflection and design notes worksheet
- Participation in peer feedback session

- Exit ticket (optional): "Name one thing you learned about biomechanics and one question you still have."

Differentiation & Accommodations:

- Visual supports and vocabulary word walls
- Sentence stems and graphic organizers for written reflection
- Partner or small group collaboration
- Extended time and verbal instructions for IEP/ELL students

Lesson 2: Engineering Movement—Applying Physics to Robotic Design

Students will build on the biomechanical understanding they acquired in Lesson 1 by applying core physics concepts, such as torque, tension, and force, to explore how movement is simulated in robotic systems. In this activity, students will work in teams to design and test a simple mechanical arm that can lift and lower a small object. The project will simulate the action of an assistive robotic device. Using cardboard, syringes, tubing, or elastic materials, students will simulate how force is transferred and regulated to create movements that are smooth and accurate.

Before they begin building with their teams, students will participate in a mini-lesson on the foundational physical science concepts of force, vectors, and mechanical advantage. They will practice making calculations related to torque and tension in simplified systems and then hypothesize how their mechanical arm can be utilized and then optimized. After building their device, they will test its effectiveness and collect data on the range of motion, precision, and load capacity. Students will then write a technical memo that summarizes their design choices, performance results, and potential improvements they would make to their mechanical arm.

This activity aligns with NGSS HS-PS2-1: Analyze data to support the claim that Newton's Second Law of Motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. Students will be assessed on the functionality of their design, detailed completion of the technical memo, and participation in a follow-up class critique session.

Lesson Number: 2
Lesson Title: Engineering Movement: Applying Physics to Robotic Design
Timeframe: 2 class periods (90–120 minutes total)

Objectives:

- Students will describe how Newton's Laws of Motion relate to robotic rehabilitation devices.
- Students will design and build a simple mechanical arm to simulate motion in physical therapy.
- Students will collect and analyze performance data and explain design choices in a technical memo.

PA STEELS Science Standards Addressed:

- **3.2.9-12.A:** Apply Newton's Laws of Motion to relate force, mass, and acceleration.
- **3.4.9-12.E:** Evaluate and optimize engineering solutions using models, data analysis, and simulations.
- **3.5.9-12.C:** Design and refine technological solutions to real-world problems using the engineering design process.

Materials Needed:

- Cardboard, popsicle sticks
- Syringes, tubing (or string and pulleys as an alternative)
- Small weights or washers
- Rubber bands, fasteners
- Rulers, protractors
- Laptops/tablets (optional, for simulations)
- Student handout: "Mechanical Arm Data and Reflection Sheet"
- Whiteboards for group data displays

Instructional Strategy Connection:

This lesson builds on scaffolded content from anatomical instruction previously acquired in Lesson 1 and introduces students to mechanical principles. It uses inquiry-based learning, project-based construction, and hands-on experimentation. Differentiated tasks and guided practice are used to support diverse learners.

Step-by-Step Lesson Narrative:

Day 1 (45–60 minutes):

1. **Engage (5 min):** Show a short clip of a robotic rehabilitation arm in use. Ask, "Which physics concepts do you think are involved in the process of this robotic device assisting a person with moving their limb?”
2. **Concept Instruction (10 min):** Mini-lesson on Newton’s Second Law, torque, and force vectors. Use physical demos (e.g., levers or weights) to illustrate concepts.
3. **Design Brief (10 min):** Introduce the challenge: Create a simple mechanical arm that can lift a small object using principles of physics. Emphasize constraints: range of motion, stability, and load capacity.
4. **Initial Brainstorming (20 min):** Students sketch plans and list materials needed. The teacher circulates to support with vocabulary, modeling ideas, and scaffolding calculations.

Day 2 (45–60 minutes):

5. **Build and Test (30 min):** Teams build mechanical arms. They perform three trials, lifting an object and recording range of motion, lifting height, and stability.
6. **Data Analysis (10 min):** Groups analyze their results and compare them to their initial hypotheses.
7. **Memo Writing (15 min):** Students complete the "Mechanical Arm Data and Reflection Sheet," including an explanation of their design choices, evaluation of success, and ideas for improvement.

Evaluation Tools:

- Completed mechanical arm model
- Technical memo and data analysis
- Observation of teamwork and engineering process
- Exit ticket: "One physics concept I applied today was..."

Differentiation & Accommodations:

- Provide templates for data collection and calculations
- Visual guides for arm assembly
- Sentence stems and structured prompts for technical writing
- Alternate build materials for students with motor skill challenges
- Small group or one-on-one support, as needed

Lesson 3: Human-Centered Innovation—Designing for Real People

In this lesson, students will shift from **designing in the abstract to designing with empathy**. Students will engage in a multi-day "design sprint" where they will conceptualize and present a rehabilitation technology or device that meets the needs of a specific user. The lesson begins with students reviewing recorded interviews and testimonials from individuals actively participating in physical therapy treatment plans. Students can also record their own interviews if they personally know someone participating in physical therapy. Students will identify the challenges that patients face—physically, emotionally, or logistically—and then brainstorm assistive technologies to address one specific challenge.

Students will work in small groups to define the user's needs, sketch and label a proposed device, and highlight their design choices. Students can use design software, such as SketchUp and TinkerCAD, to develop digital models of their proposed designs. Teams will also begin the preparation of a short pitch to present to a panel of peers, educators, and invited guests from the community (which will take place in **Lesson 5**). Throughout the process, students will be encouraged to consider human factors such as ease of use, comfort, adaptability, and the user's dignity. Final deliverables will include a user-centered design portfolio that consists of need-finding notes, design sketches, and a team reflection.

This lesson strongly supports interdisciplinary learning and ties to standards including NGSS HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. Assessment will be based on the quality of the team's portfolio, clarity of their final presentation, and their use of feedback to refine ideas.

Lesson Number: 3
Lesson Title: Designing for Recovery: Applying the Engineering Design Process to

Rehab Robotics

Timeframe: 2 class periods (90–120 minutes total)

Objectives:

- Students will apply the steps of the engineering design process to conceptualize a rehabilitation device.
- Students will evaluate user needs and constraints relevant to physical therapy.
- Students will produce and present a prototype design sketch informed by biomechanical and physical principles.

PA STEELS Science Standards Addressed:

- **3.5.9-12.A:** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs.
- **3.5.9-12.C:** Design a solution to a complex real-world problem by breaking it down into manageable sub-problems.
- **3.1.9-12.B:** Develop and use models to illustrate the organization and function of systems.

Materials Needed:

- SketchUp and TinkerCAD (digital design software)
- Engineering Design Process poster/anchor chart
- Student handout: "Rehab Robotics Design Brief"
- Large chart paper, markers
- Sample profiles of patient needs (case studies)
- Rulers, graph paper, design tools
- Laptops/tablets for research
- Sticky notes for feedback

Instructional Strategy Connection:

This lesson integrates cooperative group work, project-based learning, and real-world problem-solving through the engineering design process and design thinking. Students take on the roles of engineers and physical therapists to develop designs that are user-centered. Empathy and evidence-based reasoning are reinforced in this lesson.

Step-by-Step Lesson Narrative:

Day 1 (45–60 minutes):

1. **Hook (5 min):** Pose the question: "If you had to design a tool to help someone regain movement after an injury, what would you need to know first?" Lead a short brainstorm.

2. **Mini-Lesson (10 min):** Review the Engineering Design Process: Define the problem, research, imagine, plan, create, test, and improve. Emphasize how medical technologies must address specific physical and emotional needs.

3. **Design Challenge Introduction (10 min):** Distribute the "Rehab Robotics Design Brief." Groups are assigned case studies and patient profiles with injury background, recovery goals, and mobility limitations.

4. **Collaborative Planning (20 min):** Teams begin identifying key functional goals of the device (mobility range, comfort, adaptability) and sketch initial designs. The teacher circulates and prompts students to explain how their devices respond to biomechanical principles.

Day 2 (45–60 minutes):

5. **Design Iteration (20 min):** Students refine their sketches and annotate key features. They consult internet or book-based references for reinforcement.

6. **Peer Feedback (10 min):** Each group posts sketches for a silent gallery walk. Students leave sticky notes suggesting improvements or asking clarifying questions.

7. **Reflection & Planning (15 min):** Groups revise designs and respond to feedback. They prepare a short oral rationale explaining how their device supports rehabilitation.

Evaluation Tools:

- Annotated design sketches with functional justifications

- Completion of "Rehab Robotics Design Brief" worksheet
- Observation notes on collaboration and participation
- Oral rationale for design decisions

Differentiation & Accommodations:

- Multiple entry points into the design process (researchers, illustrators, presenters)
- Visual and written design criteria provided
- Sentence stems for rational explanations
- Allowing use of digital tools or speech-to-text where needed
- Scaffolding through teacher questioning and small group conferencing

Lesson 4: From Blueprint to Build: Prototyping Rehabilitation Robotics

This lesson serves as a major extension of **Lesson 3** and provides another hands-on experience in the unit, where students transform their design concepts into tangible models. Building on prior lessons in biomechanics, physics, and engineering design, students begin constructing functional prototypes of rehabilitation robotics designed to aid physical therapy patients. In collaborative teams, students apply the engineering design process while addressing specific injury profiles to build and test devices that simulate therapeutic tools like exoskeletons, braces, or mechanical arms.

Students experience real-world innovation processes while also solidifying their grasp of scientific and engineering principles through cycles of feedback, iteration, and testing. Students are taught to see scientific inquiry as a dynamic, ever-evolving process thanks to the emphasis on collaboration, peer review, and iterative design. The final prototypes will become centerpieces for the culminating presentations in **Lesson 5**.

Lesson Number: 4
Lesson Title: From Blueprint to Build: Prototyping Rehabilitation Robotics
Timeframe: 2–3 class periods (135–180 minutes total)

Objectives:

- Students design and build a prototype of a rehabilitation device based on their design sketches.

- Students will apply knowledge of biomechanics and engineering principles to build functional models.
- Students will test, evaluate, and refine their prototypes based on peer feedback and design criteria.

PA STEELS Science Standards Addressed:

- **3.2.9-12.A:** Apply Newton's Laws and other physics concepts to predict motion and force interactions.
- **3.5.9-12.E:** Develop and test a prototype based on scientific reasoning and user requirements.
- **3.1.9-12.C:** Use models to simulate systems and interpret results from real-world tests.

Materials Needed:

- Design sketches from Lesson 3
- Prototyping materials (cardboard, tubing, wooden sticks, rubber bands, syringes, foam, velcro, string, tape, glue, etc.)
- Hot glue guns, scissors, hole punchers, rulers, pliers, measuring tape
- Laptops/tablets for documentation and testing videos
- Student handout: "Prototype Test Log & Reflection Sheet"
- Student handout: "Peer and Self-Assessment Forms"
- Rubric: "Prototype Evaluation Criteria"
- 3-D printer (*optional if students will be 3-D printing their designs from SketchUp or TinkerCAD)

Instructional Strategy Connection:

This lesson incorporates inquiry-based learning and cooperative learning, aligning with constructivist instructional strategies and the design-thinking framework. It emphasizes hands-on experimentation and real-world problem-solving through iterative testing and teamwork.

Step-by-Step Lesson Narrative:

Day 1 (45–60 minutes):

1. **Set Up & Expectations (10 min):** Review project goals and safety guidelines for tool and material use. Review the evaluation rubric so students are aware of performance expectations.

2. **Prototype Construction (35–50 min):** Students work in teams to begin constructing their devices. The teacher circulates to offer feedback, help troubleshoot, and support tool safety and proper material use.

Day 2 (45–60 minutes):

3. **Finish Construction (30 min):** Teams complete final assembly of their prototypes.

4. **Initial Testing (15 min):** Students test their devices according to defined criteria (range of motion, load-bearing, usability, etc.).

5. **Peer Feedback (10 min):** Teams rotate through others' stations, testing or observing other devices and leaving constructive feedback.

Day 3 (Optional/Extended Time):

6. **Iteration and Finalization (45 min):** Students revise their builds based on peer and self-assessment. They prepare presentation materials and record short video demonstrations.

Evaluation Tools:

- Completed prototype
- "Prototype Test Log & Reflection Sheet"
- Peer and self-assessment forms
- Final performance against rubric criteria
- Observation of collaboration and problem-solving

Differentiation & Accommodations:

- Assign team roles suited to student strengths (builder, documentarian, safety lead, presenter)
- Provide additional modeling or video demonstrations for students needing support
- Offer scaffolded “build checklists” for executive function needs
- Allow alternative formats for reflections (oral, video, visual mapping)

Lesson 5: Prototype Presentations—Communicating Robotic Design Solutions

In this culminating design-thinking lesson, students will present their rehabilitation robotics prototypes that they designed in **Lesson 3** and constructed in **Lesson 4** to their classmates and invited guests from the community in a formal showcase, similar to that of the famous TV show “Shark Tank.” The presentations will include visual displays, design rationale, explanations of biomechanics and physics concepts that they applied, and how their device meets the needs of a specific user or user population. Students will answer questions from their peers and teachers, and receive feedback that emphasizes both the scientific merit and user-centered thinking behind their inventions.

This lesson prioritizes communication, collaboration, and the ability to synthesize learning from across the unit into a clear and persuasive presentation. Emphasis will also be placed on creativity, clarity of scientific explanation, and real-world application.

Lesson Number: 5
Lesson Title: Prototype Presentations—Communicating Robotic Design Solutions
Timeframe: 1–2 class periods (45–90 minutes total)

Objectives:

- Students will clearly present their robotic prototype using appropriate scientific and engineering vocabulary.
- Students will justify design choices based on user needs and biomechanical function.
- Students will receive and respond to peer feedback to enhance their communication skills.

PA STEELS Science Standards Addressed:

- 3.5.9-12.C: Present and defend a solution to a complex problem using data and scientific reasoning.
- 3.4.9-12.A: Use models to simulate systems and communicate design thinking.
- 3.2.9-12.B: Engage in argument from evidence when evaluating design choices.

Materials Needed:

- Completed prototypes or mock-ups
- Presentation boards or slide decks
- Peer and Teacher Feedback Form: Prototype Presentations
- Prototype Presentation Scoring Rubric
- Timer, optional guest judges or staff attendees

Instructional Strategy Connection:
This lesson draws on presentation-based learning, collaborative feedback, and applied design thinking. It reinforces the connection between student agency, real-world relevance, and mastery of science content through public speaking and critique.

Step-by-Step Lesson Narrative:

Day 1 (45–60 minutes):

1. **Setup and Rehearsal (10–15 min):** Students finalize visual displays and rehearse their main talking points.
2. **Presentation Showcase (30–40 min):** Each group presents for 3–5 minutes. Audience members complete feedback forms and ask questions.

Day 2 (Optional – 45 minutes):

3. **Gallery Walk Extension (if needed):** Groups can set up at stations and rotate for more interactive Q&A.
4. **Feedback Review (10 min):** Students read and summarize feedback from peers and/or guests.

5. **Reflection Activity (20 min):** Prompt: "How did your final design evolve over time? What would you improve if you had more time/resources?"

6. **Teacher Assessment & Closure (15 min):** Collect rubrics, thank guests, and debrief the experience as a class.

Evaluation Tools:

- Prototype Presentation Scoring Rubric
- Peer and Teacher Feedback Form: Prototype Presentations
- Student self-assessment or reflection paragraph

Differentiation & Accommodations:

- Sentence starters and visual aids for ELL/IEP students
- Modified presentation formats (video, voiceover slides) for students needing alternatives
- One-on-one rehearsal check-ins for confidence building

Lesson 6: Ethics in Action—Evaluating the Human Impact of Rehabilitation Robotics

Students will critically examine the moral and societal effects of using robots in physical rehabilitation in this lesson. The class will start with a short overview of real-life examples of how rehabilitation technology has made patients' lives better, and how they have also generated ethical questions and concerns.

Students will then participate in a structured debate or Socratic seminar focused on questions such as:

- **"Should robots replace human caregivers in physical rehabilitation?"**
- **"What responsibilities do engineers and medical professionals have when designing assistive technologies?"**
- **"How should we balance patient autonomy with technological efficiency?"**

To prepare for the debate, students will research perspectives from patients, engineers, physical therapists, and medical ethicists. They will be encouraged to consider factors such as cost, accessibility, emotional well-being, and long-term physical outcomes.

Following the debate, students will complete a reflective writing assignment where they articulate their own perspective on the ethical use of robotics in healthcare, supported by evidence from their research and classroom discussions. This reflection will challenge students to synthesize scientific, technical, and ethical considerations, reinforcing the real-world relevance of their studies.

Assessment:
Students will be evaluated on their participation in the debate, the quality of their research, and the depth of their written reflections, which will be graded using a rubric focused on critical thinking, evidence use, and clarity of communication.

Standards Addressed:
This lesson aligns with NGSS HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs. It also supports interdisciplinary connections to social studies, ethics, and communication.

Lesson Number: 6
Lesson Title: Ethics in Action: Evaluating the Human Impact of Rehabilitation Robotics
Timeframe: 1 class period (45–60 minutes)

Objectives:

- Students will evaluate the ethical considerations and human impact of using robotics in physical therapy.
- Students will analyze case studies to identify potential benefits, risks, and social implications.
- Students will engage in structured discussion to form and defend evidence-based opinions.

PA STEELS Science Standards Addressed:

- **3.4.9-12.E:** Evaluate the societal and ethical implications of engineering decisions.
- **3.5.9-12.D:** Analyze how science and technology interact with society and the environment.
- **3.1.9-12.F:** Engage in argument from evidence to support or critique claims.

Materials Needed:

- Case Study Handout: Ethical Dilemmas in Rehab Robotics (3 short fictional cases)
- Structured Discussion Protocol Handout (e.g., Socratic Seminar roles or 4 Corners Debate Guide)
- Sticky notes or sentence starter cards
- Whiteboard or chart paper for capturing group insights

Instructional Strategy Connection:

This lesson uses discussion-based learning, critical literacy, and ethical reasoning. Students engage in collaborative dialogue and argumentation aligned with STEM practices and real-world ethical inquiry.

Step-by-Step Lesson Narrative:

Engage (10 min):

- Pose a question: "Should all patients have access to robotic therapy, even if it is extremely costly?"
- Quickwrite responses in journals; share out a few perspectives to highlight complexity.

Explore (20 min):

- Distribute case studies. In small groups, students read and discuss:
  - Case 1: AI-driven exoskeleton misinterpreting user input
  - Case 2: Cost barriers for rural or underinsured patients
  - Case 3: Emotional effects of replacing human therapists with machines
- Groups annotate the dilemmas and list stakeholders, benefits, and potential harms.

Explain & Elaborate (15 min):

- Conduct a Socratic Seminar or 4 Corners Debate. Students choose a stance on one ethical issue and support it with evidence.

- Encourage respectful rebuttals and push students to consider perspectives beyond their own.

Evaluate (10 min):

- Reflection prompt: "What ethical responsibility do engineers have when designing medical technologies?"
- Exit ticket: Students record one concern and one opportunity they see in robotic rehabilitation technology.

Evaluation Tools:

- Case study annotations and group discussion notes
- Structured Discussion Protocol Handout—Participation in structured discussion (rubric-based or checklist)
- Journal reflection and exit ticket response

Differentiation & Accommodations:

- Provide audio versions of case studies for emerging readers
- Use visuals or graphic organizers to help identify stakeholders and impacts
- Offer sentence starters for students with language processing needs
- Use paired discussions before whole-class debates to reduce student anxiety

Resources

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Annotated Resources for Classroom Use

- **TED Talks: Robotics in Medicine**—Students watch selected TED Talks in Lessons 3 and 4 to connect real-world innovators and patients to classroom design goals.

- ○ “Wearable Robots for Sustainable Welfare”
- ○ “How Wearable Robots Are Transforming Human Mobility”
- ○ "Medical robots in action: Ivar Mendez at TEDxToronto"
- ○ "How AI robots are changing healthcare | Charles Gellman | TEDxFolsom"

- **ReWalk Robotics, Ekso Bionics Websites (and other robotics company websites)**—Used in Lessons 2, 3, and 6 for case studies, visual references, and student research; students cite these in their design portfolio and technical memos.
  - The Pheonix by Suitx
  - Ekso Bionics
  - Rex Bionics
  - Keeogo
  - Lokomat by Hocoma
  - G-EO System by REHA Technology
- **SketchUp/Tinkercad**—In Lesson 3, students use these platforms to digitally prototype their rehabilitation devices. They are integral to the design-thinking strategy and support differentiated expression. Students can use 3-D printers in Lesson 4 to print their digital designs.
- **YouTube Channel: Harvard Biodesign Lab**—Demonstrates soft robotics principles covered in Lessons 2 and 3. These clips help visual learners grasp mechanisms like pneumatic actuation.
  - Harvard Biodesign Lab YouTube Channel
- **APTA (American Physical Therapy Association)**—Students use this website in Lessons 4 and 6 for researching rehabilitation professions and ethical issues; it also supports career readiness.
  - American Physical Therapy Association

Appendix

Academic Standards Addressed

NGSS (Next Generation Science Standards)

- **NGSS HS-LS1-2**: Develop and use a model to illustrate the hierarchical organization of interacting systems within multicellular organisms.
- **NGSS HS-PS2-1**: Analyze data to support the claim that Newton's Second Law of Motion describes the mathematical relationship among net force, mass, and acceleration.
- **NGSS HS-ETS1-2**: Design a solution to a complex real-world problem by breaking it down into smaller, manageable problems that can be solved through engineering.

Pennsylvania STEELS (Science, Technology & Engineering, Environmental Literacy & Sustainability) Standards

Life Science (Grades 9–12)

- **3.1.9-12.B**: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
- **3.1.9-12.C**: Plan and conduct an investigation to provide evidence of the importance of maintaining homeostasis in living organisms.

Physical Science (Grades 9–12)

- **3.2.9-12.A**: Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
- **3.2.9-12.B**: Develop and use models to illustrate the relationships between systems or between components of a system.
- **3.2.9-12.C**: Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system.

Environmental Literacy & Sustainability (Grades 9–12)

- **3.4.9-12.A**: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
- **3.4.9-12.B**: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
- **3.4.9-12.C**: Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
- **3.4.9-12.E:** Evaluate and optimize engineering solutions using models, data analysis, and simulations.

Technology & Engineering (Grades 9–12)

- **3.5.9-12.A**: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
- **3.5.9-12.B**: Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.
- **3.5.9-12.C**: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Evaluative and Instructional Materials

- **Lesson 1—** "Joint Model Design Notes" Handout; includes sections for students to document their planning, design process, understanding of human anatomy, and reflection; integrates content knowledge, engineering practices, and real-world applications.
- **Lesson 2—** "Mechanical Arm Data and Reflection Sheet"; includes an explanation of the student's design choices, an evaluation of success, and ideas for improvement.

- **Lesson 3—** "Rehab Robotics Design Brief"; guides students through the user-centered design process; includes structured prompts to help students apply engineering principles, think and design with empathy, and justify their design choices.

- **Lesson 3—** "Sample Profiles of Patient Needs (Case Studies)"; includes five diverse, age-appropriate case studies that focus on different physical therapy challenges, mobility limitations, and social-emotional considerations to foster student empathy and guide thoughtful design choices.

- **Lesson 4—** "Prototype Test Log & Reflection Sheet"; designed to guide students through the testing and refinement phase of their robotic rehabilitation prototypes; includes structured sections for recording test data, reflecting on performance, incorporating peer feedback, and planning design improvements.

- **Lesson 4—** "Prototype Evaluation Criteria"**;** includes a student-friendly rubric that clearly outlines performance expectations across five key categories and can be used by teachers, peers, or students for self-assessment; rubric supports reflection and aligns with the steps of the engineering design process.

- **Lesson 4—** "Peer and Self-Assessment Forms"**;** designed to promote reflection, teamwork, and constructive critique during the prototype construction and testing phase; includes two parts—one for peer assessment during the gallery walk or rotation phase, and one for individual team member reflection.

- **Lesson 5—** "Peer and Teacher Feedback Form: Prototype Presentations"; designed to promote meaningful, constructive critique from both peers and educators while encouraging students to reflect on scientific reasoning, user-centered design, and communication skills.

- **Lesson 5—** "Prototype Presentation Scoring Rubric"; a student- and teacher-friendly rubric aligned with the lesson's emphasis on communication, scientific accuracy, design rationale, clarity, visual support, and teamwork; rubric can be used by teachers, peers, and guest evaluators to assess final presentations.

- **Lesson 6—** "Structured Discussion Protocol Handout"; designed to be a flexible tool that supports either a Socratic Seminar or a 4 Corners Debate, depending on the teacher's instructional choice; includes clear roles, prompts, and participation guidelines for high school students.

- **Lesson 6—** "Case Study Handout: Ethical Dilemmas in Rehab Robotics"; features three fictional case studies outlined in Lesson 6; includes discussion questions following each case that are designed to support structured debate or Socratic seminar.