Designing for Precision: Modeling Radiation Therapy with Robotics and Sensors (Resource Exchange)

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Dr. Molly H. Goldstein is a Teaching Assistant Professor and Product Design Lab Director in Industrial and Enterprise Systems Engineering at the Grainger College at the University of Illinois. She is also courtesy faculty in Mechanical Science and Engineering, Curriculum & Instruction (College of Education) and Industrial Design (School of Fine and Applied Arts). Dr. Goldstein's research focuses on student designers through the study of their design actions and thinking.

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Dr. Marcia ("Marci") Pool is the Assistant Director for Education at the Cancer Center at Illinois and a Teaching Associate Professor in Bioengineering. She holds a Ph.D. in Biomedical Engineering, has served for sixteen years as teaching faculty/staff in biomedical/bioengineering and nine years in departmental/institute educational administration, and is an ABET program evaluator for Bioengineering/Biomedical Engineering. She focuses on identifying and evaluating mechanisms to enhance the educational experience and develop students into engineers and researchers. Her work includes interventions to enhance training for high school students, undergraduate students, and predoctoral (graduate students) and postdoctoral trainees through training programs such as NIH T32s. These programs include curricular, extracurricular, and professional and career development components with required evaluation and tracking of student participants.

Stephanie Dietrich, University of Illinois at Urbana - Champaign

Stephanie Dietrich holds a master's degree in library and information sciences and is a certified K-12 teacher, with experience teaching computer science and engineering design to K-8 students. She currently serves as the Educational Programs Manager at the Cancer Center at Illinois, where she leads K-12 outreach and community engagement initiatives, inspiring young learners through hands-on STEM activities and cancer education.

DESIGNING FOR PRECISION:
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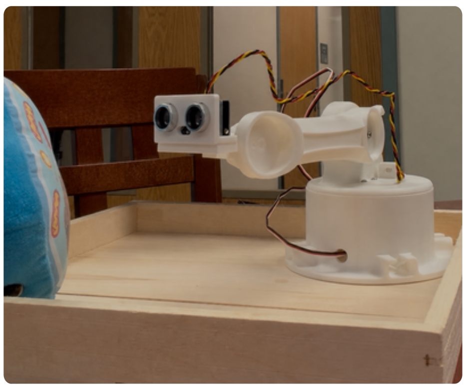
Cancer Center at Illinois
UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Developed by:	**Cancer Center at Illinois Cancer Research Training and Education Coordination Team in collaboration with students from the Cancer Scholars Program**

Time	**90-120 Minutes**	**Grade Level:**	**7-8 Grade (Middle School)**



OVERVIEW

Precision can be the difference between effective treatment and unintended harm in cancer care. This resource introduces students to the engineering design process by modeling the complex systems used in radiation therapy. Students build and code a robotic arm that uses an ultrasonic sensor to detect a "tumor" at a precise distance. When the system achieves alignment, an LED signal provides immediate feedback, simulating the safety protocols engineered into modern medical linear accelerators. Complete activity details, including coding guidance and Micro:bit instructions, are provided in the digital repository.

Learning Goals

1. **Explore** the importance of precise alignment in medical physics to protect healthy tissues.
2. **Simulate** robotic positioning using servo motors and feedback loops.
3. **Analyze** the advantages of sensor-based systems over manual measurements for medical accuracy.
4. **Integrate** hardware and software to create a functional medical technology prototype.

Standards Alignment

- **MS-ETS1-1:** Define the criteria and constraints of a design problem.
- **MS-ETS1-2:** Evaluate competing design solutions.
- **MS-ETS-1-3:** Analyze data from tests to identify similarities and differences among solutions.
- **MS-ETS1-4:** Develop a model to generate data for iterative testing and modification.
- **1B-AP-10:** Create programs that include sequence, events, loops, and conditionals.

Materials & Components

- Micro:bit or Arduino Controller
- Servo Motors (2x)
- Ultrasonic Distance Sensor
- LED & Resistor
- Popsicle Sticks
- Hot Glue/Tape
- Paper Targets
- Cardboard Base

Student Brief Design

Objective: Successfully align with the target in three consecutive trials in under 20 seconds.
Constraints: The sensor must be the only method used to verify the 15cm distance.

Instructional Procedures

1 . The "Manual" Challenge

The Problem: Can a human aim a beam as accurately as a machine?
Activity: One student acts as a radiation oncologist using a ruler and a pointer to hit a specific 15cm target.
Observation: Students record the time and difficulty of achieving "perfect" precision without a sensor.

2. Building the Robotic Arm

Assembly: Students mount the first servo for rotation (horizontal) and the second for tilt (vertical).
The "Beam": Attach a popsicle stick to the tilt servo and mount the ultrasonic at the very tip.
The Feedback: Connect an LED to a digital pin to signal when the target is acquired.

3. Programming for Precision

Logic: Write code to read the ultrasonic sensor data.
Conditionals: Create an if-then statement: If the distance is between 14.5 cm and 15.5 cm, turn on the LED.
Control: Use buttons or dials to sweep the servos until the "Tumor Found" signal (LED) activates.

4. Testing & Iteration

Blind Test: Can students align the beam without looking, relying only on the LED feedback?
Optimization: Adjust the code to change the "tolerance" (e.g., narrowing the window from 1cm to 0.5cm) to see how it affects difficulty.

Scan Me

Contact:
Project Link: https://go.illinois.edu/CCILoutreach
This outreach is supported by the Cancer Center at Illinois.

References:

- Cancer Center at Illinois. (2026). Radiation therapy simulation guide: Designing for precision. University of Illinois Urbana-Champaign.
- Computer Science Teachers Association (2017). CSTA K-12 Computer Science Standards, Revised 2017. Retrieved from https://csteachers.org/k12standards/.