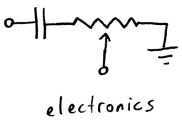
Syllabus: 60-223 Intro to Physical Computing

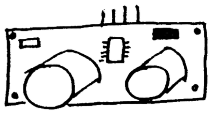
Carnegie Mellon University
Spring 2026

Course synopsis



This practical project-based course begins by covering the basic technical skills (electronics, programming, and fabrication) needed to build interactive objects with embedded behavior using the Arduino microcontroller. Inputs to read information about the world include sensors such as an ultrasonic ranger, thermometer, light sensor, and human inputs like buttons and knobs. Outputs to affect the world include actuators such as motors, LED lights, speakers, and haptic feedback devices. Individual and group projects challenge students to apply their technical skills in creative ways. The class will be working with on-campus design clients for the final project; students create novel assistive devices of a practical or whimsical nature for their critique and feedback.

```
if (x < 3) {
  digitalWrite(LED, HIGH);
}
```
programming



When, Where, and Who

We meet Mondays and Wednesdays, 10am - Noon, in IDeATe's Physical Computing Lab (Hunt A10).
The course carries ten academic units.

Professor: Joseph Paetz *(he/him)*, `rpaetz@andrew.cmu.edu`

office: Hunt A9A (across the hall from the Phys Comp Lab, the room with the wavy glass door)

lab hours:

- Mondays and Wednesdays, noon–1pm in Hunt A9A (or possibly A10)
- and *liberally* by appointment (just email me with your request and I'll be happy to set up a time to talk)

Important links

- **Main course site**: courses.ideate.cmu.edu/60-223 This site is updated throughout the semester with assignment information, and has lots of reference pages and tutorials.
- **Student documentation site**: sites.google.com/andrew.cmu.edu/60-223-s26/home Students post documentation for the three major projects here.
- **Canvas page**: https://canvas.cmu.edu/courses/51096 Some asynchronous learning modules are completed via Canvas; you'll submit homeworks there; and it's where grades are posted.
- **This syllabus** is available at courses.ideate.cmu.edu/60-223/s2026/syllabus.pdf

Prerequisites

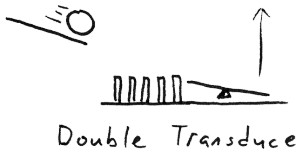
There are no formal prerequisites or assumed topical knowledge for this class. However, some basic programming understanding (such as familiarity with variables and their use, the `if…else` structure, `for` and `while` iterators, etc.) will be helpful, as we spend little time in class on the rudiments of programming. In the past, students without any prior programming experience have been able to succeed by learning as they go, and asking for help as needed.

Major deliverables

There are a sequence of homeworks, some domain-specific skill-building exercises, as well as two larger projects in the course. See the particular assignments on the main course site for further details on each. Briefly:

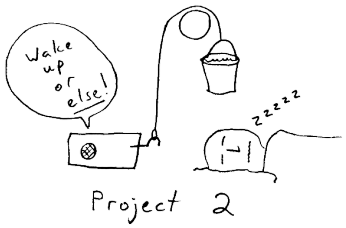
- **Homework** *(15% of final grade)*
  - *Asynchronous learning modules* are recorded video lectures that cover the bulk of the course's technical learning, addressing topics like circuit design and programming. These are accessed via the course Canvas site.

  - *Reading/watching homeworks* typically consist of journal articles or videos addressing issues pertinent to the course. There are only a handful of these assigned during the semester.
  - *Weekly check-ins* are brief, weekly opportunities for you to ask any questions you've got and/or tell me about your experience in the course. Turn them in on time for full credit, or up to 24 hours late for half credit.
  - *Error Bounty Hunting* is an opportunity to earn extra credit points. If you find an error, broken link, typo, etc., in the course website or Canvas page, email me to claim a bounty. See the relevant Canvas assignment page for details on this.
- **Project 1: A Double Transducer** *(15% of final grade)* is a technical exercise in changing the form that a physical input signal takes, changing it again, and then outputting another signal. Students are



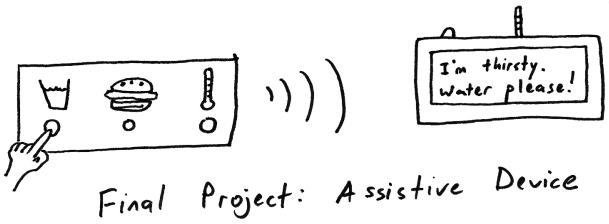
assigned to work in teams of two, but each student builds their own machine, learning the basics of electronics fabrication along the way.

- **Domain-specific Skill-building Exercises** *(two exercises, each worth 15% of final grade for a total of 30%)* take one week each, and provide opportunities for technical learning across multiple physical computing domains. Each exercise starts with some baseline technical learning and then allows you to make a brief exploration on that topic, concluding with a quick demo.
- **Project 2: An Assistive Device for Yourself** *(20% of final grade)* is an opportunity to build yourself something that may be useful to you in your own life. Students work on their own project. Prior works include:
  - a variety of creative alarm clocks which, for instance, require a special procedure to silence,
  - a long-term memory aid to keep precious memories intact by printing out a reminder before bedtime,
  - a device to reward the owner for not using their phone during a timed interval,
  - a reminder for a thrombosis patient not to remain sitting for too long,
  - a bolted-on turn signal for a scooter, and
  - a timed lock box to prevent the designer from eating chocolate too late at night.

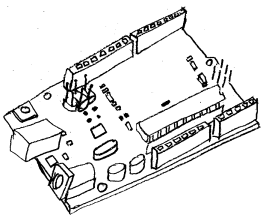


- **Final project: An Assistive Device for a Campus Client** *(20% of final grade)* is an opportunity to build something for a design client on our campus. Students work in assigned groups to produce a novel interactive physical computing device meant to help that person in some way that's relevant to their work at CMU. Semesters prior to Fall 2025 focused on helping people with disability, and projects under that version of the assignment included:
  - a portable device to help a color blind user determine the color of any object/surface,
  - a dog-shaped machine that prints written positive affirmations to cheer up a user,
  - a custom keyboard/mouse input to help a user more comfortably play computer games online,
  - an alarm clock with a braille interface for a deafblind user, and
  - a foot-controlled MIDI instrument for a wheelchair user to make music.

  The Fall 2025 semester worked with the campus FMS department. Those projects included:
  - a tool box that reminded a pair of carpenters which tools they hadn't put away,
  - a scale to weigh paint cans and calculate the surface area that could be painted with what was left in the can, and
  - a sign that automatically prevented people from interrupting the supply office staff during their lunch break.



Course materials



Enrolled students are supplied with a kit of electronics that is theirs to keep, and throughout the semester (as well as beyond), students are encouraged to take advantage of IDeATe's Physical Computing Lab equipment and resources. The Arduino Uno R3 is our primary microcontroller in the course. To program that hardware, we use the Arduino integrated development environment, which is open-source and gratis software, available for download from arduino.cc. There are no required texts, and there is no course materials/lab fee.

Learning goals for this course

Some of our learning goals are:

- Develop an appreciation for and ability to participate in critique of one's own and others' work
- Develop an understanding of the role of reflection in learning and designing
- Develop an ability to articulate the story (visually, verbally, etc.) of one's own work and learning
- Demonstrate the ability to learn and work in a multidisciplinary environment
- Demonstrate an understanding of the cultural context, and social and environmental implications of electronics in the modern world
- Engage sincerely and thoughtfully with the preferences and needs of an outside client
- Build prototypes as a way of answering critical questions about a project's design goals
- Conduct a meaningful needfinding interview for a client in an open-ended design project
- Demonstrate technical and creative skills in writing software for the Arduino microcontroller, create circuits that safely work as intended, and make an effective, useful device to help someone

Schedule overview

This Gantt chart shows a week-by-week course overview:

			course week															
Course event or project	start	end	1	2	3	4	5	6	7	break	8	9	10	11	12	13	14	finals
Introductory homeworks	1	2	x	x														
Project 1 ideation	2	3		x	x													
Project 1 work	3	4			x	x												
Project 1 due	4	4				!												
Laser training	5	5					!											
Domain-specific Skill-building Exercise 1	5	6					x	x										
Domain-specific Skill-building Exercise 2	6	7						x	x									
Fun hack day / Project 2 intro	7	7							!									
Project 2 ideation	8	8									!							
Project 2 work time	8	10									x	x	x					
Project 2 final critique	10	10											!					
Final project interviews	11	11												!				
Final project work time	11	14												x	x	x	x	
Final project final critique	14	14															!	
Final project documentation	finals	finals																!

Note that red ! exclamation points indicate due dates or singular events, while green x's indicate ranges during which work happens.

Course grading scheme

In general, assignments and projects have a rubric posted on the course website. Once an assignment grade is returned to you, that opens a seven-day window during which you can resubmit updated work if you choose. It is important that you actually *resubmit that assignment via Canvas* in order to affirmatively communicate that you've made improvements and would like that work to be regraded.

The overall course grade is computed from these components:

- 15% homeworks
- 15% Project 1
- 30% Domain-specific Skill-building Exercises
- 20% Project 2
- 20% Final project

The final percentage is rounded to the nearest whole number and midterm and final letter grades are allocated using the following scales:

final grade (%)	≥97	93–96	90–92	87–89	83–86	80–82	77–79	73–76	70–72	67–69	60–66	<60
undergraduate student grade	A	A	A	B	B	B	C	C	C	D	D	R
graduate student grade	A+	A	A–	B+	B	B–	C+	C	C–	D+	D	R

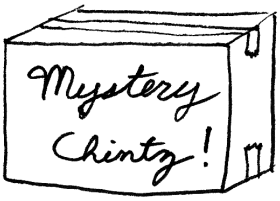
Class policies

Presence

Class time is quite precious; we've got only 26 class meetings in total, about 48 hours over the course of the semester. Because of this, there are some clear expectations for all of us:

- ⎍ I will get to class early and ready to go. During class time, I'll focus exclusively on our course.
- ⎍ I'll use class time as wisely as I can: e.g. if the whole group does not need to be involved in a discussion, I'll try to bring only the needed group together.
- ⎍ In that same spirit, if I'm able to assign a pre-recorded lecture as homework, rather than taking class time to do that teaching, then I will aim to do that.
- ⎍ You'll also respect class time: you will come on time and ready to learn.
- ⎍ You'll use class time to focus on the class, and not the fun things happening inside your phone or out on the internet. (See next section for more on that.)

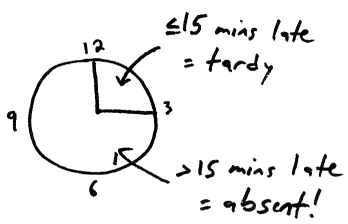
Students with a perfect attendance record at the end of the semester (no tardies, no absences) will get a charmingly chintzy award made by the instructor.



Absence

You are expected to attend class, and to arrive on time. Past experience has repeatedly shown that higher attendance correlates with greater success in the class, so it's in your best interest to come to class!

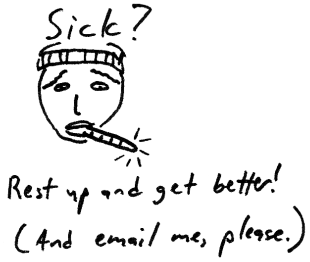
You are given two unexcused absences without penalty; beyond that, any additional unexcused absence will result in a 3 point deduction off of your final grade in the course. E.g.: if at the end of the semester your final average is 92.4% (which would earn an A for an undergraduate) but you have three unexcused absences, your grade falls to 89.4%, which earns a B.



Late arrivals to class are disruptive to the group. Please arrive on time (or early). Tardiness of more than 15 minutes is counted as an absence.

If you expect you won't be able to attend a class session for any reason, or if you'll be late, please *email me as early as feasible to let me know and request an excused absence*.

If you're feeling ill, please email me advising of the circumstance as early as you're reasonably able and focus on taking care of yourself. You will never be penalized for missing class for a health-related reason. Seek medical care as needed, and rest up so you can regain your health and return to full participation.



The outline of each class session is posted after the class on the class log page. If you missed a class, that's the first place to look.

Phone/computer use

While we're in class, please don't use your phone for non-class purposes. If you need to use your phone to contact others, just step out into the hallway. Similarly, while we're in class, please don't use your computer for random internetting, social mediation, or any other use that isn't pertinent to class. You've got the whole rest of your life to TweetGram sweet memes and #tags (though I don't especially recommend it).

The use of distracting technology by students in the physical classroom is obviously deleterious to the student who's choosing to use it, but it's also harmful to other students *who are merely sitting near the distracted student*. An article in "Computers & Education" pretty much spells it out in the title: "Laptop multitasking hinders classroom learning for both users and nearby peers."[1] A 2015 survey of 675 college students in the U.S. found that they spent "an average of 20.9% of class time using a digital device for non-class purposes,"[2] which is pretty alarming. Please do your best to focus on class during class.

[1] Sana, F., T. Weston, and N. J. Cepeda. "Laptop multitasking hinders classroom learning for both users and nearby peers". Computers & Education, volume 62. 2013. pp. 24–31. https://doi.org/10.1016/j.compedu.2012.10.003

[2] McCoy, B. R., "Digital Distractions in the Classroom Phase II: Student Classroom Use of Digital Devices for Non-Class Related Purposes". Faculty Publications, College of Journalism & Mass Communications, vol 90. 2016. pp. 5–32. http://digitalcommons.unl.edu/journalismfacpub/90

Accommodation

In the spirit of encouraging everyone to be maximally present in class together, it's important that students feel comfortable and supported. If there is anything physically in the environment that can be reasonably adjusted to make your learning experience better, you should feel generally empowered to make that adjustment. If the lights are too bright at your table, please ask your neighbors if it's ok to dim them, and if yes, go ahead and do so; if we're playing music at a work session and it's too loud, please say so; etc.

If there is any aspect of instruction that is giving you difficulty, such as my not spending long enough on a topic or making reference to a point we haven't covered yet, please speak up. This sort of feedback is very helpful to maintaining a successful classroom and much appreciated.

If you have a disability and have an accommodations letter from the Disability Resources office, I encourage you to discuss your accommodations and needs with me as early in the semester as possible. I will work with you to ensure that accommodations are provided as appropriate. If you suspect that you may have a disability and would benefit from accommodations but are not yet registered with the Office of Disability Resources, I encourage you to contact them at `access@andrew.cmu.edu`.

Statement on diversity

IDeATe is a heterogeneous environment by design, and our classroom is as well. Having students from a variety of academic backgrounds and college years is one way in which we aim to diversify the space; but also we also embrace diversity along other axes such as culture, national/state origin, race, gender, language, socioeconomic status, disability, and religious adherence. We sincerely believe that bringing together many different kinds of people makes for a richer learning environment for everybody.

If at any point you feel that you're experiencing discomfort brought about by discrimination along any of these lines (or others), please immediately notify me so that I can take appropriate steps to rectify the circumstance. I'm always happy to make time to speak with you individually about any concern you've got; I'm just an email away. If you would like to submit feedback or comments to me anonymously for any reason, please use this form I've created for that purpose.

Additionally, there are two University-wide resources for reporting incidents of bias or discrimination:

- *The Center for Student Diversity and Inclusion*
  - email: `csdi@andrew.cmu.edu`
  - phone: (412) 268-2150

- *Confidential third-party ethics reporting service*
  - https://cmu.ethicspoint.com

Lab access and policies

Enrolled students have access to the IDeATe Physical Computing Lab whenever Hunt Library is open. Hunt library's hours are posted on their website. IDeATe spaces' schedules are available here (you'll have to log in to see them).

The Phys Comp Lab's inventory is online for your convenience. If you discover that we are running low, or are out of, any part or material in the lab, please fill this form out so it can be quickly replenished.

While in the Phys Comp Lab please observe some simple rules:

- Food and nonwater drinks may only be consumed in the *Zone of Shame* by the door; this is an electronic lab space, and it's important to sequester comestibles from our work environment for the protection of both.
- The exception to this rule is that covered water containers are permitted at work tables.
- Please store project material in your cubby; if you need more space let me know and we'll make arrangements.
- Tools that belong to the room (like those on the pegboard in the Heavy Work Zone, or in the red tool cabinet) must always remain in the room. Don't take them elsewhere without asking, and don't hide them in your cubby!
- Electronics in the drawers are available for your use; take them as you need. The expectation is that you'll return things when you're done with them. Don't worry too much about returning little stuff like resistors and LEDs; worry more about things like motor drivers, rotary encoders, or pumps.
- Broken electronic components should be disposed of in the Electronic Waste Bin underneath the electronics bench; these contain toxic metals and need to enter a different waste stream than regular garbage.
- If you're reading this, please click this link.
- It's kind of a kindergarten situation: when you're done working, please clean up after yourself.

Projects and collaboration

As mentioned above, this and all IDeATe courses purposefully attract students from a wide disciplinary range, including art, design, engineering, architecture, computer science, business, science, and more.

Some of the projects in the course are completed in groups rather than individually. The expectation is that group members will honestly strive to work together on their projects and will rise or fall as a unit, understanding that identifying complementary strengths and weaknesses early on will help the team succeed. All members of a group receive the same grade for a project except in unusual circumstances.

If your group is having trouble working together, please reach out to the instructor as soon as you think there may be some real issues. As an authoritative outsider, I can step in to help in ways that group members themselves can't.

Grading and due dates

Assignments are generally due at the beginning of class, and arriving late to class because you are finishing the assignment results in a late assignment mark (so you might as well come to class and finish the assignment later).

Homeworks and **project documentation** turned in late for grading will be penalized 10% per 24-hour period of tardiness. It's always better to submit something on time and update it later than submit nothing at all.

Projects are graded based on their state at the time they are due, i.e. the day of the in-class critique or demo. Late submissions are possible only at the instructor's discretion. If you are worried about not being able to complete a project on time, contact the instructor as early on as possible. It is better to hand in or present *something* rather than nothing. If your project is only partially functioning, on critique/demo day show us what you've got and you'll get partial credit.

Grading timeline

You can expect feedback on assignments within one week of handing them in. If you don't get a grade or other response from me within that timeline, please contact me right away to let me know—I might've overlooked your work accidentally, and I don't want you to be waiting unnecessarily long for feedback from me.

In order to help ensure that I get you your grades on time, I'll bring in snacks for the class on any day when I've owed grades for more than a week.

Academic integrity

In this class, you are *expected* to incorporate ideas, hardware/electronics design elements, and software fragments from outside sources; this isn't considered plagiarism if you properly cite your sources. If you're not sure if you're borrowing too much from somebody else, or you don't know how to credit the work you're borrowing from, please discuss it with the professor.

Use of ChatGPT or other generative AI systems for coursework is generally permissible, with two exceptions:

1. You cannot use generative AI to help write code in Project 1.
2. When writing any reflection, homework, or project documentation in this course, you cannot use generative AI nor any language translation service/system (AI or not). Every word of the writings in these submissions must be entirely your own, i.e. written solely by you and without any machine assistance.

Failure to cite sources and/or use of generative AI where it's prohibited are both considered plagiarism. The penalty for plagiarism consists of a grade of –200% on that assignment, e.g. for a 10-point assignment the student receives a grade of negative 20 points, and an Academic Integrity Report will be filed to report the violation to the Office of Community Responsibility. Don't copy code from any place or person without properly citing it, and don't use any generative AI system to help write reflections, homework, or project documentation. As always, if you have questions, ask!

Recording class

Unless you have special dispensation via the Office of Disability Resources to record as an accommodation, do not record class without obtaining prior written permission from the instructor.

IDeATe

IDeATe, the **I**ntegrative **De**sign, **A**rts, and **Te**chnology network at Carnegie Mellon, offers undergraduate minors and courses in Game Design, Animation & Special Effects, Media Design, Sonic Arts, Design for Learning, Innovation & Entrepreneurship, Intelligent Environments, Soft Technologies, Physical Computing, and Immersive Technologies in Arts & Culture. These areas merge technology and creativity and provide learning opportunities for interdisciplinary collaboration. IDeATe minors and courses are open to all majors. We welcome students from every discipline to the unique learning environment that exists at Carnegie Mellon.

IDeATe is not its own department. Rather, Carnegie Mellon's departments contribute faculty and courses to the IDeATe curriculum. Therefore, IDeATe does not have its own course number prefix. You can find the

IDeATe course offerings for the upcoming semester by going to the "IDeATe Courses" section of ideate.cmu.edu.

Relevant IDeATe skill-building micro courses

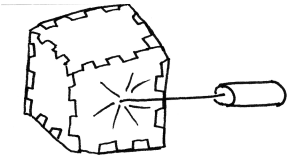
IDeATe offers a selection of "micro" courses; these are skill-building workshop-style classes which meet only a few times and confer 1 academic credit. Here are some micro courses relevant to Physical Computing:

- **99-352 IDeATe Soft Fabrication Skills** (opening a whole new world of textile possibilities)
- **99-353 IDeATe Design Essentials for Laser Cutting** (super useful for fabrication!)
- **99-354 IDeATe Essentials for Woodworking** (timeless material, great life skills, too)
- **99-357 IDeATe Pragmatic Photography** (a broadly portable skill to have in your bag)
- **99-359 IDeATe 3D Modeling and 3D Printing** (also very useful for fabrication and design)
- **99-360 IDeATe E-Textiles** (integrating electronics and fabrics. Very neat!)

IDeATe Open Fabrication Hours

IDeATe offers Open Fabrication Hours Monday–Friday, 5–6 p.m. for the duration of the regular academic year. During this time, you can get individual help from IDeATe student staff in using the laser cutters, 3D printers, and other IDeATe facilities. This resource is available to all university affiliates. See IDeATe's page on this for further details.

Laser cutter and 3D printer access



IDeATe maintains three Epilog Fusion Pro laser cutters in the digital fabrication alcove off of room A5. These machines are very precise, very fast, and very useful for all sorts of fabrication. Note that there are certain safety trainings required[3] before you'll be able to use the lasers; ask me for details. Schedule permitting, we will run a laser safety and use tutorial during class time which can serve as part—but not all—of the credentialing necessary to access the IDeATe laser cutters.

IDeATe runs a variety of 3D printing machines also in the alcove off of room A5. For further information about 3D printing and lasing with IDeATe, get in touch with Cody Soska (`csoska@andrew.cmu.edu`), IDeATe's Technical Specialist who manages all of that equipment. His desk is in the main IDeATe administrative offices, in Hunt A9.

[3] If you think you may want to get certified to use the lasercutters (and I highly recommend it), it's a good idea to sign up early for a Fire Extinguisher Training through BioRAFT, since they're offered on a limited basis: signup link.

IDeATe advising

If you have questions or need advice about IDeATe minors or courses, please get in touch with Kelly Delaney, the Associate Dean for IDeATe. Her office is in Hunt A5A (right outside the double doors to A5, the digital fabrication space), and her email is `kellydel@andrew.cmu.edu`

Taking care of yourself

I look forward to hearing from you in your weekly check-ins so I can get a sense of your progress and wellbeing, but **I also ask that you reach out to contact me if there's anything that you think that I should know about your circumstances which can help inform my teaching and expectations. I'm always happy to make time to speak privately with students about any concerns.**

Take care of yourself. Do your best to maintain a healthy lifestyle this semester by eating well, exercising, avoiding drugs and alcohol, getting enough sleep and taking some time to relax.

Be sure to take breaks if you've got large blocks of screen time. Get some fresh air in your lungs. Schenley Park, a beautiful 456-acre city park, is *literally* across Frew Street from Hunt Library. Go take a walk some time! Maintaining healthy habits will help you achieve your goals and cope with stress.

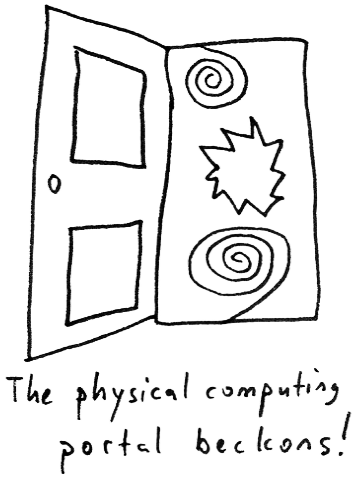
If you or anyone you know experiences any academic stress, difficult life events, or feelings like anxiety or depression, we strongly encourage you to seek support. Counseling and Psychological Services (CaPS) is here to help: call 412-268-2922 or visit cmu.edu/counseling. The Student Academic Success Center is a great resource—visit them at cmu.edu/student-success. Consider reaching out to a friend, faculty member (I really am always happy to talk), or family member you trust for help getting connected to the support that can help.

Coda

Thank you for reading this lengthy syllabus. I've tried to be thorough in my discussion of the class so that you have a good sense of what to expect from me and likewise have clarity around what I expect from you. My goal is to help you have a successful semester, and I will be repetitive and again ask you to please reach out and write me an email if you've got any concerns I can help with. I'm always happy to make time to meet with students.

I hope you're taking this class because you're interested in learning something new and useful. I feel privileged to teach it and I sincerely believe that gaining the ability and confidence to use these technological tools can be

transformative. Through this course, I invite you to join me in taking a small step towards a world in which everyone is empowered to solve meaningful problems in creative ways, build interesting things, and enrich our shared human experience through the act of helping each other.



Acknowledgements: This syllabus was originally written by Robert "Zach" Zacharias for this Intro to Physical computing course. Only the most minimal updates have been made from his original.