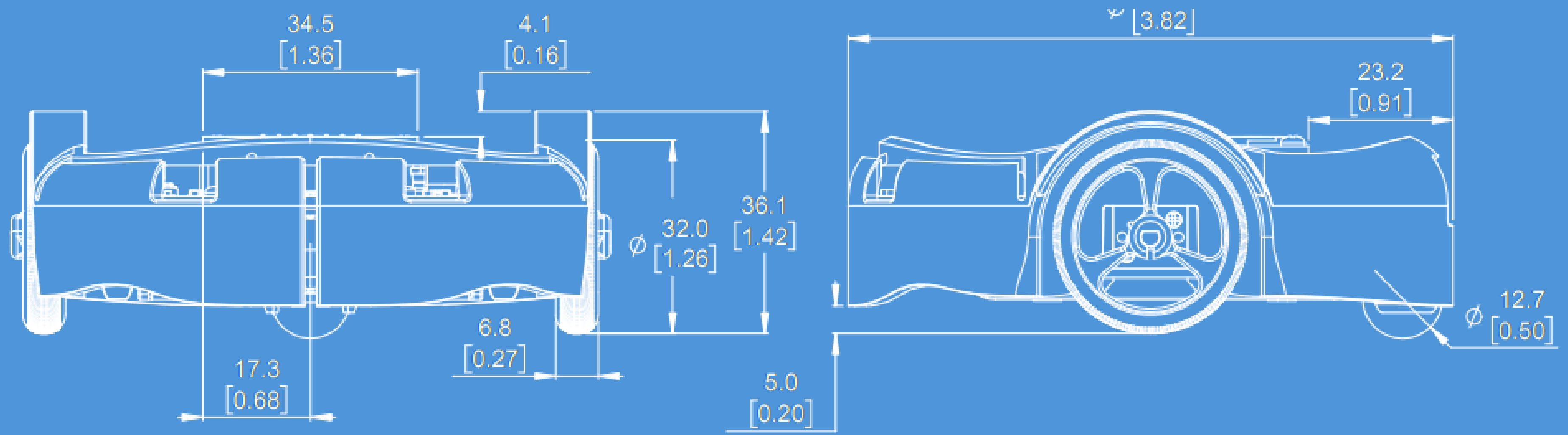
SEMTM0043
Robotics Science & Systems

TB2, AY 2025-2026

Unit Director: Paul O’Dowd (paul.odowd@bristol.ac.uk)

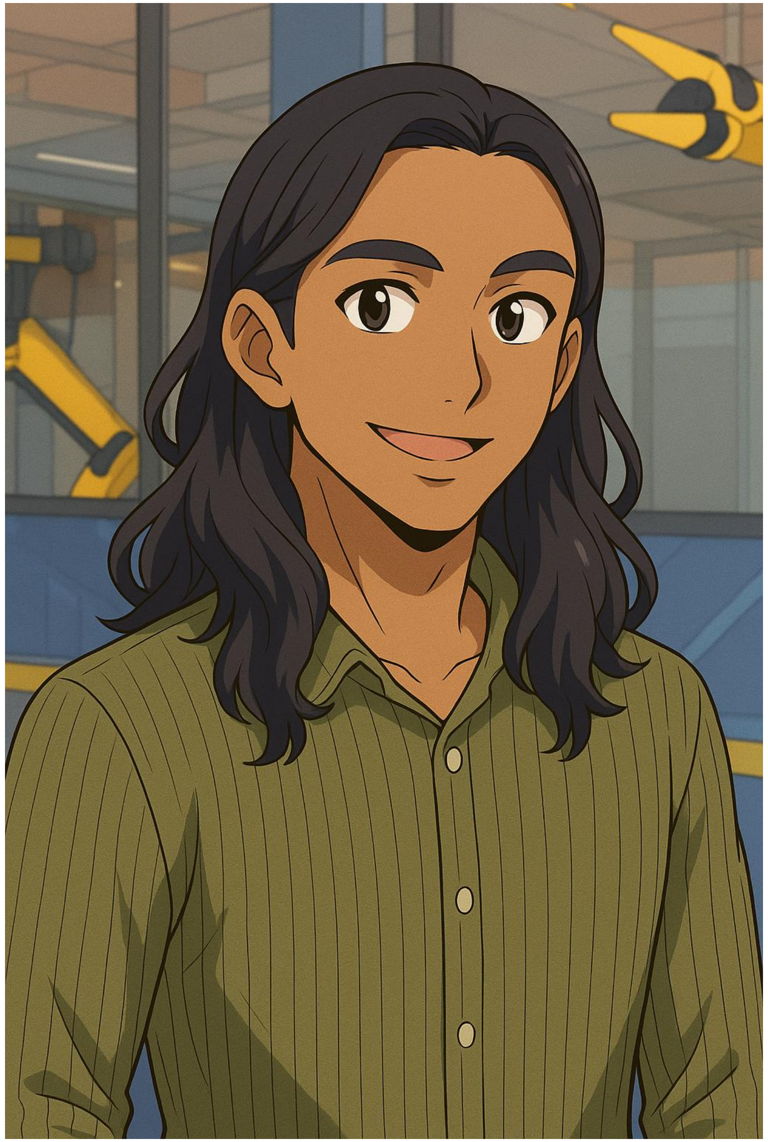


What is…

…Robotics *Science*?

…Robotics *Systems*?

Robotics Science & Systems?



“The scariest thing about a triple backflip on the spot is probably

finding all the different ways that the hardware can fail

in these scenarios

and finding ways to mitigate them...”

Experiment to…

…gain a **deep understanding.**

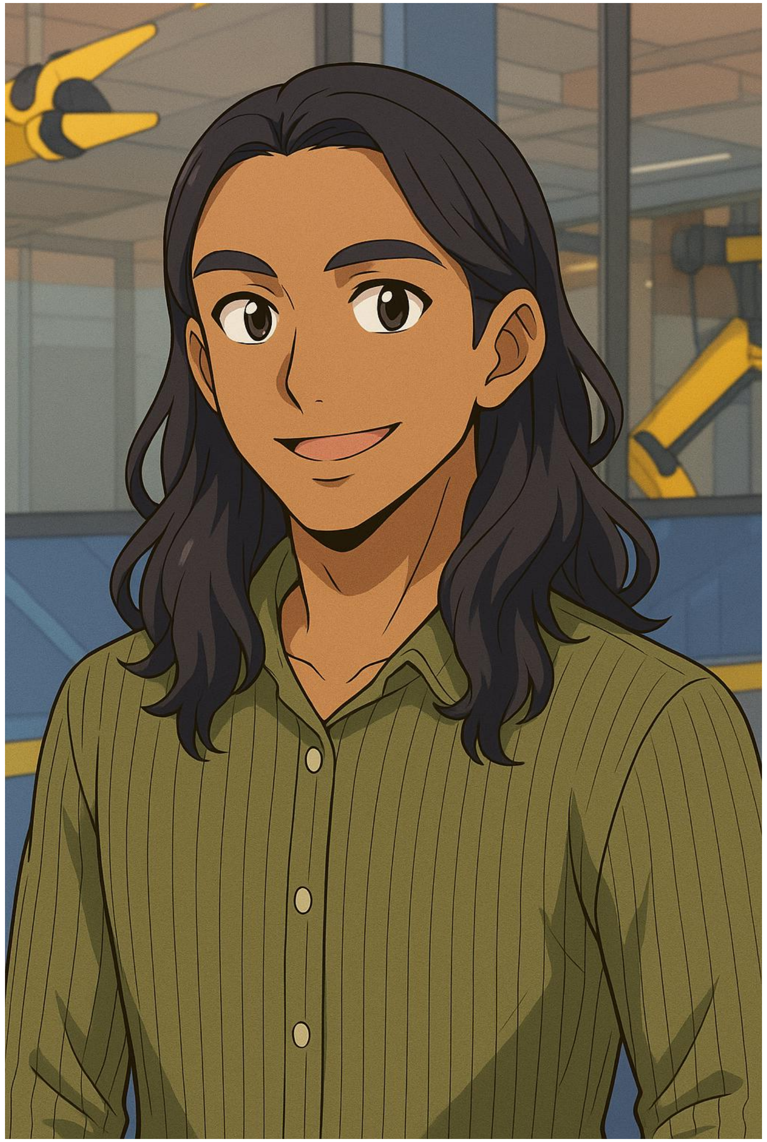
“Customers don’t need this…”:

- What can my robot do?
- How does it work?
- When does it fail?
- How can we fix unexpected issues?
- How can we make it robust/reliable?

"We need
***a coordination system** to chain all*
those behaviours together.

*Our **control** software needs to know*
how to move all the motors so Spot walks smoothly.

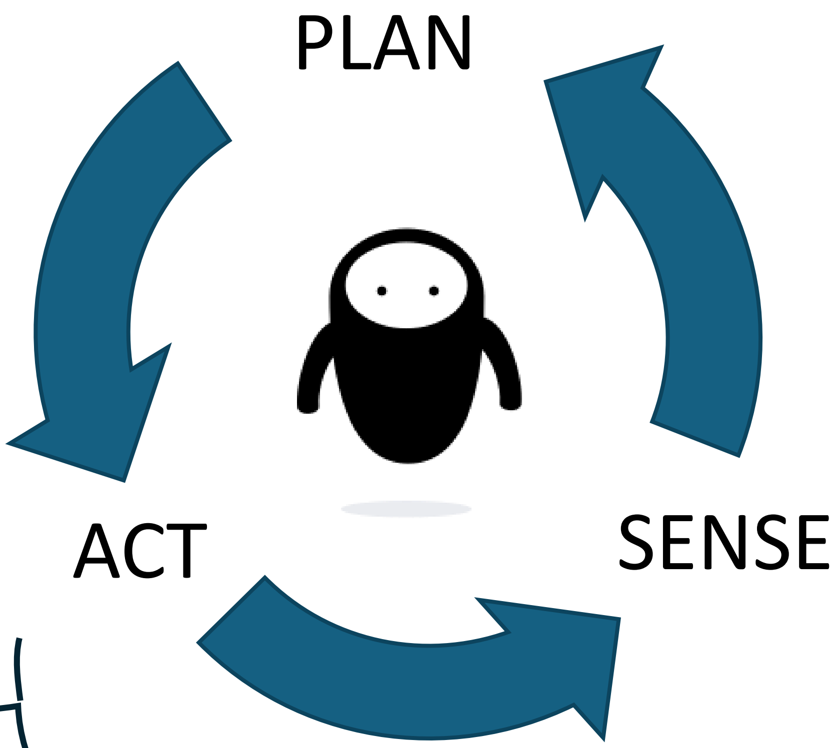
*Our **perception** software needs to*
understand information from the camera and allow Spot to navigate through a factory."

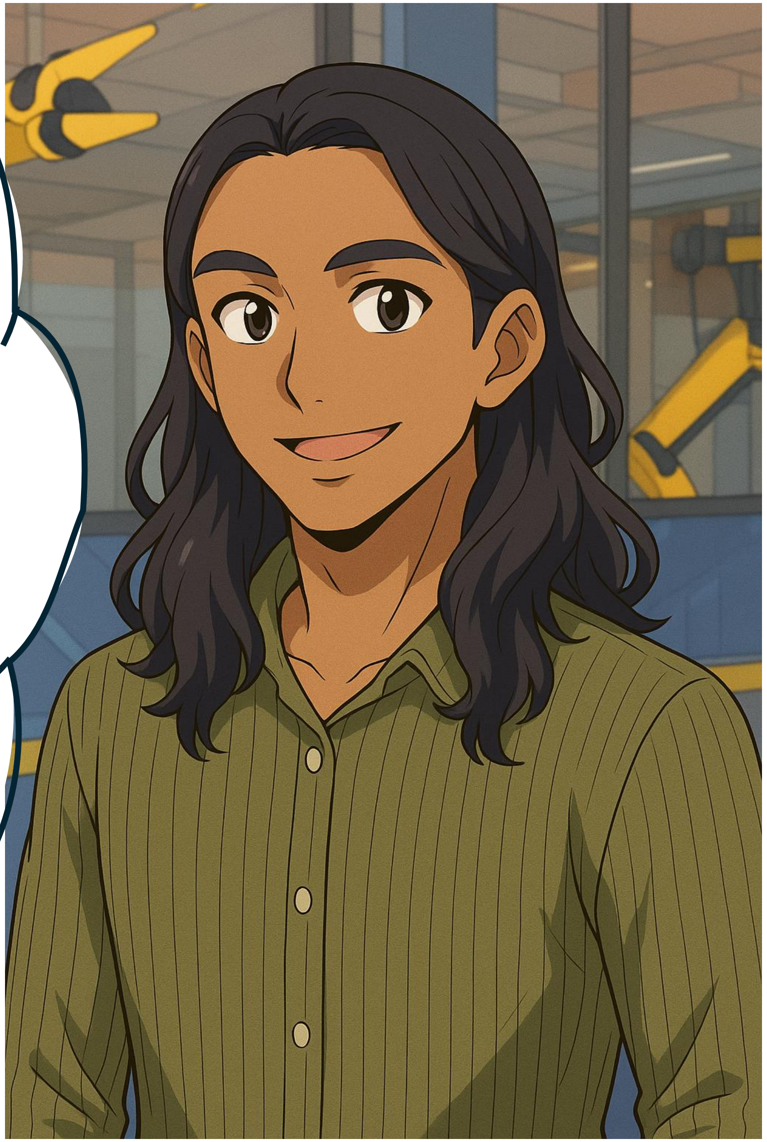


“We ne

hain

3 Robotics Primitives:





*"...**sometimes** they slip, **sometimes** they trip, **and to recover**, you need to exert a lot of power to **reliably** recover.*

*If our robots know how to fully utilise their hardware, we can **make robots that are better** at recovering...*

Autonomous robots in unknown environments.

“Better” recovery, fault tolerance, **reliable**.

How could we argue that our system is “better?”

*“It **never works first time** on the hardware.*

***It’s going to fail somehow.** Anytime something fails,*

*we **generate a log of everything that the robot observed** during the failure.*

Try to find why the robot failed**. We fix that issue. **Then we repeat the cycle.

Collecting evidence:
- *to debug*
- *to investigate*
- *to understand*

A ***scientific*** *process*:
Observe → Predict → Test → Observe →

“Try to find why the robot failed*. We fix that issue.* ***Then we repeat the cycle.***

Run it on hardware. ***Find the next failure. Debug it****.* ***Fix it.*** *Run it on hardware.*

And the more you do that, the more reliable your behaviours will be.

A simulation is never as good as reality.

Testing in reality requires time.

What matters is **reliable**, **safe** operation in reality.

We can reduce the time by thinking scientifically.

We need quantifiable evidence that our robots are safe.

What do we want to learn? (core skills)

- ✅ How to **program** and **debug** a robot.
  - ✅ How to read **sensors** (sense).
  - ✅ How to make autonomous **decisions** (plan).
  - ✅ How to operate **motors** (act).

What do we want to learn? (advanced skills)

- ✓ How to **think scientifically / critical thinking.**
  - ✓ Demonstrate our **understanding.**
  - ✓ Make a **theory or prediction (hypothesis)**
  - ✓ Take **measurements, analyse evidence.**
  - ✓ Make an **argument.**

How are we going to do this?

100% Coursework (Practical Study)

No Exam

Assessment 1
Coursework
Individual Basis
30%

Assessment 2
Coursework
Team Work / Group Work
2,3 or 4 students per Team
70%

Practical Lab Sessions
Period of **Core Skill** Development
"Solve a Problem"

Project Supervision
Period of **Critical Thinking** Skill Development
"Make a Scientific Argument"

Expectation: Post-Graduate Study

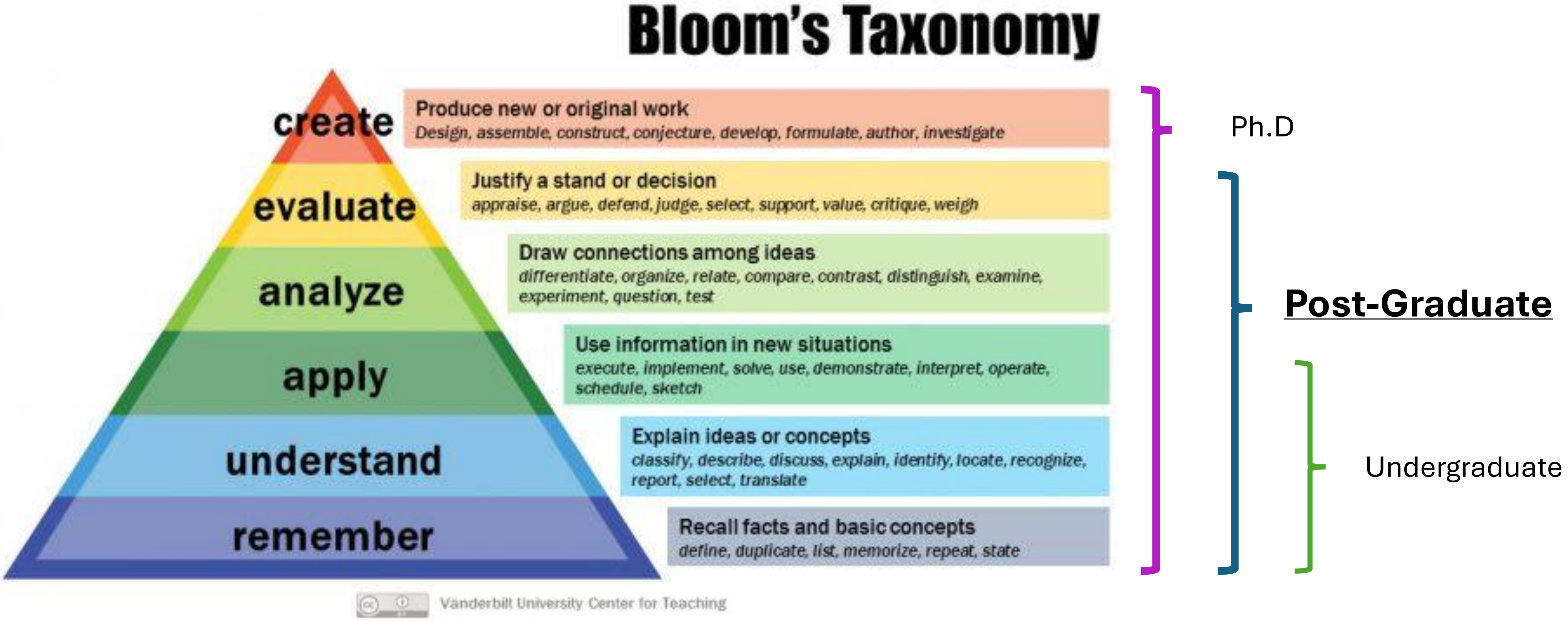


Image from: Vanderbilt University Center for Teaching, https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/
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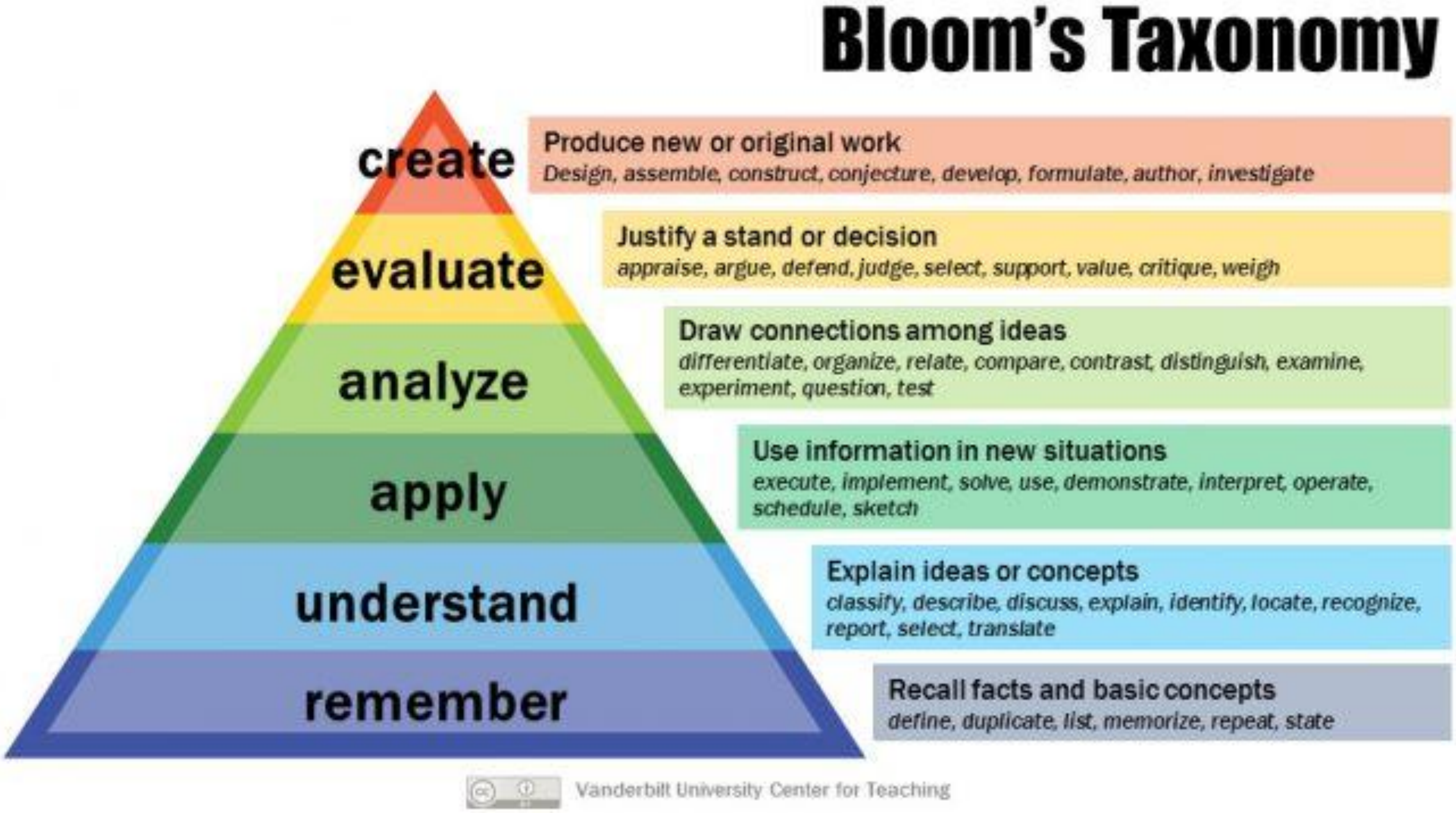
http://www.bristol.ac.uk/academic-quality/assessment/regulations-and-code-of-practice-for-taught-programmes/marking-criteria/

Expectation: Post-Graduate Study



Post-Graduate
Assessment 2
"Scientific Argument"

Undergraduate
Assessment 1
"Solve a Problem"

Image from: Vanderbilt University Center for Teaching, https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/
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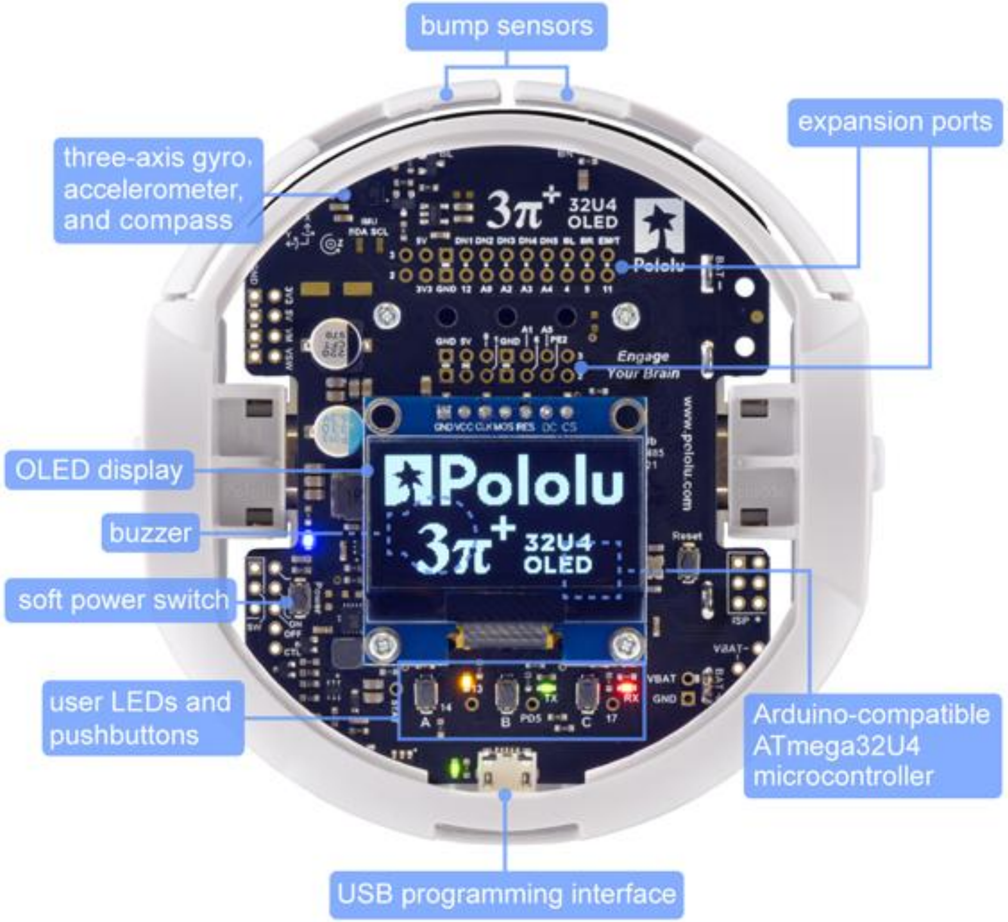
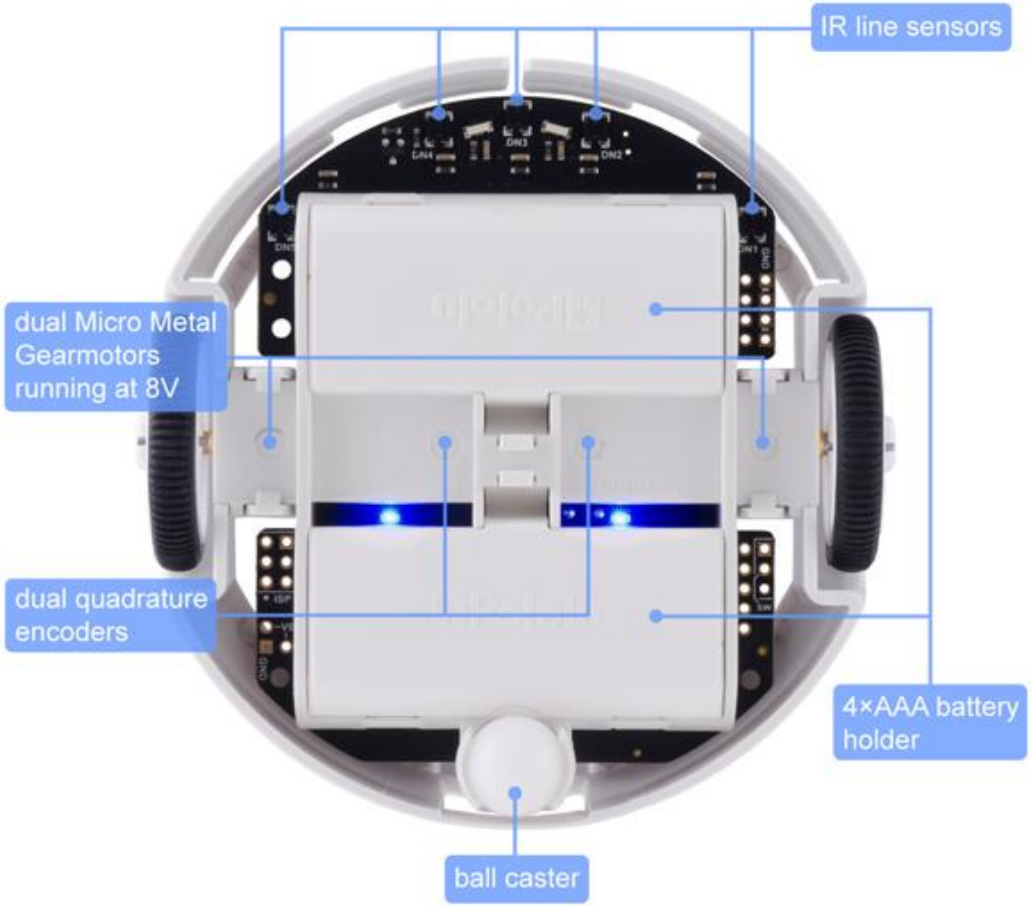
http://www.bristol.ac.uk/academic-quality/assessment/regulations-and-code-of-practice-for-taught-programmes/marking-criteria/

Pololu 3Pi+ Mobile Robot

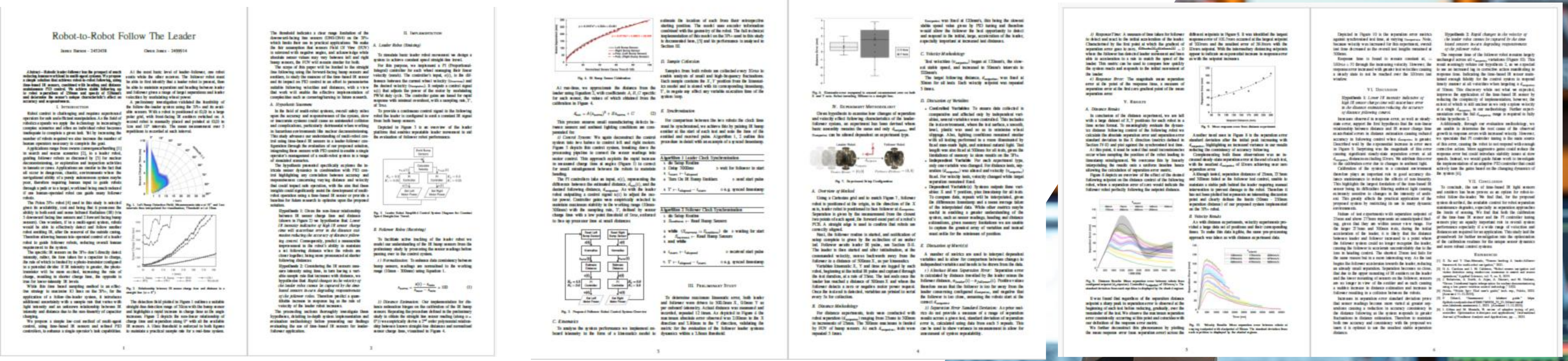




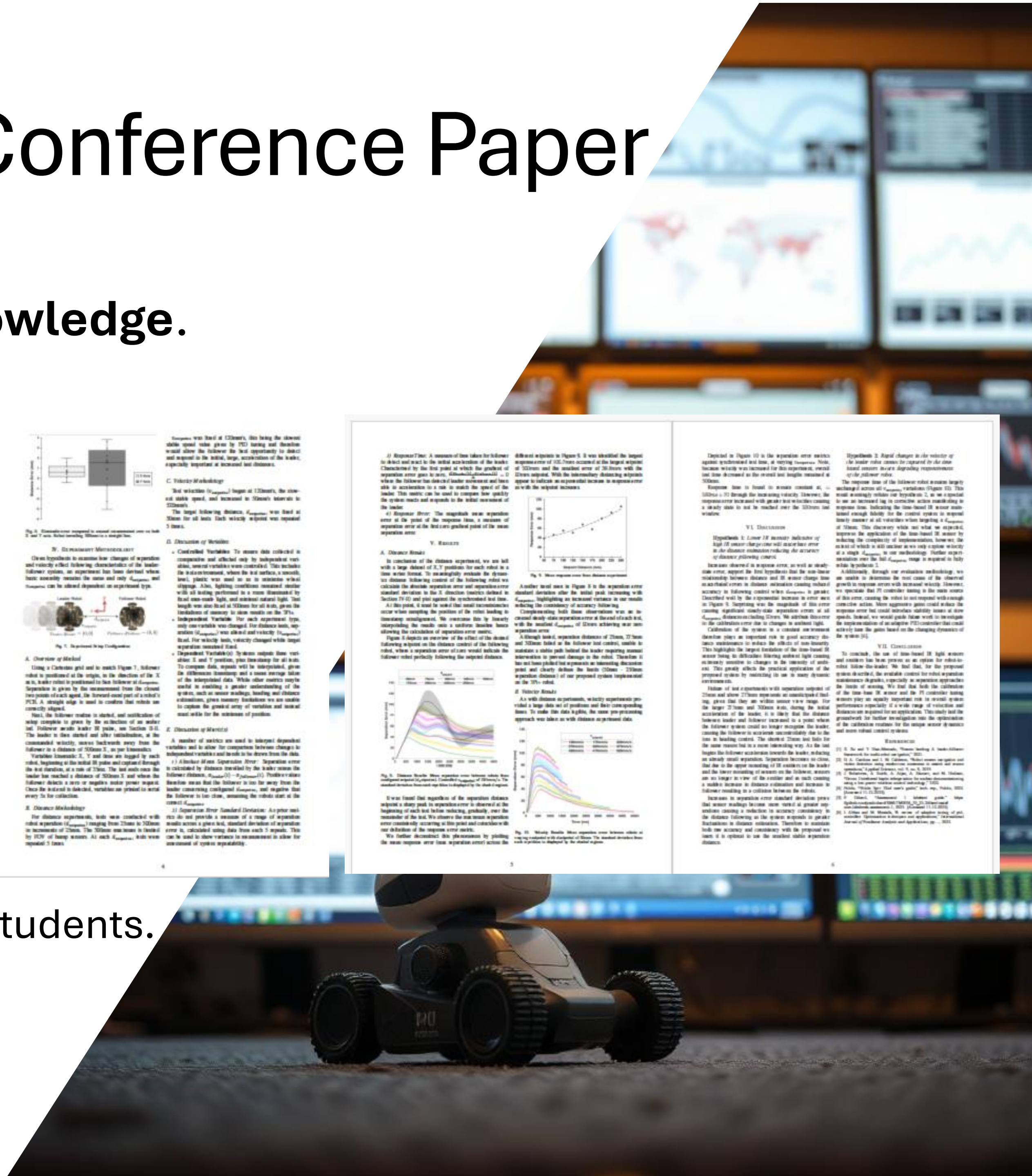
In 11 weeks….

Assessment 2: 6 Page Conference Paper

How to **evidence a contribution to knowledge.**

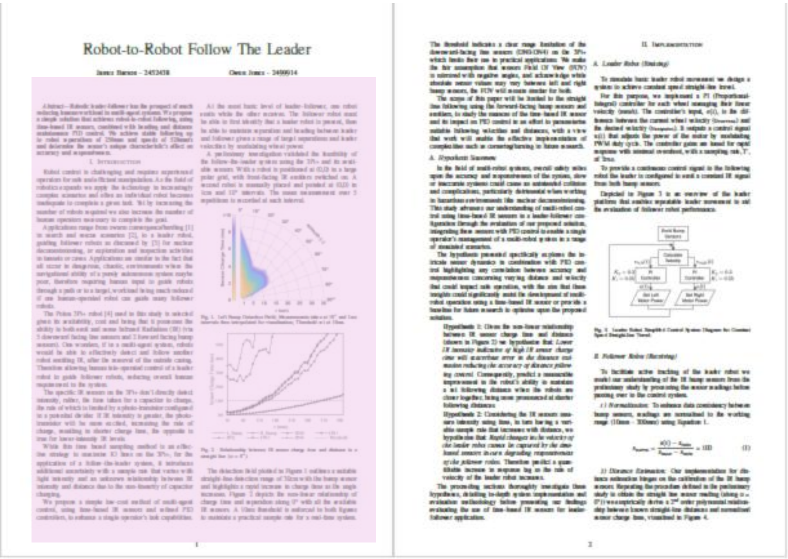


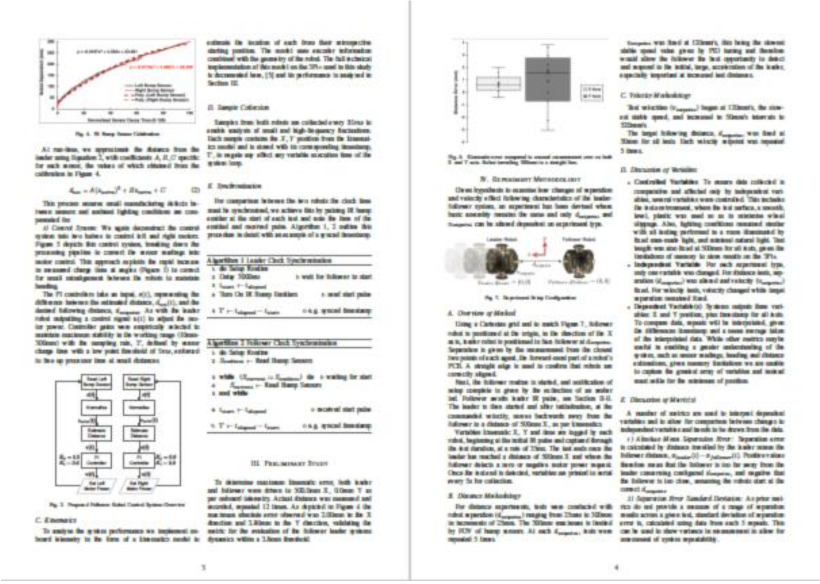
Assessment 2 is Team Work: groups of 2,3 or 4 students.

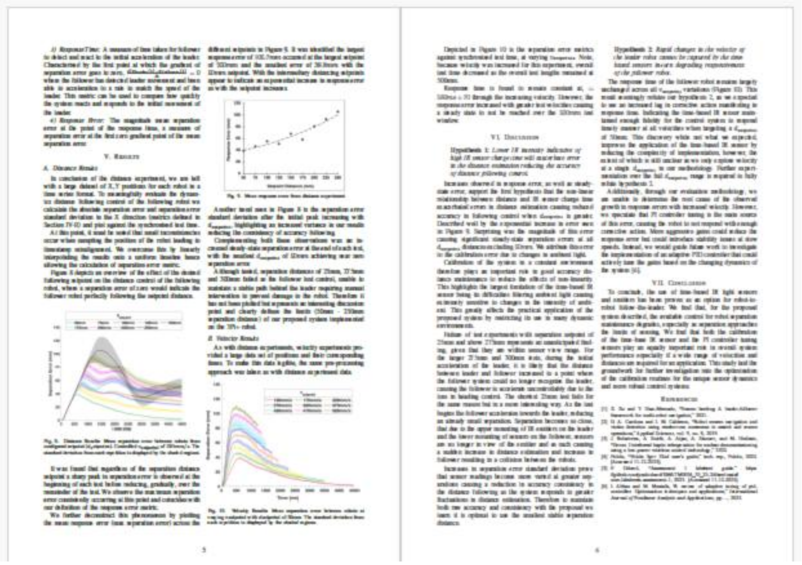


Assessment 2: 6 Page Conference Paper

How to **evidence a contribution to knowledge.**


Robot-to-Robot Follow The Leader



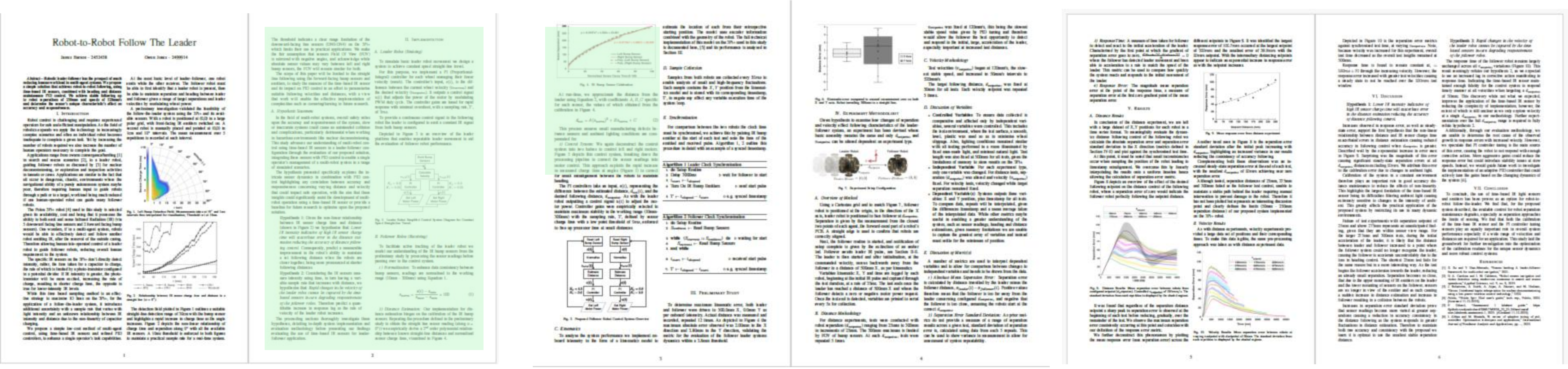


Describing a problem:

- Value
- Interest
- Scope

Assessment 2: 6 Page Conference Paper

How to **evidence a contribution to knowledge.**

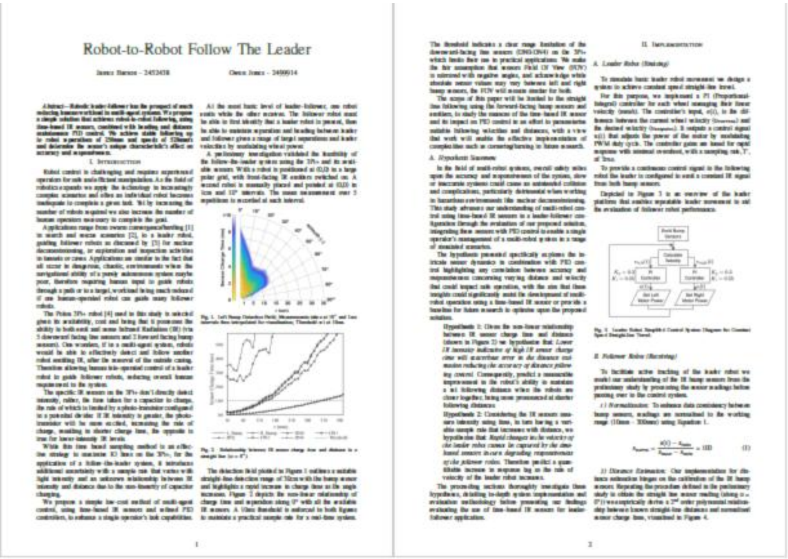

Robot-to-Robot Follow The Leader

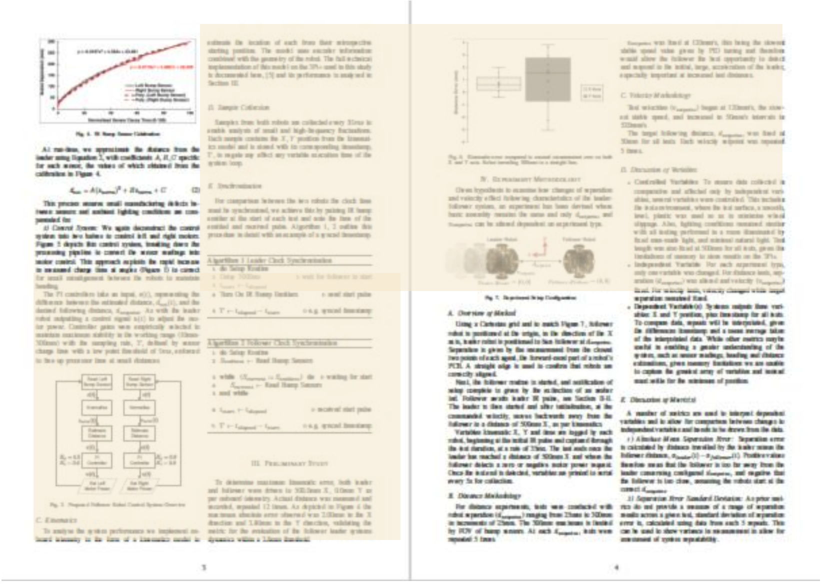
Implementation:

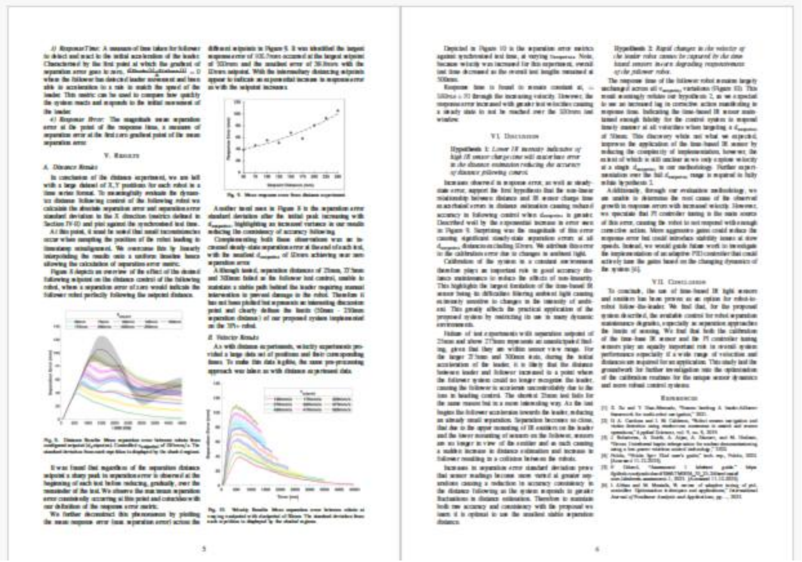
- "How it was made".
- <u>Reproducible</u>
- Rigorous

Assessment 2: 6 Page Conference Paper

How to **report a contribution to knowledge.**





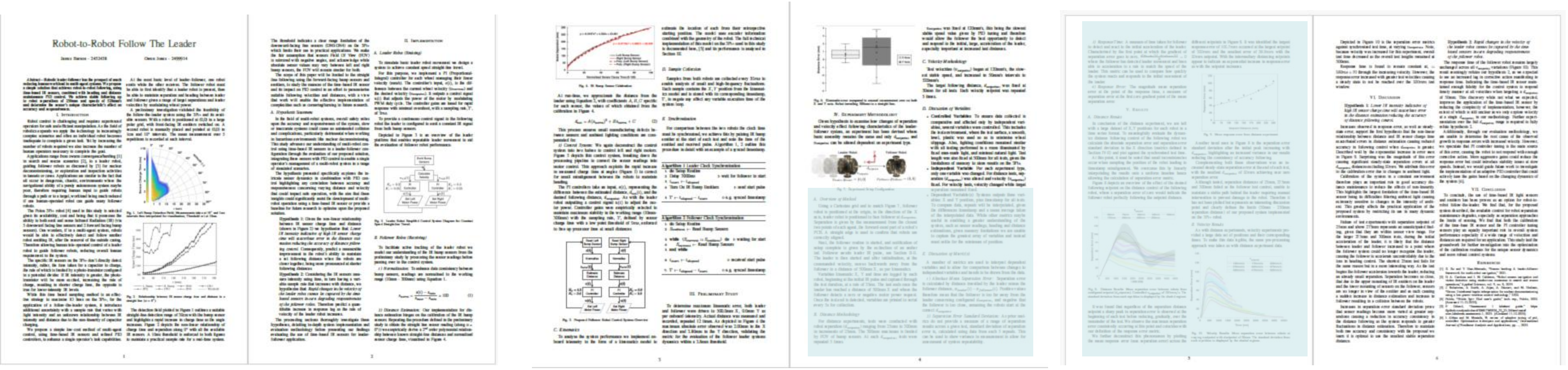


Method:

- How it was “measured”
- Isolating the matter of interest
- To capture credible data
- Tools for analysis (metrics)

Assessment 2: 6 Page Conference Paper

How to **evidence a contribution to knowledge.**

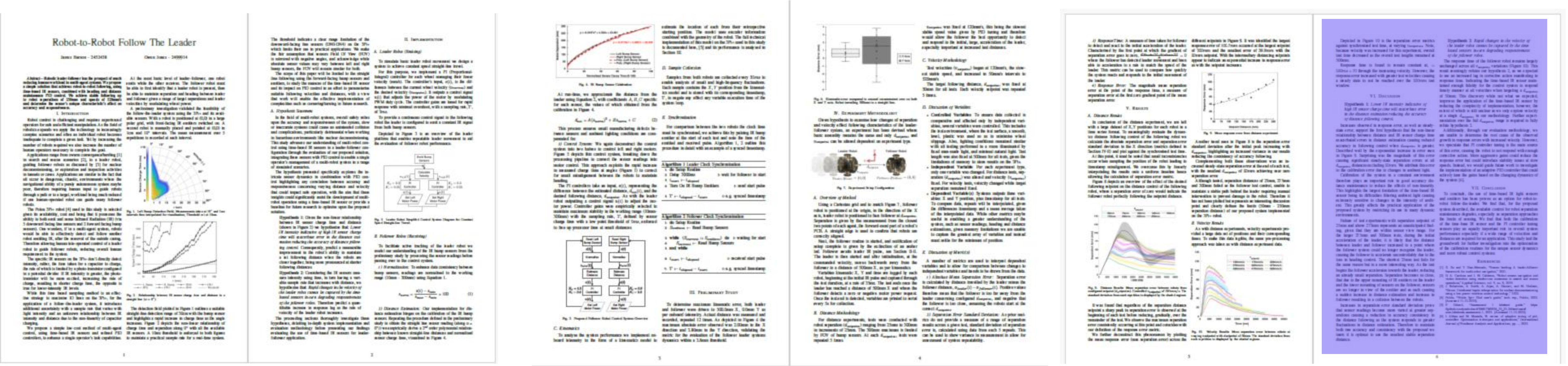

Robot-to-Robot Follow The Leader

Results:

- What can be observed?
- What is evidenced?
- How confident can we be?

Assessment 2: 6 Page Conference Paper

How to **evidence a contribution to knowledge.**

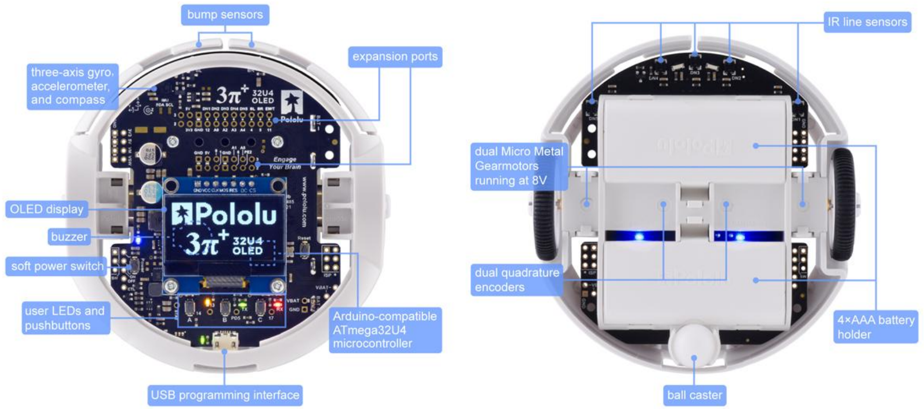

Robot-to-Robot Follow The Leader

Conclusions:

- What was learnt?
- What would be next?

Assessment 2: 6 Page Conference Paper

- We need to learn how to use this robot first.
- We need to **understand** how it operates.
- **Observations:** investigate and evidence something interesting.



How are we going to do this?

100% Coursework (Practical Study)
No Exam

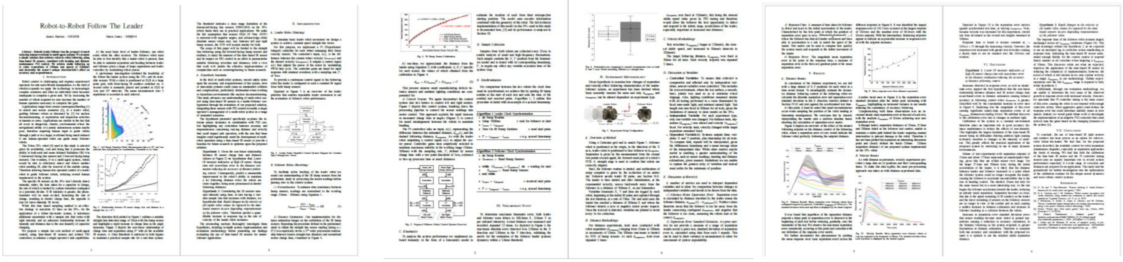
Assessment 1
Coursework
Individual Basis
30%

Assessment 2
Coursework
Team Work / Group Work
2,3 or 4 students per Team
70%

Practical Lab Sessions
Period of **Core Skill** Development
“Solve a Problem”

Project Supervision
Period of **Critical Thinking** Skill Development
“Make a Scientific Argument”

Timeline



Assessment 1 Deadline
1pm, Thursday 23rd October 2025

Assessment 2

Experiment/Report, Team work.
Summative Assessment, 70%

Teaching Block 1

Week Commencing:

22 Sep	29 Sep	6 Oct	13 Oct	20 Oct	27 Oct	3 Nov	10 Nov	17 Nov	24 Nov	1 Dec	8 Dec
W1	W2	W3	W4	W5	W6 CW	W7	W8	W9	W10	W11	W12

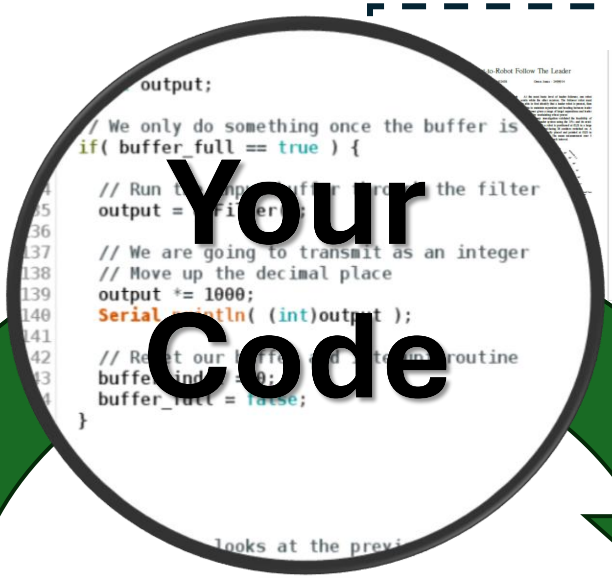
Assessment 1

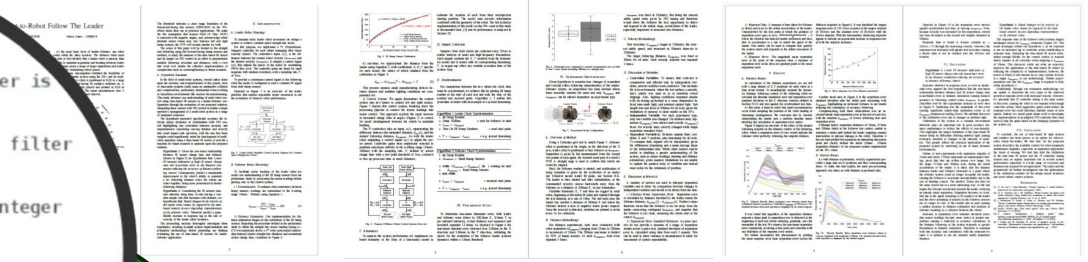
Skill Building, *Individual Work*
Summative Assessment, 30%

WE ARE HERE

Assessment 2 Deadline
1pm, Thursday 4th December 2025

Timeline





Assessment 2

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Teaching Block 1

Week Commencing:

22 Sep	29 Sep	6 Oct	13 Oct	20 Oct	27 Oct	3 Nov	10 Nov	17 Nov	24 Nov	1 Dec	8 Dec
W1	W2	W3	W4	W5	W6 CW	W7	W8	W9	W10	W11	W12

Assessment 1

Skill Building, *Individual Work*

Summative Assessment, 30%

WE ARE HERE

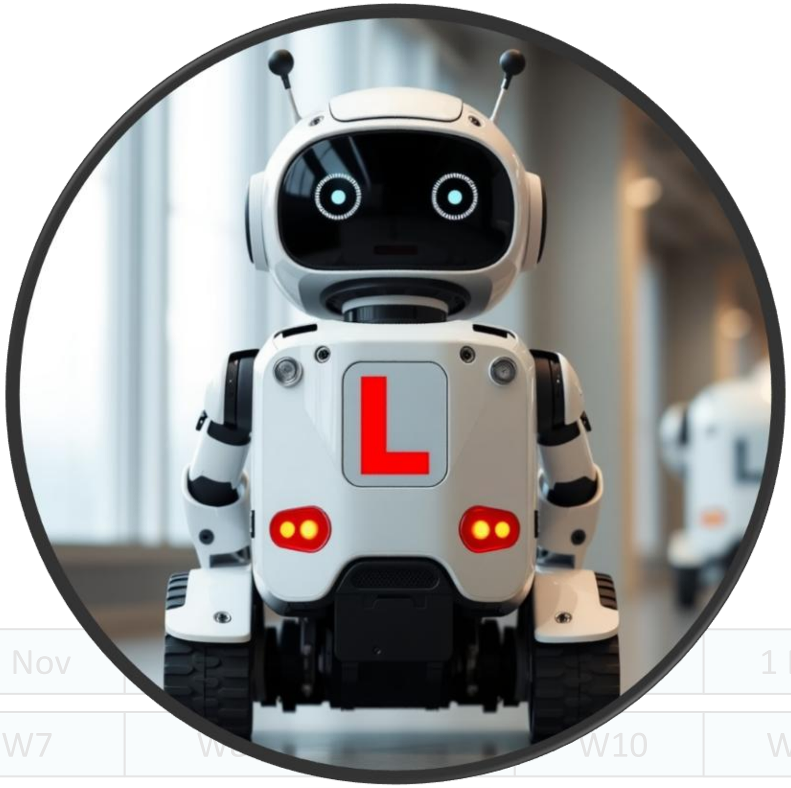
Timeline

Teaching Block 1

Assessment 1 Deadline
1pm, Thursday 23rd October 2025

Week Commencing:

22 Sep	29 Sep	6 Oct	13 Oct	20 Oct	27 Oct	3 Nov				1 Dec	8 Dec
W1	W2	W3	W4	W5	W6 CW	W7			W10	W11	W12



WE ARE HERE

Assessment 1

Skill Building, *Individual Work*

Summative Assessment, 30%

✓ Pass our driving test!

Assessment 1: Foraging Challenge (Expert)

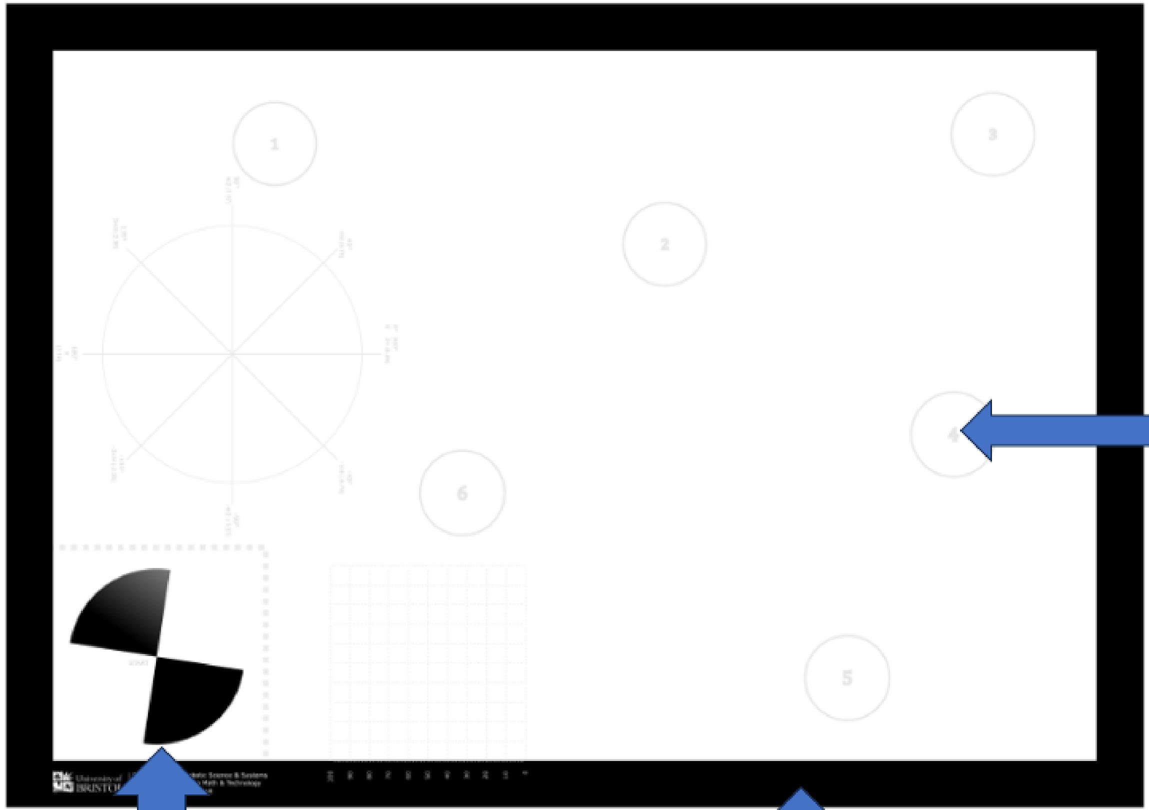
Assessment 1 Deadline
1pm, Thursday 23rd October 2025

1. Record video
2. Complete an online self-assessment form
3. Upload your code to Blackboard

Mark: 70 – 100%

Assessment 1: Foraging Challenge

Assessment 1, Foraging Challenge Coursework Map



The **Coursework Map** to the left should be printed either on a single piece of A2 paper, or two A3 pieces of paper. These are provided to you. You may also download and print your own.

You are permitted to use clear tape to stick two sheets of paper together.

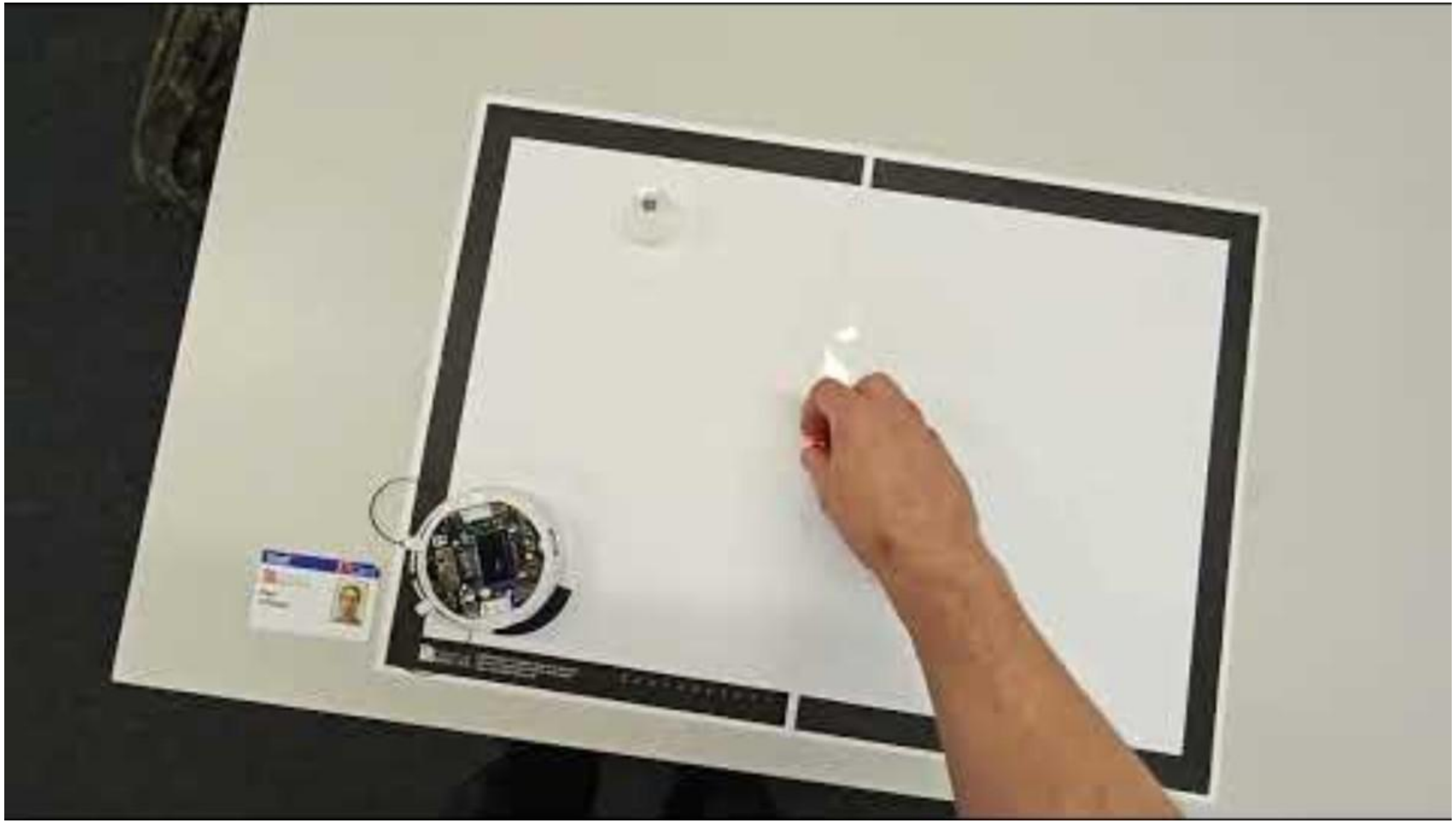
Puck locations labelled 1-6. Puck should be placed to cover the circle marking.

The 6 sided dice and **puck** provided to you.

Start Area, boundary marked by the dashed line.

Map Area, boundary marked by the thick black line.

Assessment 1: Foraging Challenge (Intermediate)

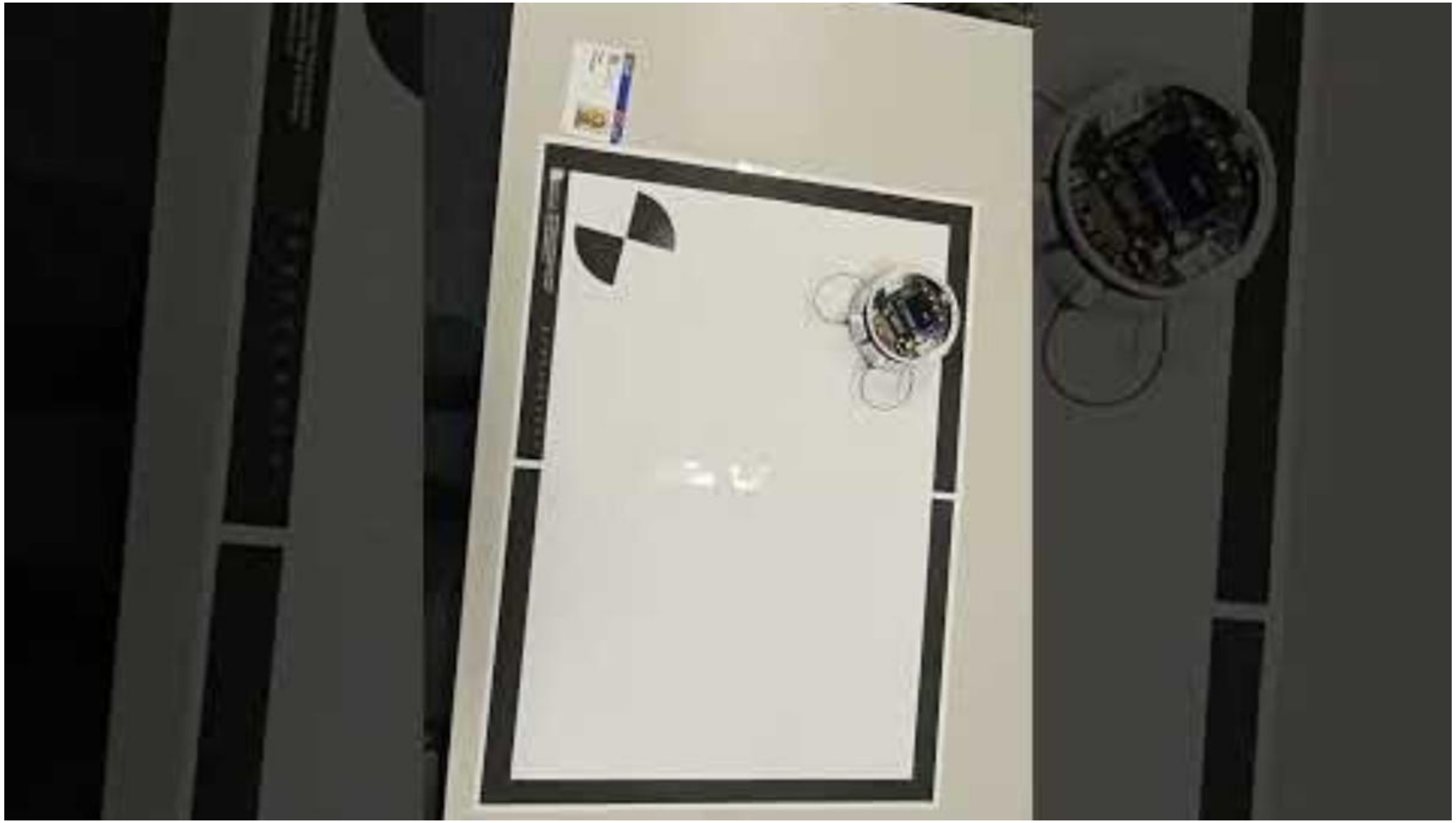


Assessment 1 Deadline
1pm, Thursday 23rd October 2025

1. Record video
2. Complete an online self-assessment form
3. Upload your code to Blackboard

Mark: 60-68%

Assessment 1: Foraging Challenge (Beginner)



Assessment 1 Deadline
1pm, Thursday 23rd October 2025

1. Record video
2. Complete an online self-assessment form
3. Upload your code to Blackboard

Mark: 50 - 58%

Assessment 1: Marking Criteria

Assessment 1 Marking Criteria, 30% Weighting

More detailed descriptions and context of these challenges are provided on subsequent pages.

Criteria Description	Mark (max 100)	Skills Demonstrated
Beginner Difficulty	(50-58%)	
Actively search within the map area for 4 minutes then stop. The robot must not leave the map area. Your video must demonstrate the robot interacting with the black boundary of the coursework map. The robot should not stop moving within the 4 minute period. The robot must be shown to stop after 4 minutes.	50	The ability to control motors and read sensors to produce safe autonomous behaviour within a time limited period. Example Video
Actively search area for 4 minutes as per "Beginner Difficulty". After 4 minutes, the robot is demonstrated to return to the start area, with the robot stopping with some part of the white robot body within the start area. The robot must be shown to come to a complete stop.	58	The ability to control motors and read sensors to produce safe autonomous behaviours within a time limited period. The ability to control the motion of the robot towards a target location with higher precision.
Intermediate Difficulty	(60-68%)	
Puck location must be randomised using the dice. Robot must actively search area, correctly detect puck, and push the puck outside the map area. The robot can then return to the start area, and stop with some part of the white robot body within start area, pausing moving for a minimum of 4 seconds to wait for a new puck location to be randomised using the dice. The robot should then repeat the above requirements. The robot must stop after 4 minutes of activity regardless of which activity it is engaged in. Apart from pausing for the puck relocation, your robot should remain active for 4 minutes without leaving the map at any point.	$58 + (n * 2)$ where *n* is the number of pucks correctly pushed outside the map, requiring a minimum of 1 puck, up to 5 pucks total.	The ability to control motors and read sensors to produce a series of discrete robot behaviours to achieve different goals. The ability to control the motion of the robot towards different target locations with higher precision, and a repeatable level of performance within a time limited period. Example Video
Expert Difficulty	(70-100%)	
Puck location must be randomised using the dice. Robot must actively search area, correctly detect puck, push the puck back into the start area, stopping with some part of the puck within the start area. The robot should then pause for a minimum of 4 seconds to wait for a new puck location to be randomised using the dice. The robot must stop after 4minutes of activity regardless of which activity it is engaged in. Apart from pausing for the puck relocation, your robot should remain active for 4 minutes, only leaving the map to position itself to return a puck.	$65 + (n * 5)$ where *n* is the number of pucks correctly returned, requiring a minimum of 1 puck, up to 7 pucks total.	The ability to control motors and read sensors to produce more complex autonomous behaviours, including basic path planning and fault tolerance. The ability to analyse and refine a solution to mitigate the effects of noise/error over extended periods of continuous robot operation with guaranteed reliability. Example Video

PASS

Labsheets

SEMTM0042/43 Robotic Science & Systems

Navigating the Labsheets

The Labsheets provide some icons to help reinforce the scientific skills we are practicing. These icons should also help you to navigate the labsheets quickly.

! This is a section that contains important information you must respect to avoid damaging the robot, or to stay within the requirements for your Assessments.

✓ This is a section that provides advice on best practice, or confirms what we have achieved so far.

T This is a section that provides background theory for what we are about to work on. You can complete the exercises without the theory, but you will be able to make smarter choices if you gain a deeper understanding first.

i This is a section that contains information on **common problems** or **common solutions**. These are designed to help you to avoid common pitfalls (time spent inefficiently). They should help you to question your assumptions.

O This is a section that encourages you to observe, reflect and think about implications for the exercises we are completing. It is necessary to make observations of the system we are studying, from which we can then articulate a hypothesis.

H This is a section that asks you to make a prediction or theory, drawing on your knowledge and experience so far. You will also want to consider how you could then observe and measure the effects.

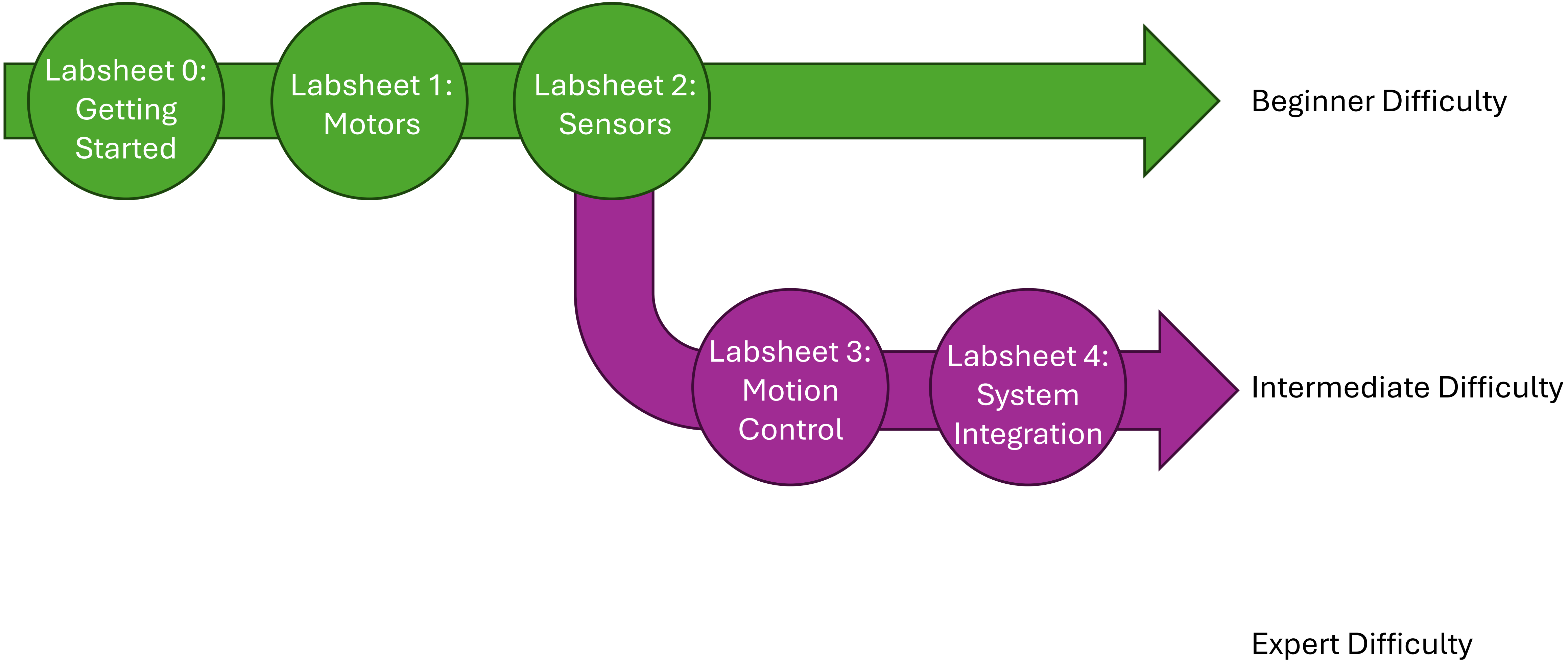
Trouble Shooting (FAQ)

Open in Colab **TroubleShooting/FAQ**: Help for common problems, like **"my robot won't connect"**

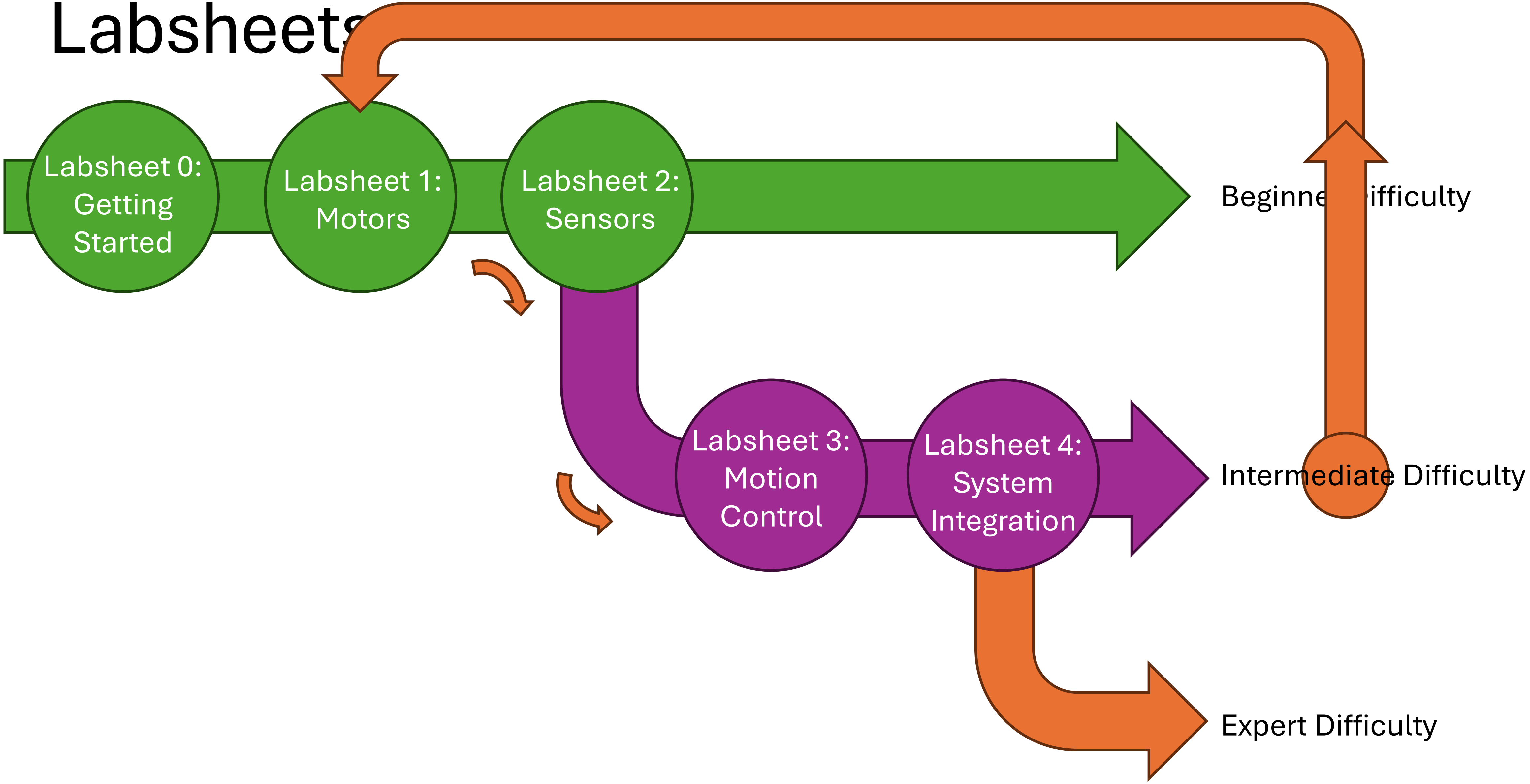
Assessment 1 Labsheets

	Labsheet Title	Estimated Time	Description
Open in Colab	**Labsheet 0**: Getting Started	2-6 hours	Instructions on how to get started, and exercises with millis() for non-blocking code.
Open in Colab	**Labsheet 1**: Motors	4 - 10 hours	Exercises to get your robot moving, steps to be confident that your code will behave predictably, building up a Class. Advanced Exercises include PID Control
Open in Colab	**Labsheet 2**: Sensors	2 - 4 hours	Exerices to achieve reliable turning, travelling, and movement between two locations.
Open in Colab	**Labsheet 3**: Motion Control	4 - 8 hours	Exercises to use the motors and sensors to stay within the coursework map, as well as find and detect the puck.
Open in Colab	**Labsheet 4**: System Integration	8 - 16 hours	Exercises to help you integrate your work so far into a solution for the Foraging Challenge.

Labsheets


Labsheet 0: Getting Started
Labsheet 1: Motors
Labsheet 2: Sensors
Labsheet 3: Motion Control
Labsheet 4: System Integration
Beginner Difficulty
Intermediate Difficulty
Expert Difficulty

Labsheets

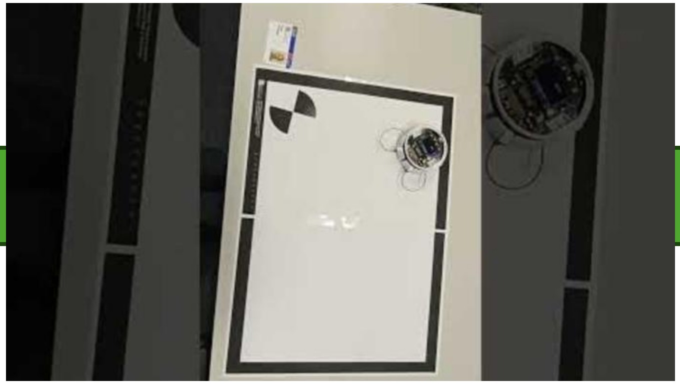

Labsheet 0: Getting Started
Labsheet 1: Motors
Labsheet 2: Sensors
Labsheet 3: Motion Control
Labsheet 4: System Integration
Beginner Difficulty
Intermediate Difficulty
Expert Difficulty

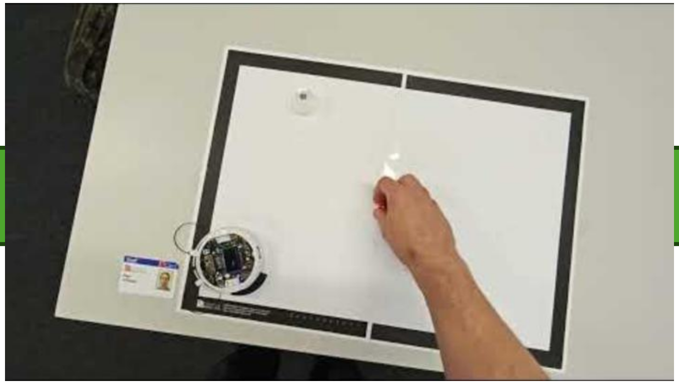
Recommended Approach:

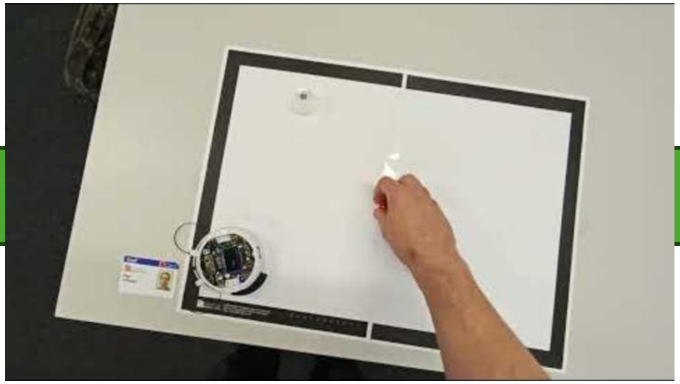
Beginner

Intermediate

Expert

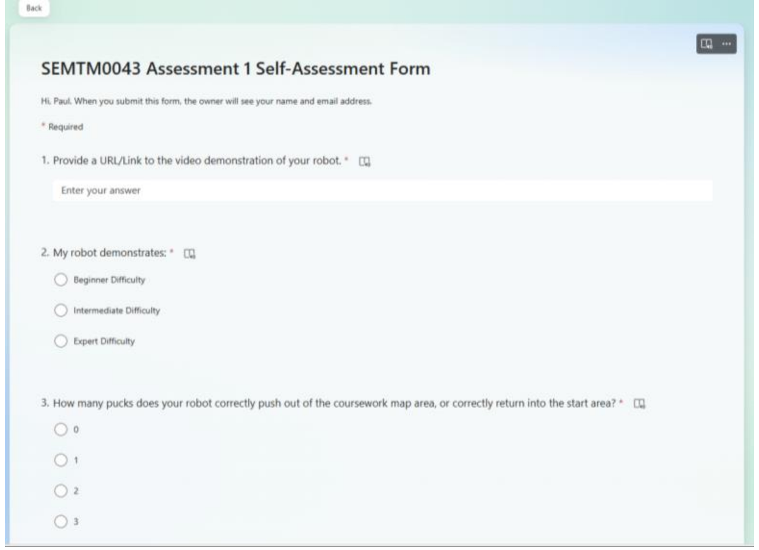




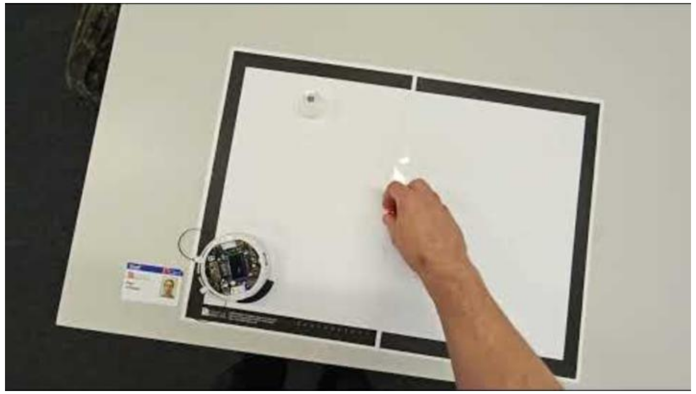


Assessment 1 Submission

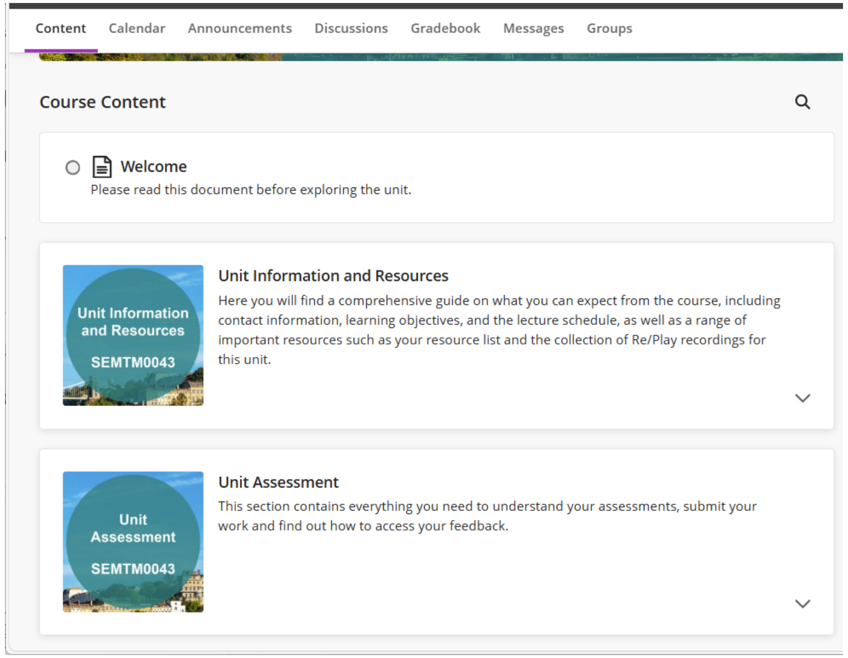
Complete a Self-Assessment form:



Provide a URL/Link to a video:



Upload your final code to Blackboard:



Full-Time Study

Assessment 2

Experiment/Report, Team work.

Summative Assessment, 70%

Teaching Block 1

Week Commencing:

22 Sep	29 Sep	6 Oct	13 Oct	20 Oct	27 Oct	3 Nov	10 Nov	17 Nov	24 Nov	1 Dec	8 Dec
W1	W2	W3	W4	W5	W6 CW	W7	W8	W9	W10	W11	W12

Assessment 1

Skill Building, *Individual Work*

Summative Assessment, 30%

WE ARE HERE

Full-Time Study

Assessment 1 Deadline

1pm, Thursday 23rd October 2025

Teaching Block 1: Assessment 1

Week Commencing:

22 Sep	29 Sep	6 Oct	13 Oct	20 Oct
W1	W2	W3	W4	W5

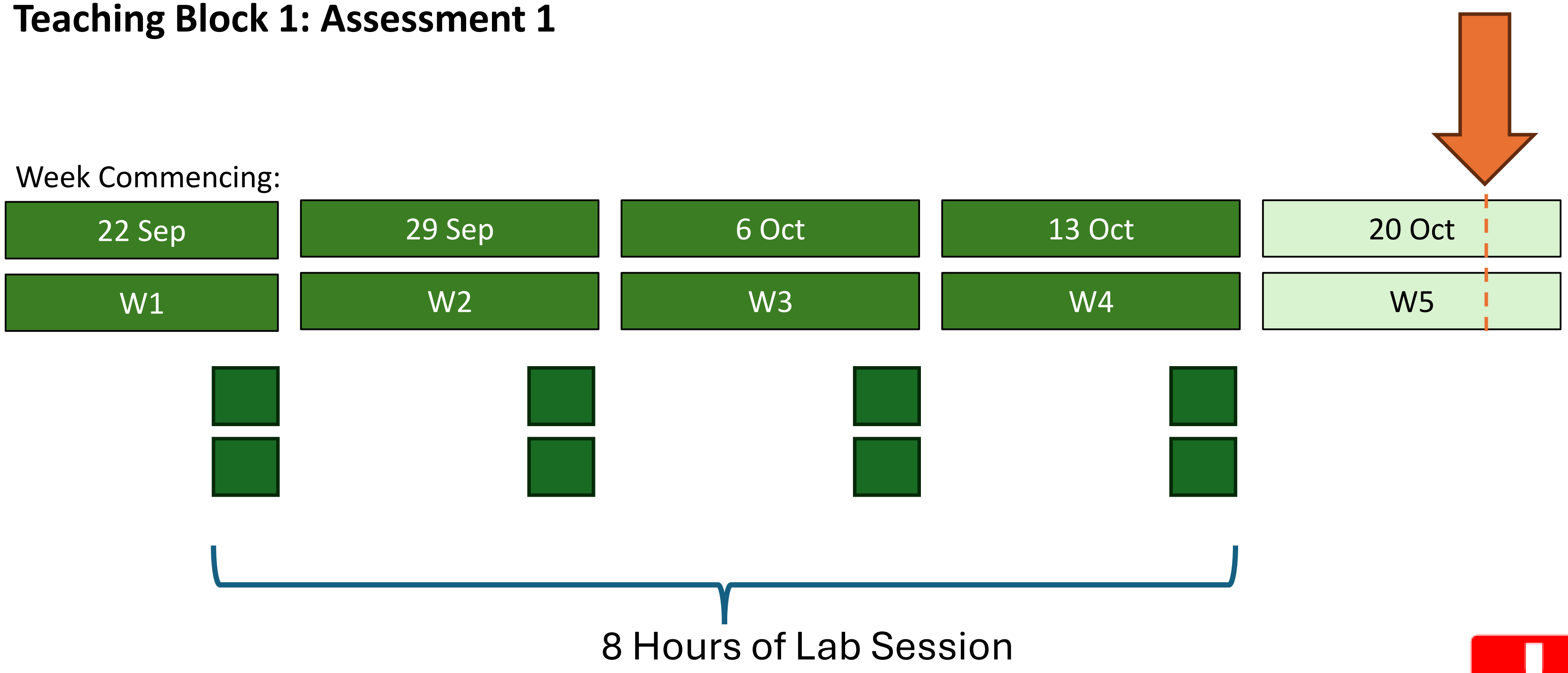
2 Hour
Lab Session
Bill Brown Suite

Full-Time Study

Assessment 1 Deadline

1pm, Thursday 23rd October 2025

Teaching Block 1: Assessment 1



8 Hours: If you only work in the 2 Hour Lab Sessions, you will probably not pass.

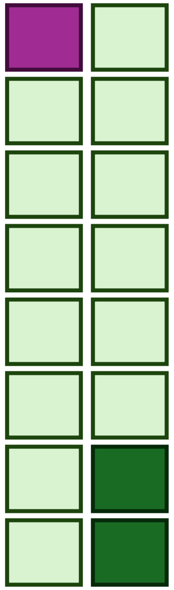
Full-Time Study

Assessment 1 Deadline
1pm, Thursday 23rd October 2025

Labsheet 0
Labsheet 1
?

Week Commencing:

22 Sep	29 Sep	6 Oct	13 Oct	20 Oct
W1	W2	W3	W4	W5



Per Week (16):
1 Hour lecture

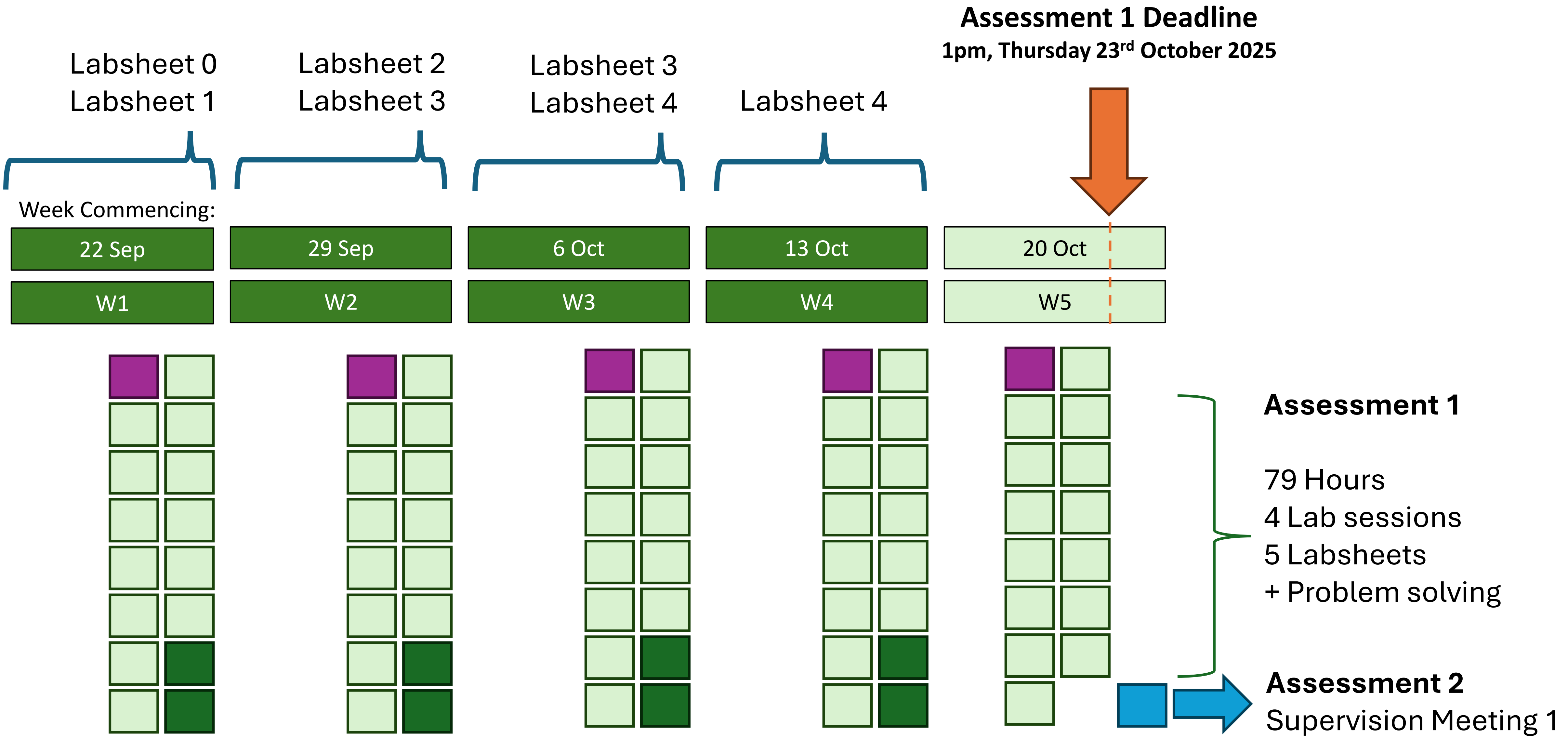
13 Hours of
independent study

2 Hour
Lab Session
Bill Brown Suite

SEMTM0043 <u>20 Credits</u>

20 Credits = 16 hours per week (approximately)

Full-Time Study

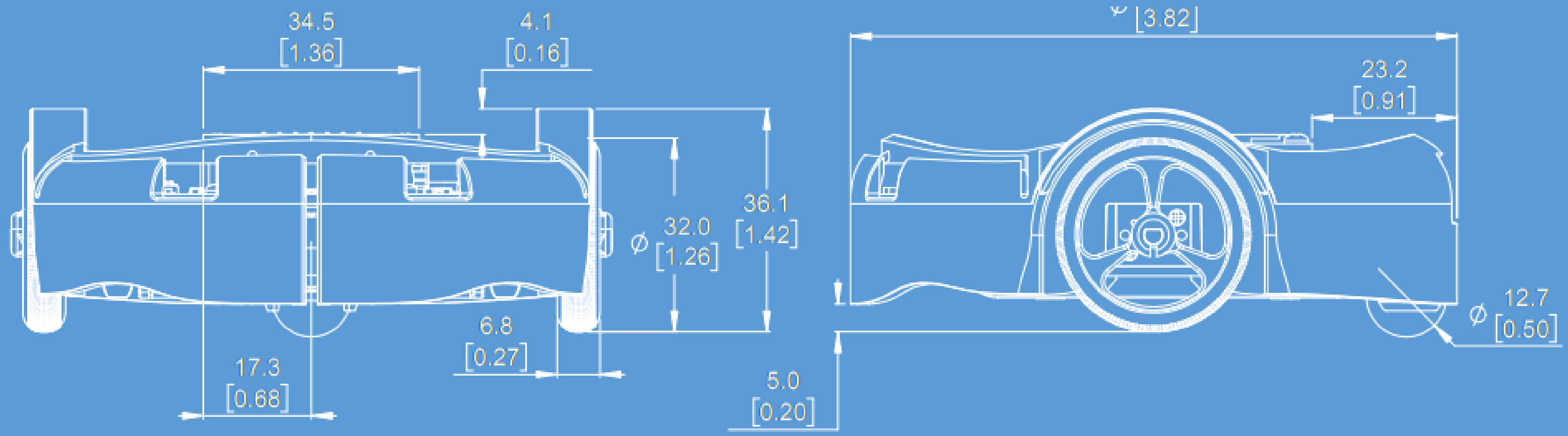


Plagiarism

Please read the Assessment Specification on Blackboard

- If you use a GitHub repository (or similar) it **must be set to private.** If someone uses your code – even without your knowing – it constitutes **cheating, and academic offense.**
- Sharing your code solution with others is cheating, an academic offense. Accepting code from someone (inside or outside the university) is cheating, an academic offense.
- **Using code you find online**, including **software libraries**, and copy-pasting library code, is considered **plagiarism** (claiming credit for another person's work), an academic offense. The Labsheets specify the exact libraries you may use.
- Assessment 1 is an **Individual Assessment**. You must produce your own, **individual solution to the coursework**. You may discuss solutions, but you must produce your own code solutions.
- **Code** for **Assessment 1** and **Assessment 2** will be **algorithmically checked for similarity** against all other code submissions with the tool **Sim_c** (https://manpages.ubuntu.com/manpages/bionic/en/man1/sim_c++.1.html)
- You are encouraged & supported to use the template code (3Pi_CodeStub) and the examples in the labsheets. These will be ignored when checking for code similarity.

Kit Hand-Out



34.5
[1.36]
4.1
[0.16]
36.1
[1.42]
32.0
[1.26]
6.8
[0.27]
17.3
[0.68]
5.0
[0.20]
[3.82]
23.2
[0.91]
12.7
[0.50]

Your Robot Kit – Your Responsibility

On Loan for 11 Weeks:
You can take it home.

- 1 Box
- Pololu 3Pi+ Robot
- 4 AAA Rechargable Batteries
- Battery Recharger (UK)
- 2 Cable ties
- 4 Plastic Hooks
- 1 Puck with Magnet
- 1 USB cable
- 1 Dice

You are required to return all parts in week 11.

Your Robot – Common Damage

Stepping on the Robot.
This bends the wheel axles – **permanent damage.**
Do not leave your robot on the floor.

Operating the motors at high speed for a long time.
This causes the motors to over-heat – **permanent damage.**
When you need to debug your code, turn the battery power off.

Robot falling of a table.
Your robot might move suddenly and fall off the table. This bends the wheel axles – **permanent damage.**
You can lift the robot off the surface or turn it upside-down. Be careful.

"I cannot connect to my robot"
See the Troubleshooting labsheet

Risk Assessment

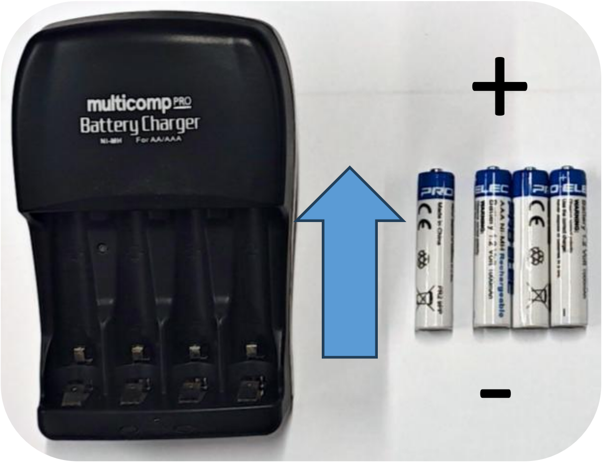
Please read the Risk Assessment on Blackboard

The robot is for your use – do not give it to children or other people.

Be aware of your surroundings.
Your robot may move suddenly. Avoid people **tripping** on your robot by ensuring you are in a safe environment. Tell others about what you are doing. As much as possible, keep your work in contained area.

Magnet:
The magnet is not a toy. Do not give it to children or allow children to find it. A magnet may cause problems for people with medical devices such as pace makers. Keep your magnet with your kit at all times.

Batteries:
Please ensure batteries are inserted into the charger in the correct orientation. Do not leave batteries to charge unattended or whilst you sleep.



Arduino IDE

Getting Started: https://www.arduino.cc/en/software

Legacy IDE (1.8.X)

Much more stable

Arduino IDE 1.8.19

The open-source Arduino Software (IDE) makes it easy to write code and upload it to the board. This software can be used with any Arduino board.

Refer to the **Getting Started** page for Installation instructions.

SOURCE CODE

Active development of the Arduino software is **hosted by GitHub**. See the instructions for **building the code**. Latest release source code archives are available **here**. The archives are PGP-signed so they can be verified using **this** gpg key.

DOWNLOAD OPTIONS

Windows Win 7 and newer
Windows ZIP file

Windows app Win 8.1 or 10 Get

Linux 32 bits
Linux 64 bits
Linux ARM 32 bits
Linux ARM 64 bits

Mac OS X 10.10 or newer

Release Notes

Checksums (sha512)

Kits

Problem with your Robot?

Keep the same Box.

OLD

SWAP

NEW

Kits

Use the QR Code to Register your Kit

Your Kit Number

Waiting?
Team Self-Allocation