CYBER PHYSICAL SYSTEM EDUCATION THROUGH PROJECT-BASED LEARNING

Jenny Highfield & Alex Deverson

Cardiff University
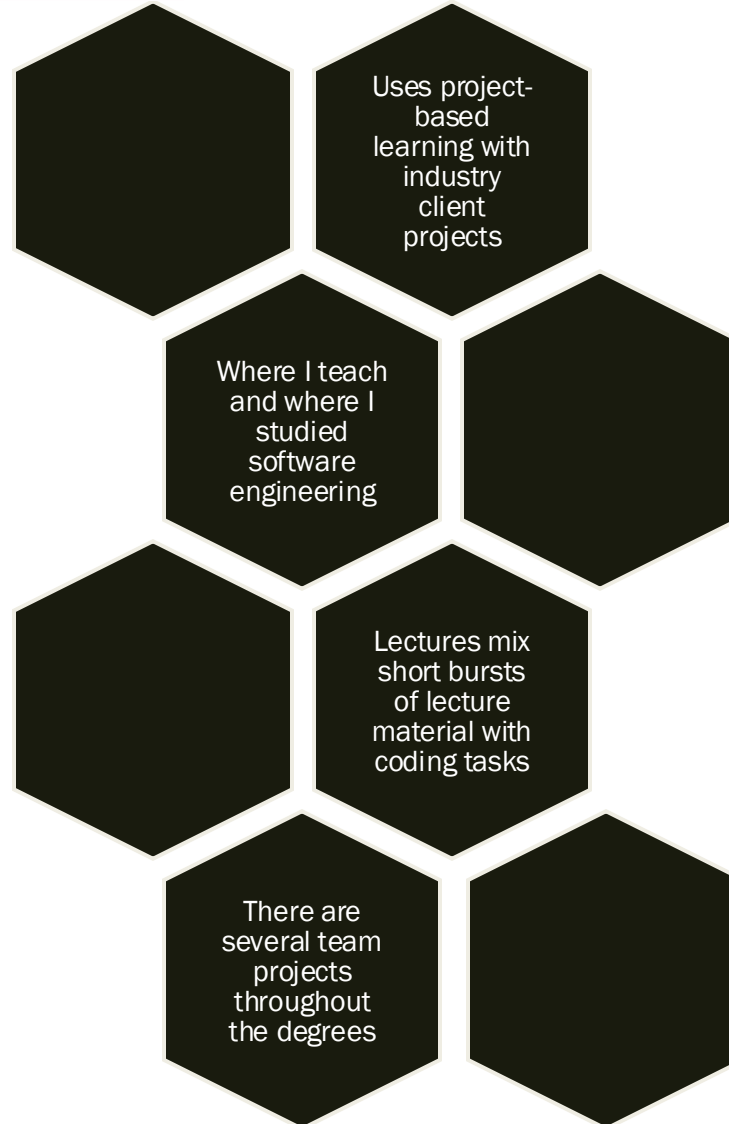
Project-based learning

"Project-based learning (PBL) involves students designing, developing, and constructing hands-on solutions to a problem. The educational value of PBL is that it aims to build students' creative capacity to work through difficult or ill-structured problems, commonly in small teams."

- Boston University

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Uses project-based learning with industry client projects

Where I teach and where I studied software engineering

Lectures mix short bursts of lecture material with coding tasks

There are several team projects throughout the degrees

Side note: National Software Academy

Cyber-physical systems

"Cyber-physical systems have physical inputs and/or outputs which are controlled by computers." - RITICS

These include the umbrella term of Operational Technology (OT) and industrial systems such as:

- Industrial Control Systems (ICS)

- Distributed Control Systems (DCS)

- Supervisory Control & Data Acquisition (SCADA) Systems

- The Industrial Internet of Things (IIoT)

https://www.ncsc.gov.uk/blog-post/ritics-securing-cyber-physical-systems

Introducing Jenny Highfield

- PhD candidate in Cybersecurity (end 2030)

- T&S Teacher in Software Engineering

- Working towards becoming a Fellow of HEA

- BSc Information Security from Uni South Wales

- MSc Software Engineering from Cardiff Uni

- Worked in Cybersecurity start-ups and SMEs

Student research associates

Students can be hired through JobShop as research associates

We worked with a group of students through several projects

Funding included Alan Turing Institute & Cyber Innovation Hub

Introducing Alex Deverson

- Cybersecurity Research Engineer at CIH

- Research Associate in second and third year

- Involved in both Alan Turing & CIH projects

- ExtDip in Electrical and Electronics Engineering

- BSc Computer Science from Cardiff University

- Builds testbeds and codes simulations
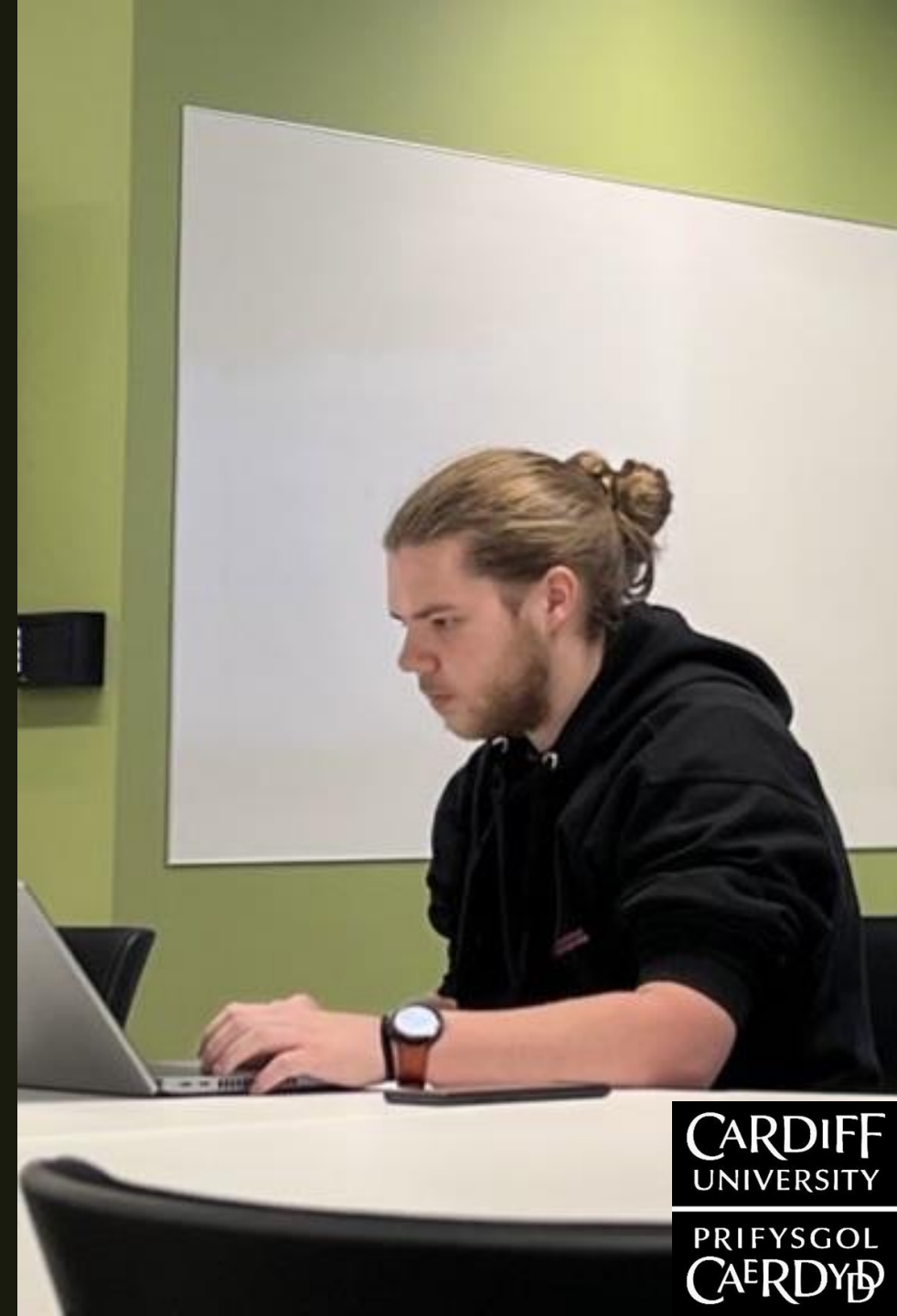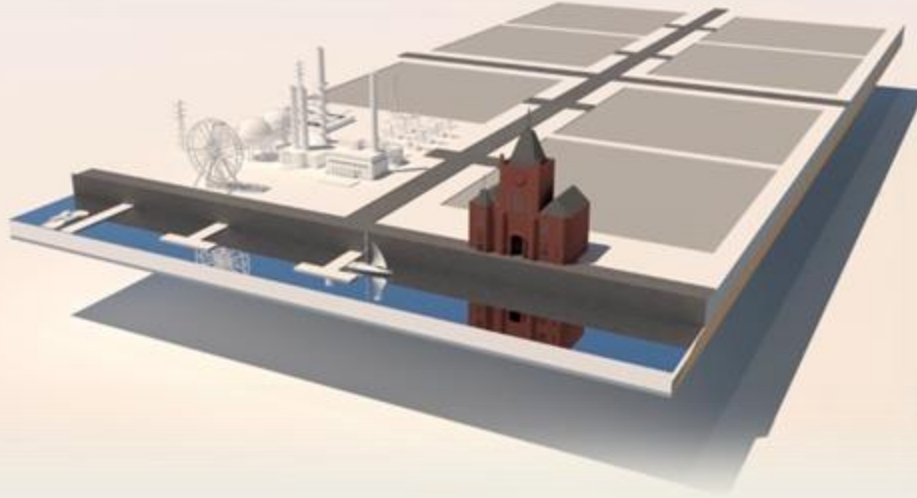
THE VISION

An interactive demonstrator

The student team from April 2023

Marwa Omar

Samuel Thacker

Liban Ahmed

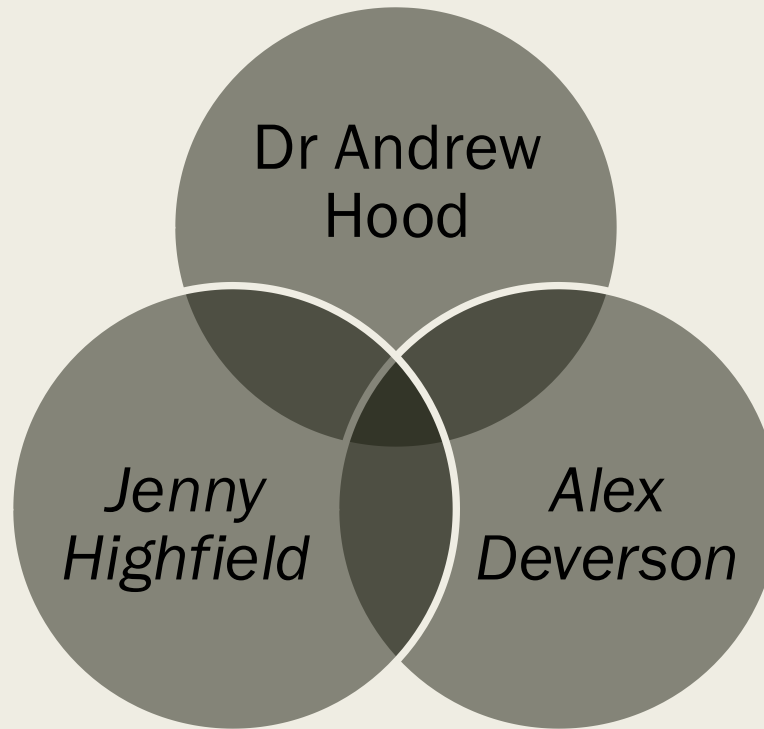Iolo Jones

Jake Samuels

Kendra Tyler

Liam Underhill

Ben Bevan

Eva Kelly

Asad Islam

Harry Franklin

Management team from April 2023

Planning and requirements gathering

- Lots of brainstorming as a team – whiteboard sessions

- Students involved in meetings with DUnit studios to understand the bigger picture

- All members of the team treated as equal and important

- Each task tailored to student abilities and upskilling desires

- Backlog created on GitLab – NSA alumni worked on user stories
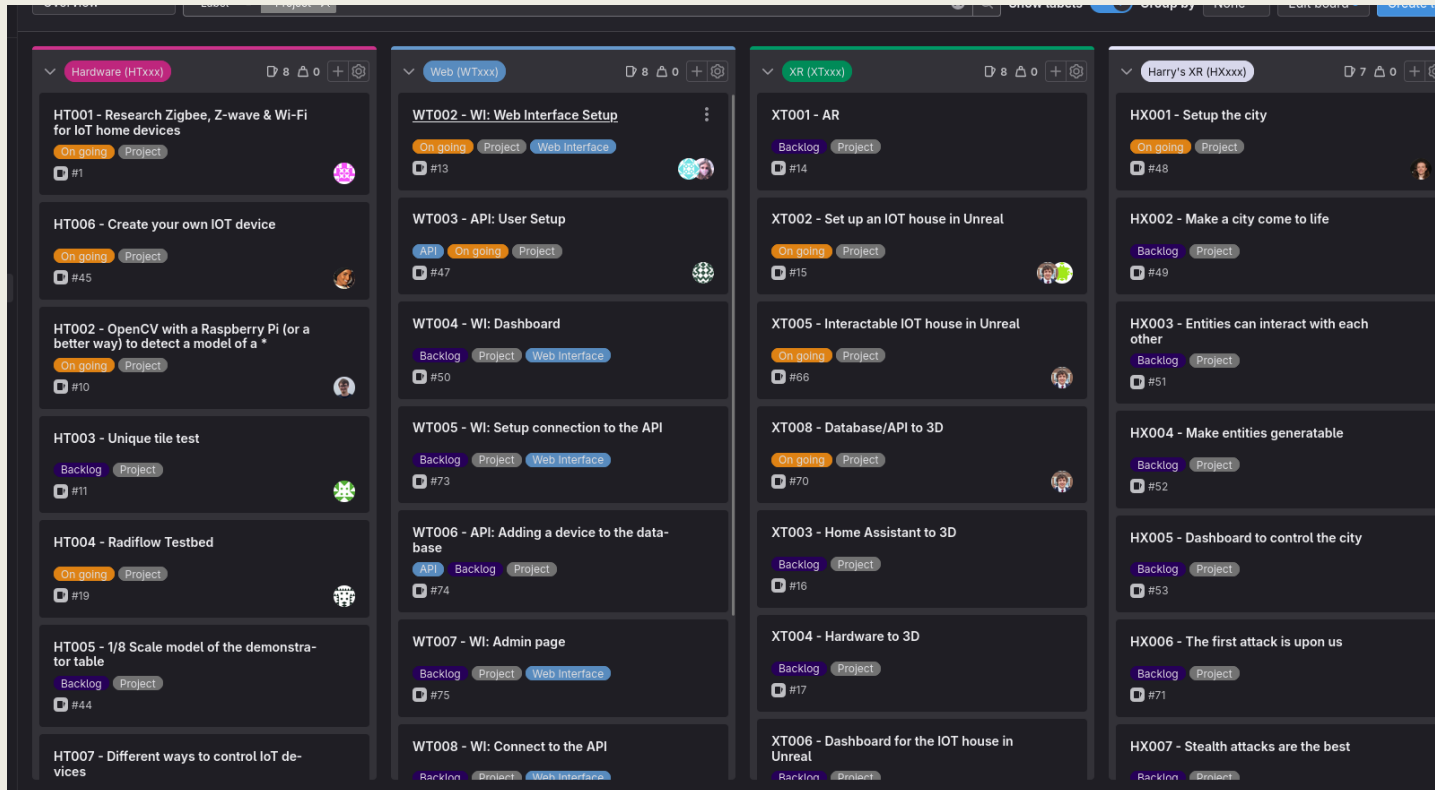
Project management methodology

- Followed an agile methodology

- Tracked issues on a board on GitLab

- Weekly meetings to 'walk the board'

- Daily scrums were not needed

- Ticket kick offs done with Alex / Jenny

The pastoral side

I (Jenny) provided some technical input but I'd like to highlight the following:

 – *Managed the meetings and sent out minutes*
 – *Asked the right questions, rather than giving answers*
 – *Provided support when API keys were pushed to GitLab*
 – *Listened when they were overwhelmed and signposted*

I'm in this job to guide and encourage my students do amazing things.

We created a safe space for them to fail.

The team was split into

- Hardware
- Extended reality
- Web

Mapping the tasks together

Web and research

- **Sam Thacker**– Created an API that connected hardware, XR and web tasks.

- **Eva Kelly** – design of a web interface for testbed status, configuration and management.

- **Kendra Tyler** – Research into case studies of hacks on PLCs, malware known to target PLCs, with a focus on Stuxnet and Industroyer.
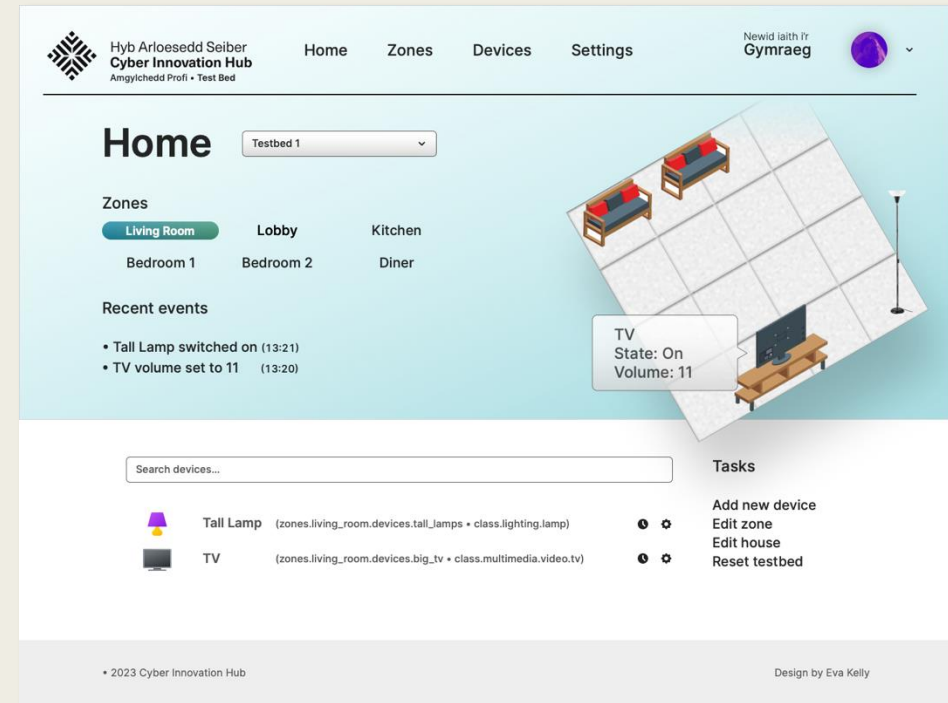
# Simulations and XR

- **Ben Bevan –** House built in Unity with utility levels and room that intergrates with Jake Samuel's IoT

- **Harry Frankllin** - 3D City Simulation in Unity showing cars on roads with working traffic light junctions.

- **Liban Ahmed** - Developed Realistic Virtual test Beds which synchronise over a network to deliver attack threat replication to vulnerable ICS environments.
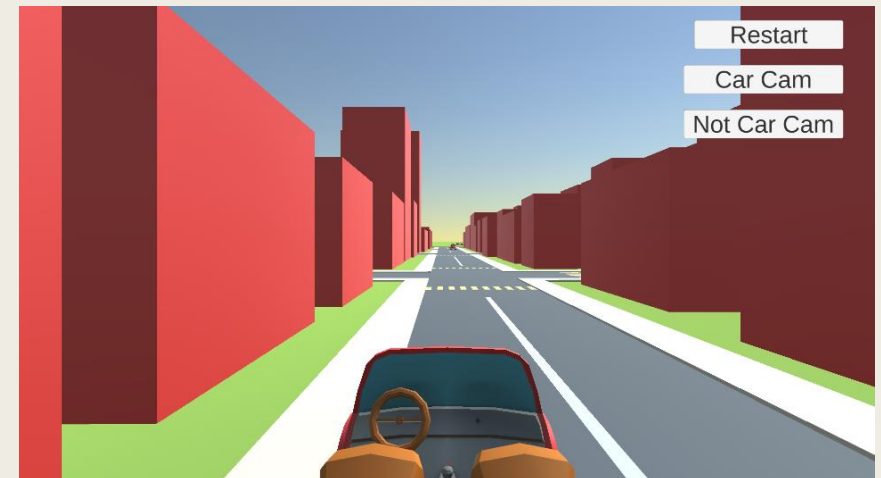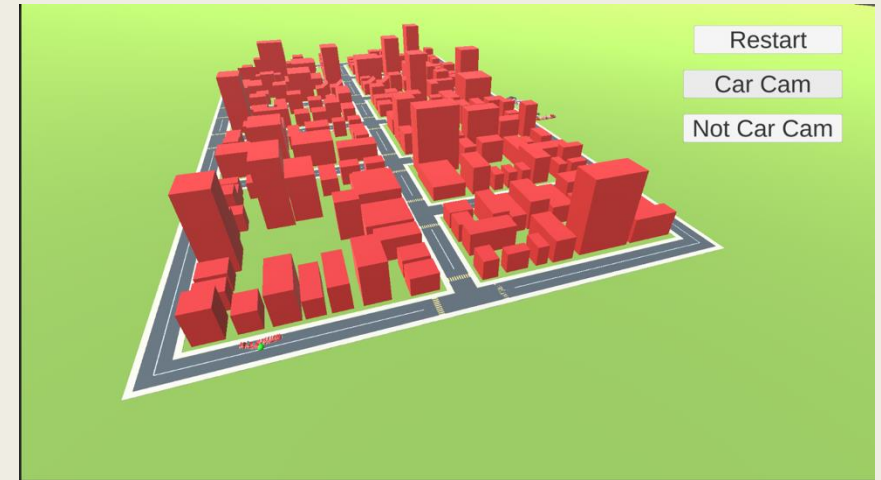
Hardware

- **Marwa Omer** - working with microcontrollers and sensors that could be atteched to the demonstrator.

- **Iolo Jones** - working with microcontrollers and RFID sensors to align tiles on the table.

- **Liam Underhill** - working with fiducial markers (initially QR codes) to track location on table.

- **Jake Samuels** – Connected Home Assistant to Ben's digital room using Sam Thacker's API so that turning an IoT lamp on turned on digital lamp.
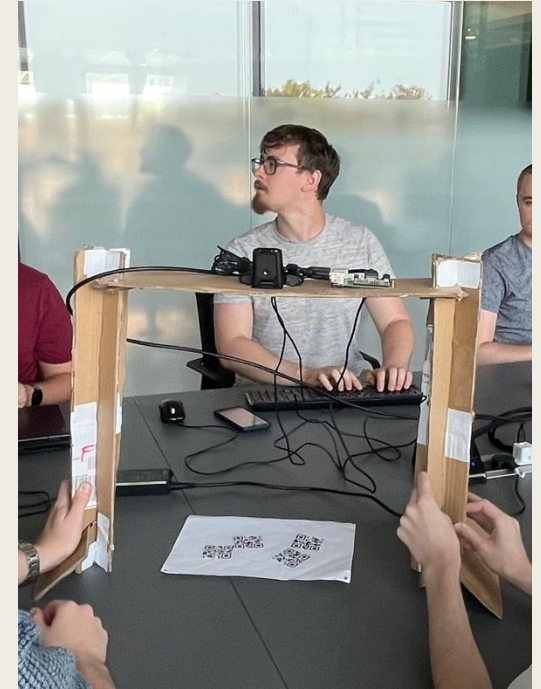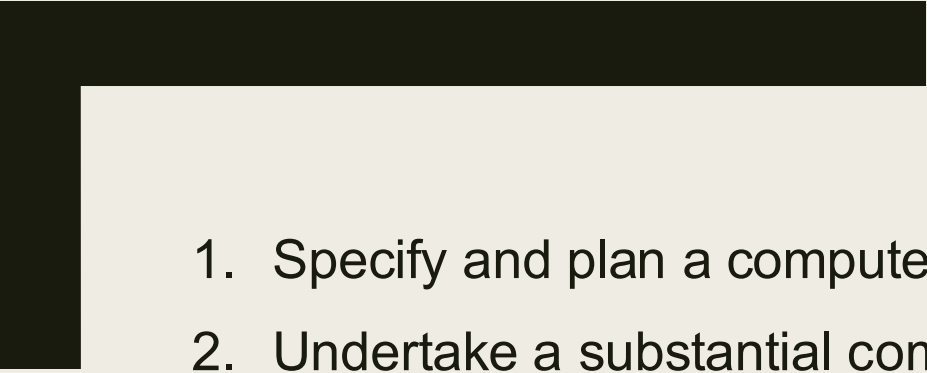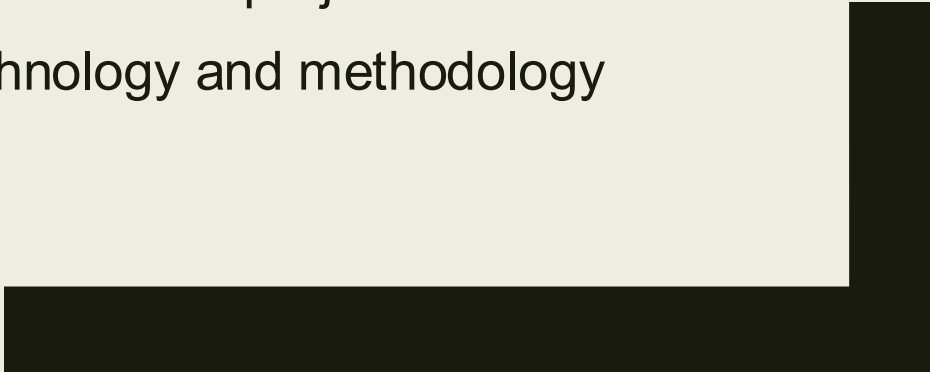
Integrations

- ■ **Ben Bevan's** smart house and Jake Samuels' Home Assistant integration with IoT light turning on and off in real life and lamp turning on and of in Unity.

- ■ **Liam Underhill** fiducial markers integrated with virtual mapping, initially basic grid, upgraded to Unity 3D grid with assets moving around built by Ben Bevan.
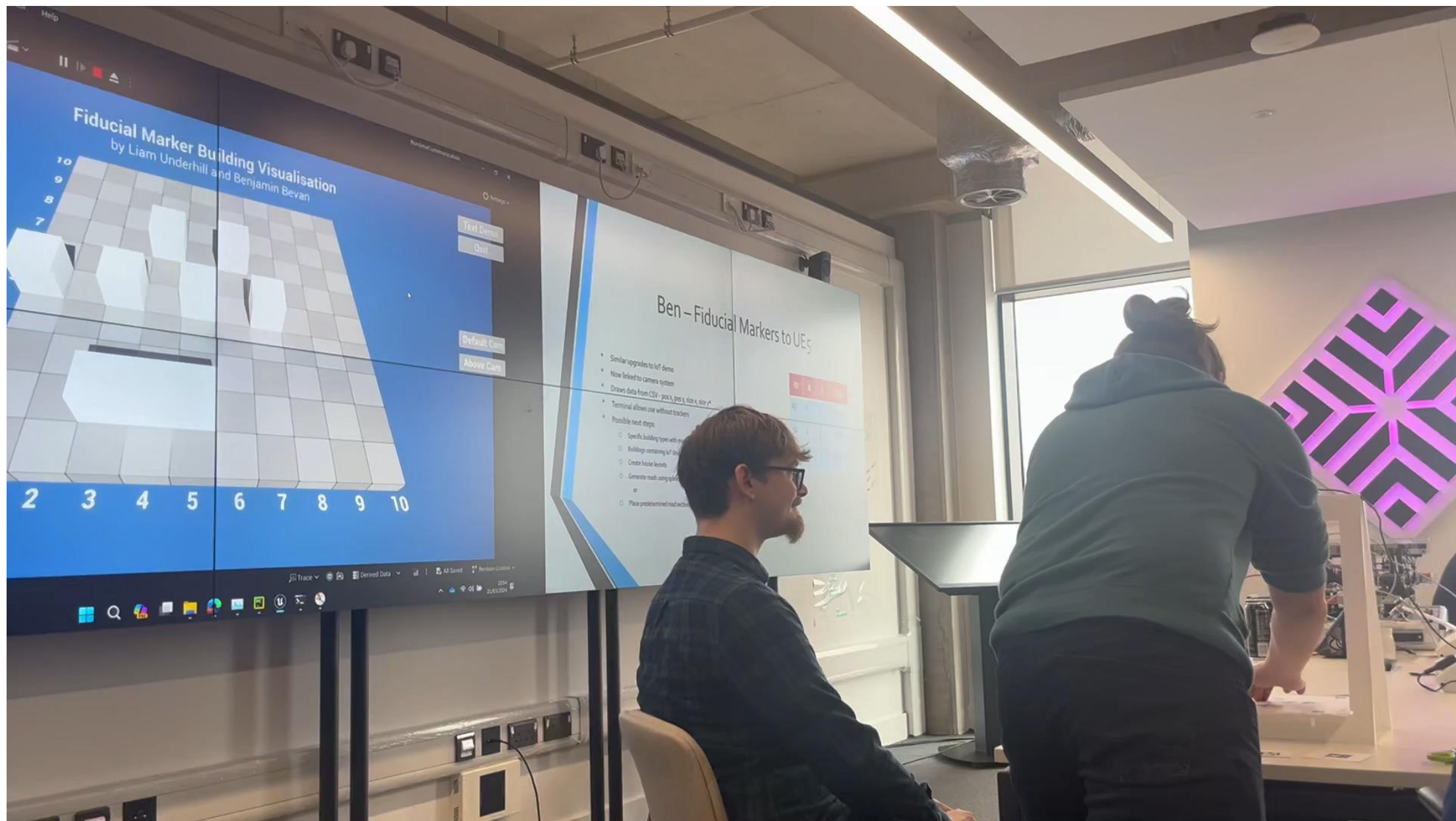
1. Specify and plan a computer science project

2. Undertake a substantial computer science project in a professional manner

3. Understand the elements of a successful computer science project

4. Show an appreciation of best practice in solving computer science problems

5. Exhibit a sound knowledge in the subject area related to the project

6. Demonstrate an in-depth understanding of the technology and methodology used in the project

Final year project learning outcomes

- Summarise and evaluate background work and literature relevant to the project

- Use appropriate tools, techniques, experiments and validation methods in developing and evaluating solutions

- Critically evaluate solutions and findings resulting from the project

- Plan, organise and implement tasks within time constraints

- Work independently under the project supervisor's guidance

- Report, present and document the findings and deliverables resulting from the project

- Apply appropriate theory and technology to solving the specific problem

- Develop solutions rationally using a disciplined approach, and with regard to the social and legal context of the project

Skills to be practiced & developed

First year of group supervision

- **Liam Underhill** used fiducial markers for tracking tabletop gaming

- **Kendra Tyler** created a database of OT cyberattack motivations

- **Iolo Jones** created a fractal based stenography tool hosted in a web app

- **Ben Bevan** created a simulation of hydrological impact and treatment

- **Jake Samuels** developed a framework for assessing vulnerabilities in IoT devices

- **Asad Islam** used a HackRF to exploit vulnerabilities in TPMS

(Supervised by Jenny Highfield / Dr. Andrew Hood, supported by Alex Deverson)

NSA Project with CIH

- In Autumn semester I teach Web Development at NSA

- Six agile teams working on a client project for CIH

- Building a dashboard for booking time on testbeds

- First year, first semester, so a wide range of skill level

- Access to an API for the more experienced developers

My second year of group supervision

- Organised a visit to see the demonstrator and testbeds

- Shared proposals and met brand new students (new to me!)

- They all get along like a house on fire and love group supervision

- They will present their dissertations at the end to CIH employees

- Harry has been employed by CIH!

The projects

- **Harry Franklin**
  - *Digital cyber demonstrator to show cascading effects from the renewable energy sector to the other 14 sectors of CNI*

- **Nathan Blundell**
  - *Digital cyber demonstrator to show cascading effects from the transport sector to the other 14 sectors of CNI*

- **William Sims**
  - *Creation of a prototype SCADA testbed with a focus on the newest sector of CNI – datacentres*

- **David Gurr**
  - *Creation of a prototype SCADA testbed with a focus to be defined by background reading*

- **Maame Darty**
  - *Gamification of CPS education through creation of a third party role play game (RPG) where the user finds security vulnerabilities*

- **Jacob Knapp**
  - *Exploration of security risks associated with the Remote Frame Buffer (RFB) protocol used for Virtual Network Computing (VNC)*

- **Evie Jones**
  - *Analysis of cyberattack case studies in a specific CNI sector (transport) to find common risks and patterns in data*

- **Kai Hailstone**
  - *Gamification of digital Abacws (our school's building) for new potential students, mapped to the DCF*

Where are the OG students now?

- Alex Deverson is a Cybersecurity Research Engineer

- Eva Kelly is working as a Web Developer as she was during her degree

- Jake Samuels is now a PhD student funded by CIH

- Kendra Tyler is pursuing a MSc in Computational & Data Journalism

- Iolo Jones is pursuing a MSc in Cybersecurity & Technology

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A defined and improving method of supervision

- This journey for me, has allowed me to reflect and defined how I supervise final year projects

- There are very clear learning outcomes for the final year projects that need to be met

- This process is nothing new to academia, but it's good to map practices to teaching methods

- Teaching is an iterative, reflective process, and each year is a learning curve

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PhD in pedagogical approaches for cyber physical system education

- Pivoted from industrial cybersecurity incident response to pedagogical approaches

- Looking at how digital and physical artefacts can be used for education:
  - *Testbeds*
  - *Demonstrators*
  - *Simulations*

- This will become part of a framework for the education of industrial cybersecurity

- For collaboration or to give advice on the topic, please get in touch!

With special thanks to:

Jenny's PhD supervision team:

- Dr Catherine Teehan

- Dr Yulia Cherdantseva

- Dr Amir Javed

- Dr Andrew Hood (previous supervisor)

Jenny's mentors:

- Dr Sandy Gould

- Dr Wendy Ivins

- Dr Ian Cooper

& of course, all the students mentioned in this presentation.

Thank you for listening ☺
Any questions?

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