Ri Engineering Masterclasses

WMG, University of Warwick

Robotics – Moving Intelligently

Overview

This project provided students with an experience of building, testing, tinkering with and calibrating a robotic vehicle kit. The learning materials were set out in a challenge-based approach backed with industry-inspired calibration checklists that students needed to 'sign off' on to indicate whether the vehicle works well out of the box, and if not, which settings would meet 'standards'. The third challenge was incredibly difficult and required an experimental, creative approach to make progress with. Students had built confidence and resilience to make, test, evaluate and improve by this point.

The project was run at two schools; Nicholas Chamberlaine (30 students) and Northleigh House (6 students) and had a total budget of £1500. The kit boxes were a custom product made specifically for this project by Kitronik Ltd and sold to us at a discount.

Evaluation materials and feedback from teachers show that the event was a success through the enjoyment the students had while taking part, though there were elements of frustration for the students that could have been averted or reduced by in-person delivery. Several suggestions for improvements of the activity are documented in the 'Summary' section for future versions of this activity.

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Project planning

Project aims

Tinkering, Mechanics and Robotics (Initial Proposal)

The world is filled with vehicles and there is a huge movement to make those vehicles smarter and greener. We have the technology to make the air clearer and easier to breathe while making vehicles safer to be in and around – we just need the engineers who will take those theories and turn them into real ideas.

This project will give young people an experience of putting together a vehicle powered by batteries and going through a make-test-evaluate cycle. If students have a computer available (at home or at school) they could use block-based coding to extend the activity. The real skills of engineering come from tinkering and improving a product bit-by-bit and that is at the core of this project. Ideally suited for Year 9/10 students, there is no need for experience of coding, building, or using tools beforehand. Our original concept was for 4 × 2-hour sessions but there is flexibility in delivery to make the session work for you (or your school).

This project is part of the Royal Institution Engineering Masterclass series at Warwick. WMG, the University of Warwick and the Royal Institution aim to give people from all backgrounds a fair chance to try engineering and see whether they could build their own future around it.

Do you (or your students) want to contribute to a sustainable future for vehicles? This project could be the starting line and put you on the right track!

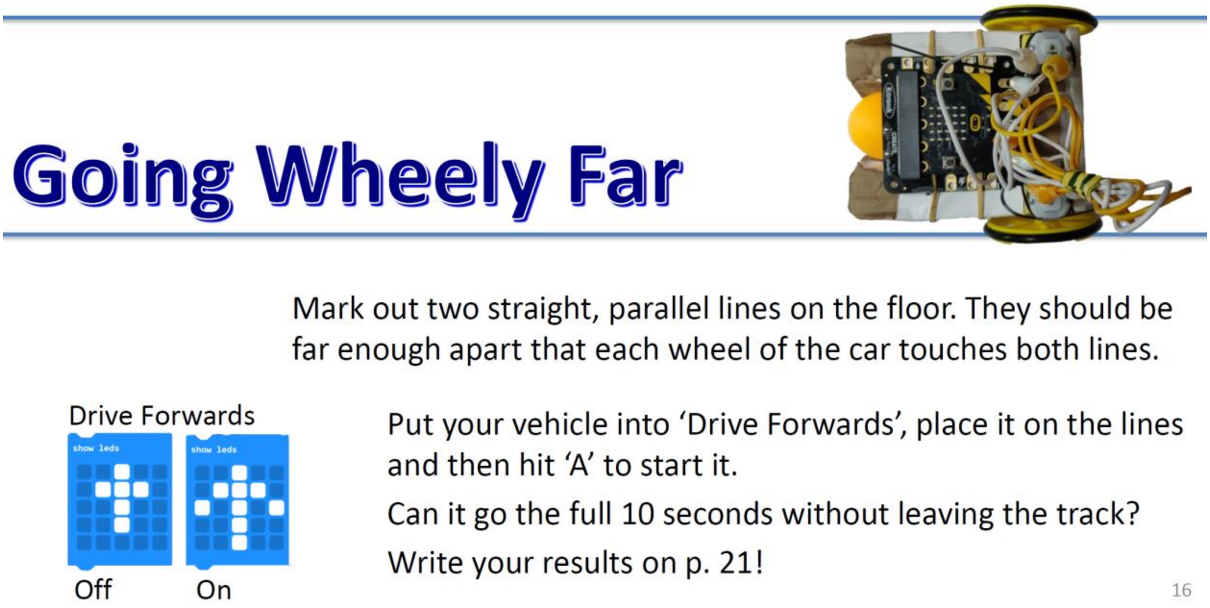
Challenge-based approach

The vehicle kits will have some issues – they are being built under time pressure out of cardboard with minimal fixings holding motors in place and so on – but this is a valuable lesson to the students that an initial prototype always has bugs and issues. The skill of a good engineer is to iron out the creases and resolve these bugs to get a functional robot. The 'Make, test, evaluate, improve' cycle is key to this series of tasks.

The challenges are:

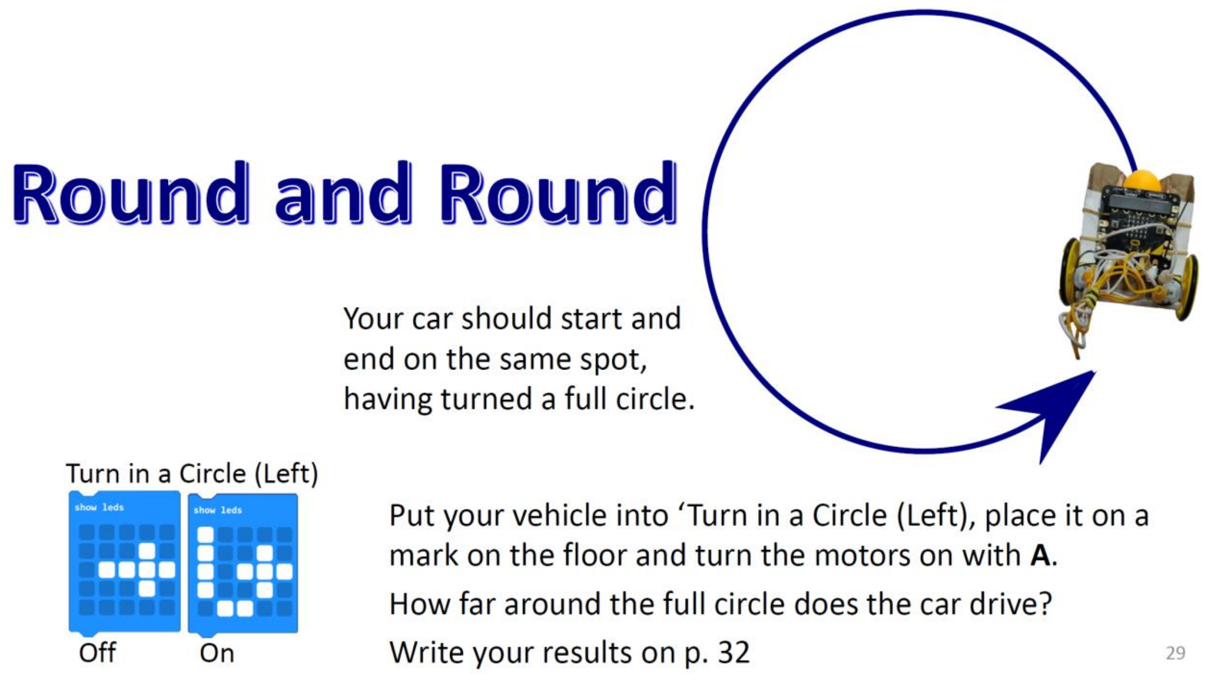
- Drive in a straight line for 10 seconds (forwards and backwards)

A programmatic 'bias' variable can be set by the students without having to edit any code. They will therefore be able to adjust the motors on either side of the vehicle to get it to drive in a straight line.



- Turn in a circle (left and right)

The vehicle drives with one motor turning faster than the other for a length of time. The students can then measure how far around a circle their vehicle goes using a protractor. They can then calculate the ideal amount of time this function should run for to turn the vehicle exactly 360 degrees.



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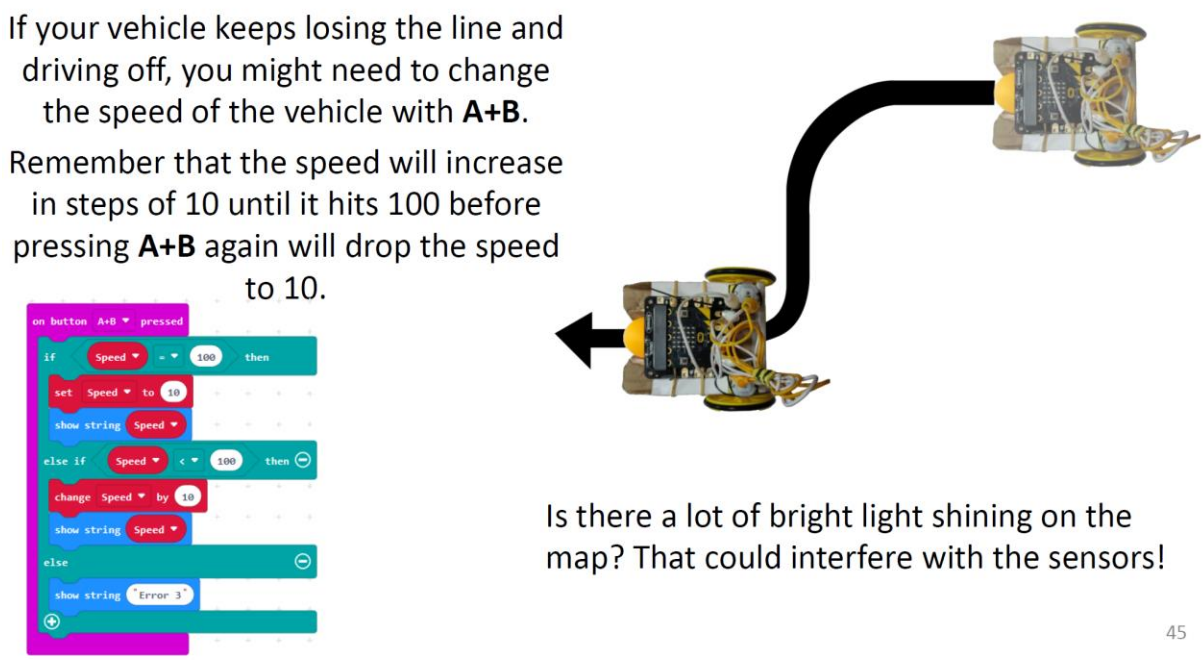
- Follow a line

Vehicles often struggle with line following based on how fast they are moving and trying to over-correct for inputs from the sensors. Getting the speed the vehicle moves at while following a line will balance speed and performance.



Extra resources

In the 'What Have You Learned?' section of the workbook there is a comment from Amar Gohil about what difference intelligent vehicles could make for our world. If you'd like to show your students more about this idea, Amar has a 10 minute talk that was written for school students available online here (https://warwick.ac.uk/fac/sci/wmg/people/wmgtalks/teaching-cars-to-sense-our-world/)

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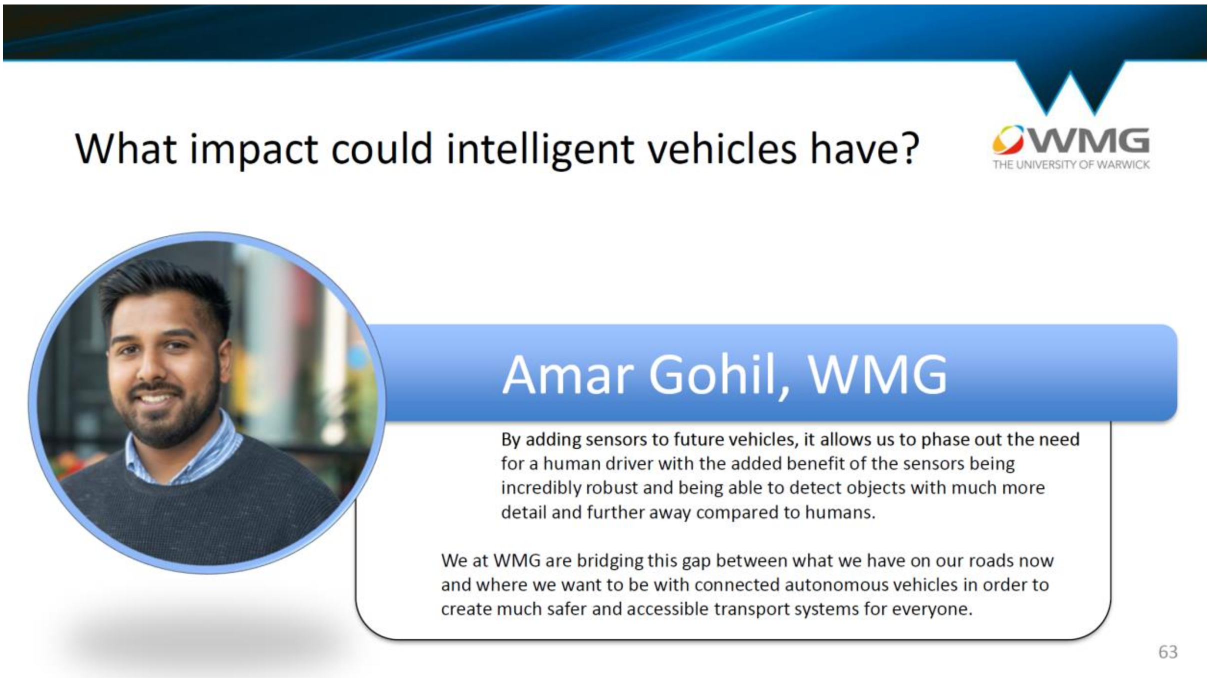


There is also a talk about how self-driving cars might have unexpected consequences on how we travel and interact with vehicles from Dr Joe Smyth available here: https://warwick.ac.uk/fac/sci/wmg/people/wmgtalks/self-driving

Activity format choices

Our choices on how to run these masterclasses were obviously impacted by the Covid-19 situation. We needed to be prepared for students to work on these kits with, or without, access to a computer. Whether they were in school or at home. The activities were therefore designed to work straight out of the box with the programmable micro:bits having code pre-installed onto them.

We were mindful of the challenges of presenting to a class full of students through a web meeting and therefore waited to find sets of teachers in schools who were able to take on the scale of the challenge. These teachers would need to provide far more input into the sessions than would normally have been the case with face-to-face delivery. It was also a challenge to support students building kits and diagnosing issues with their builds *via* webcam.

Final format

Northleigh House

Phil joined the class at Northleigh house *via* a Zoom call. The students built the vehicle in the first session, tested and improved it in the second session and, by the third session, while only one student as present, that student made improvements to the line following module set up to improve performance of the vehicle. An agreement was made that Phil would visit in person when safe to do so and work with the students on the vehicles to improve performance further.

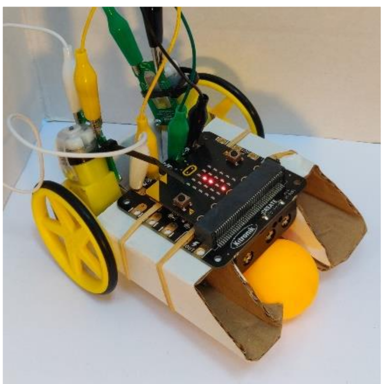
The progress of the students through the material was impressive and showed great skill and determination. Particularly in the case of the single student who attended the final session – their perseverance, analytical thinking and experimental skills were obvious and impressive.

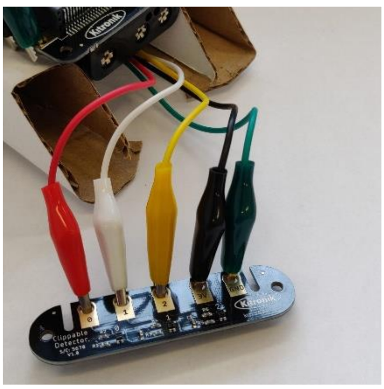
Nicholas Chamberlaine

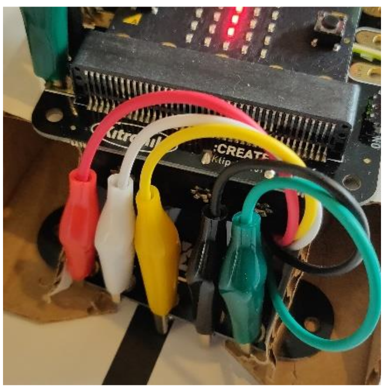
A Google Meet link was provided and Phil joined the sessions either through a teacher's laptop or *via* the large projector screen at the front of the class. Students worked in pairs to build the vehicle in the first session (1 h 40 m) and then on the second day students spent the first two periods (1 h 40 m) improving and continuing with the challenges. Students were able to change the code on the micro:bit controlling the vehicle to test the performance of the vehicle with modified parameters. In the third period (50 minutes) students were able to ask questions of WMG engineers in the Q&A session. In the final session (50 minutes) the context was reinforced to remind students that even if they hadn't completed the third challenge they had learned a lot of industry-related skills including calibration, testing and evaluation. The students filled in an online evaluation form.

Vehicle Kit

The vehicle cardboard chassis was simple to fold and put together. Adding the motors and the wheels required some force. The wiring required some dexterity.







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Evaluation

Teacher feedback

Some elements of the teacher feedback quotes have been removed to protect either their or a student's anonymity.

Teacher 1

Thank you so much for putting this session on, the kids thoroughly enjoyed the sessions and found them very useful.

Teacher 2

Firstly a massive thank you for the sessions Phil, I can't really express how thankful we are you worked tirelessly and a lot of prep must have gone into that. You were also very calm and fantastic with the students. The students were really engaged and … got so much out of it. Considering it was video link and the first event they've been able to do like that in ages I thought they were well behaved all things considered.

The feedback was rushed with tidying up taking longer than expected, I hope it was ok, it probably affected the quality of feedback and we perhaps should have done it earlier.

Teacher 3

As for feedback:

Positives: - YOU and your positive attitude and patience

- Having the opportunity to make the cars

Opportunities for improvement: - Too much could go wrong. Too fiddly. So good for a small group of people who are already interested in engineering.... BUT a bit soul-destroying for young people to not come out with some wins.

Its clearly not one for virtual learning - needs to be hands on in the classroom.

Student feedback (form)

Full responses and questions asked are presented in the appendix.

'Before the event' questions

All the questions were asked to the students after the event but were worded in a way to ask the students to reflect on the position they were in before the event. The 'before the event' questions aimed to form a baseline of how interested and engaged they were with STEM subjects to start with. This should allow us to understand whether our activities had a positive impact on the students.

Students generally feel that they understand the subject 'engineering' despite it not being a formal offered subject in schools (Figure 1). 14 out of 15 students (93%) either agreed or strongly agreed that they understood the subject 'engineering'. These students were selected by the school and therefore it is unsurprising that the majority were interested in pursuing STEM careers and qualifications.

13 out of 15 students (87%) either agreed or strongly agreed that they had considered a career in STEM, and 12 out of 15 students (80%) agreed or strongly agreed that they had considered studying STEM qualifications.

'After the event' questions

The first three questions were answered with at least 14 out of 15 (93%) responses being positive (Figure 2). The questions were whether the students enjoyed the event (93% positive), are confident setting up fair experimental conditions (100% positive), their understanding of how code and computers interact (93% positive). This shows that the students were capable and confident on their own ability, likely a result of the school choosing able students given the limited number of spaces on the course.

The following two questions were comparison questions to the pre-event responses.

Comparison of "intention" Likert-scale questions

These responses are colour coded to show whether the 'post' response showed any change to the 'pre' response (Figure 3).

There is no consensus of positive or negative impacts from this project on students intentions to continue towards STEM roles. A longer, more sustained project, with higher quality interactions (in person), more formal links between the content and the context of real world engineering progress would likely increase the chances of a positive impact on students' intentions.

Free text feedback – any other comments

These responses are again mixed (Figure 4). Some students were frustrated by the vehicle not working perfectly at the end of the sessions (the line following module is notoriously difficult to calibrate perfectly). These students would have benefited from an in person event as it would have been easier to approach the students in smaller groups and explain that what they are learning is the process of make-test-evaluate-improve that engineers use regularly.

Several students understood the concept that simple code with simple kit makes a good starting point to progress towards self-driving cars.

The students reported that being able to make and build a kit was their favourite part of the activity (Figure 5).

When asked what the most useful thing the students had learned during their session the students responded with answers such as 'coding' or 'wiring' (Figure 6). A personal highlight is the 'fast innovation' response as I think this perfectly sums up the students' activity while trying to get the line following module to work. The students tried to change variables in the code as well as physically in the classroom (where the line was placed, lighting, shade) and on the vehicle (where the sensor is placed). Patience and dexterity being reported as useful things students have learned is also a good reflection that the students have internalised the non-curricular skills this type of project aims to teach.

Again, the opportunity for more sessions was offered to the school when it is safe for an in person visit to go ahead. This could take the form of a STEM club or have the students who have already taken part in this masterclass teach and mentor a new cohort of students through building and testing the vehicle.

Evaluation by Pedagogical Intern

In 2021 an intern was recruited through the Pedagogical Internship Group to evaluate the materials provided as part of the RI Engineering Masterclasses at Warwick. The full report can be found here and the main learning points from the intern's evaluation are:

- Edit the learning materials to remove or reduce discrepancies between the Kitronik booklet and the WMG building instructions (*e.g.* the colours of the wires used are different between the two booklets).
- Either demonstrate (in person) or explicitly explain in the instructions (remote) that the wheels can be pushed on quite firmly and they will then hold in place as the intern (and students) found it frustrating that the wheels would wobble or fall off.
- Produce accompanying videos to show the vehicle assembly.
- Build into the activity a chance for students to modify the code (where access to a computer is guaranteed).
- Build into the activity a chance for students to modify the vehicles to try and creatively solve issues with components (*e.g.* the sensors).
- Include a description of how sensors work.
- Create strong links between WMG research projects and the materials used in outreach activities.
- Consider a terrain-based challenge where students need to pick appropriate wheels to navigate different surfaces.

Summary

The teacher feedback shows that the event was successful but would definitely benefit from in person delivery. The teachers were happy with the style and quality of presentation and remote teaching provided by the outreach team but would like a more robust kit to be available for any future events. A suggestion from Teacher 3 to have more 'quick wins' along the course of the activity so that students feel excited and proud of their accomplishments is a good one, and will be built into future activity.

Student feedback highlights that there were frustrating elements to the activity but that it was enjoyable regardless. It is impossible to conclude whether this event had any impacts on the students intentions to study STEM in the future. Clearly, the uncertainty over how this event would be run during Covid-19 restrictions limited the approaches we were able to take, but in future a more cohesive evaluation plan should be in place before starting activity. The main point from the student feedback is the confirmation that they enjoy building and tinkering with physical kit. This is reassuring as a large proportion of our activity centres around this tinkering approach.

An evaluation of the kit by a pedagogical intern revealed some discrepancies in the different documents provided as learning materials and suggested some additional materials such as videos of the vehicle assembly, which will be taken on board to improve the materials.

The materials used in this event reached 36 students for a total of £1,500 (£42 per head) and provided enough material for approximately 6 hours of engaging, tinkering-based learning. The materials should be expanded, and improved using the tips above, to make a more robust and streamlined activity for use in the future.

Appendix: Student Feedback Responses

'Before the Event' Likert Scales

I thought I understood what the subject 'Engineering' is about.	*I had considered pursing a STEM (Science Technology Engineering and Maths) career.*	*I had considered pursuing STEM qualifications beyond GCSE (A level/ degree/ apprenticeship/ etc.)*
Slightly agree	Totally agree	Totally agree
Slightly agree	Slightly agree	Slightly agree
Totally agree	Slightly agree	Totally agree
Totally agree	Slightly agree	Totally agree
Slightly agree	Totally agree	Totally agree
Totally agree	Totally agree	Totally agree
Slightly agree	Slightly disagree	Slightly agree
Totally agree	Slightly agree	Slightly disagree
Slightly agree	Totally disagree	Totally disagree
Slightly disagree	Totally agree	Totally agree
Totally agree	Slightly agree	Slightly agree
Slightly agree	Slightly agree	Don't know
Slightly agree	Slightly agree	Slightly agree
Totally agree	Slightly agree	Slightly agree
Slightly agree	Slightly agree	Slightly agree

Figure 1

'After the Event' Likert Scales

I enjoyed the masterclasses "Robotics - Moving Intelligently".	*I am confident in testing equipment with fair experiment conditions.*	*I am able to understand how code can control computers.*	*I would now consider pursuing STEM qualifications.*	*I would now consider pursuing a STEM career.*	*Hearing from the Engineers in the Q&A helped me think about my future.*	*I would trust a computer to assist the driver of a car I was a passenger in.*	*I would trust a computer to control a car I was a passenger in.*
Totally agree	Totally agree	Slightly agree	Totally agree	Totally agree	Totally agree	Slightly agree	Slightly agree
Totally agree	Totally agree	Slightly agree	Slightly agree	Slightly agree	Slightly agree	Slightly agree	Slightly agree
Totally agree	Totally agree	Totally agree	Slightly agree	Totally agree	Slightly agree	Totally agree	Slightly agree
Slightly agree	Totally agree	Totally agree	Slightly agree	Slightly agree	Slightly disagree	Totally agree	Slightly agree
Totally agree	Totally agree	Totally agree	Totally agree	Totally agree	Totally agree	Totally agree	Slightly disagree
Totally disagree	Totally agree	Totally agree	Slightly disagree	Slightly disagree	Totally disagree	Slightly agree	Slightly agree
Totally agree	Slightly agree	Totally disagree	Slightly agree	Totally disagree	Totally disagree	Totally disagree	Don't know
Slightly agree	Slightly agree	Slightly agree	Slightly agree	Slightly agree	Totally agree	Slightly agree	Slightly agree
Totally agree	Slightly agree	Totally agree	Slightly agree	Slightly agree	Totally agree	Totally agree	Slightly agree
Totally agree	Slightly agree	Slightly agree	Totally agree	Totally agree	Slightly agree	Totally agree	Slightly agree
Totally agree	Totally agree	Slightly agree	Slightly agree	Slightly agree	Slightly agree	Totally agree	Totally agree
Slightly agree	Slightly agree	Slightly agree	Slightly agree	Slightly agree	Slightly agree	Slightly disagree	Slightly disagree
Slightly agree	Slightly agree	Slightly agree	Slightly agree	Don't know	Slightly agree	Totally disagree	Totally disagree
Totally agree	Totally agree	Totally agree	Slightly agree	Slightly agree	Slightly agree	Totally agree	Totally agree
Totally agree	Slightly agree	Slightly agree	Slightly agree	Slightly agree	Slightly agree	Slightly disagree	Slightly disagree

Figure 2

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Comparison of 'Before the Event' and 'After the Event' Paired questions

If students reported being more likely to want to study STEM qualifications or pursue a STEM career the boxes are highlighted in green. If students reported being less likely to do so, the boxes are highlighted in red.

STEM Career		STEM Qualifications	
Pre	**Post**	**Pre**	**Post**
Totally agree	Totally agree	Totally agree	Totally agree
Slightly agree	Slightly agree	Slightly agree	Slightly agree
Slightly agree	Totally agree	Totally agree	Slightly agree
Slightly agree	Slightly agree	Totally agree	Slightly agree
Totally agree	Totally agree	Totally agree	Totally agree
Totally agree	Slightly disagree	Totally agree	Slightly disagree
Slightly disagree	Totally disagree	Slightly agree	Slightly agree
Slightly agree	Slightly agree	Slightly disagree	Slightly agree
Totally disagree	Slightly agree	Totally disagree	Slightly agree
Totally agree	Totally agree	Totally agree	Totally agree
Slightly agree	Slightly agree	Slightly agree	Slightly agree
Slightly agree	Slightly agree	Don't know	Slightly agree
Slightly agree	Don't know	Slightly agree	Slightly agree
Slightly agree	Slightly agree	Slightly agree	Slightly agree
Slightly agree	Slightly agree	Slightly agree	Slightly agree

Figure 3 - Internal note: student 6 reported some concerns of classroom behaviour in the 'extra comments' section. The comments were removed from this report for safeguarding.

The results inferred from these pre- *vs* post-event Likert scale questions on STEM intentions are mixed. One student became more positive about pursuing a STEM career (student 3) but less positive about pursuing STEM qualifications, counterintuitively. Two students became less confident or inclined to study or pursue STEM (students 6 and 7) while two further students (students 8 and 9) became more inclined to study STEM qualifications. Student 9 also became far more inclined (totally disagree to slightly agree) to pursue a STEM career.

Free Text Feedback

Please could you describe how the vehicle you have built relates to a wider context like real driverless cars appearing on our streets.
it shows us what the future will be like
Its shows how the future will be.
It doesnt because it didnt work
It has a sensor that detects the difference between black and white lines. In the near future we could have markings on the road that allow all cars to do that.
No way at all, the things we built were so dumbed down it had no resemblance for what is being planned.
It doesn't use gas
It can work with you controlling it
the car could drive itself slightly but not completley
My vehicle relates to wider contexts because it had sensors on that cars today would for example, parking and reversing in terms of safety.
the masterclass has greatly expanded my view on the details of self driving cars and the code behind them
It was all coded and wasn't made for human drivers it is a concept of being driverless.
We had a sensor that tracked the lines, in the real wprld this would follow roads.
the vehicle we have made has mirrored a protype of the cars we see on the streets today

Figure 4

What was your favourite part during the Masterclasses?
testing
Car wrestling/testing
making the cars
Tinkering with it
the wiring and (re)coding of the microbit
None
Testing the car
Getting to experience how engineering works
watching the car drive
wiring and connecting all of the crocodile clips
building the car
Making the robot
building the car
Tweaking parts of the car.
building and coding the car

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Figure 5

What was the most useful thing you have learned during these sessions?
building the car
Codding
Patience
wiring and coding
A good way to re-attach alligator clip coverings, how to use alligator clips effectively and cable management
How to build a car
How things function and getting them to work
that motors are way simpler than i thought
how different lightings and surroundings affect an experiment
how to use microbit
To be patient and don't be too heavy handed
coding the robot
Fast innovation.
how different codes can make the car do different things

Figure 6

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