# Creative computing with Minecraft

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# Creative Computing with Minecraft

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*Computer Science in schools has gained momentum in the last two years resulting in GCSEs in the discipline and teachers looking to up-skill from Digital Literacy (ICT). This paper explores using the popular online 3D environment Minecraft as a tool for understanding computational thinking, computer aided design (CAD) and manufacturing.*

**1. The difference between ICT and Computer Science**

To discuss Computer Science it is first important to distinguish between it and ICT. The study of Information and Communication Technology (ICT) involves understanding how to navigate computers and use software. For young people in school this generally involves learning software packages such as Microsoft Office. Computer science is a discipline that spans both theory and practice and centres on problem solving, reason and logic. Young people can become better problem solvers by learning to be analytical, to breakdown complex activity into bite-sized chunks of activity, and to be precise. Central to Computer Science is computational thinking - "thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent" (Cuny, 2010). It is because of this that computational thinking is referred to as a very 21st century skills (Einhorn, 2012). In order to think computationally we are required to think "step-by-step, literal, mechanical" (Pepert, 1980). Computer programming is not the same as computational thinking. It is a practical application of it (Posey, 2013). Both computational thinking and computer programming are required within the discipline of Computer Science.

Since the Royal Society's report "*Shut down or Restart?"* published in January 2012 there has been a huge increase in the appreciation and support of computer science education and the need for the curriculum to reflect technological changes in society resulting in striking transformations to policy in England (Society, 2012). For instance in September 2013 four major examination boards began to offer Computer Science GCSE. In England, a new statutory Programme of Study (PoS) for computing at key stages one to four (both primary and secondary school children) will begin in September this year (Education, Statutory Guidance: National Curriculum in England: computing programmes of study, 2013). Under this new PoS in English schools ICT will be subsumed under the broader discipline of Computer Science. In the last two and a half years attitudes to studying computing has changed rapidly from the approach used during the 1990's and 2000's. In Wales, in September 2013, an appointed ICT Steering Group made recommendations which became included in the wider Curriculum for Wales review (Government, 2014) and reflected the changes happening over the border in England. As yet, there is not change in Welsh education policy in respect to Computer Science.

Without an introduction to computer science at schools young people have a very limited understanding of what studying the discipline as degree level involves. As a result, few pupils choose to study computing post-18 and for those that do there is a large attrition rate – students leaving courses because they do not have the necessary skills required. In order to ensure that there is no future skills gap in the UK in this area more students need to undertake computing degrees as well as have the necessary abilities to ensure that they complete their degrees.

Under the new English Computer Science curriculum pupils aged 11 to 14 years of age, for instance, will be required to "design, use and evaluate computational abstractions that model the state and behaviour of real-world problems and physical systems […]. Understand several key algorithms […] use two or more programming languages, at least one of which is textual, to solve a variety of computational problems; understand simple Boolean logic [for example, AND, OR and NOT] and some of its uses in circuits and programming" (Education, Computing programmes of study: key stages 3 and 4, National curriculum in England, 2014). Statutory requirements to cover the subject area to such as high level of detail have naturally raised concern amongst some ICT teachers who can feel ill equipped to deliver the new computer science curriculum and who have little time for upskilling.

**2. Technocamps enthusing Young People to be Producers, rather than consumers, of Technology**

There are a number of reasons to encourage young people to be producers of technology: with more young people gaining in-depth knowledge of computer science the UK will be more able to meet the depth of expertise required to ensure a strong economy in the future; young people, living in an increasingly technologised society, need to understand technology and its implications to be engaged, informed and critically aware citizens (Naughton,

2012); DIY generally encourages self-reliance and thus learning to be a producer of technology increases a young person's resilience in this rapidly changing world (Collective, 2007).

Young people enjoy hacking their way into existing tools and hardware. Knowing that they have the expertise to take something apart or build it gives learners real confidence (Petre, 2012). The technology 'DIY culture', led by Make Magazine and Maker Faires (Maker Media, 2014), has grown with the resurgence of 'doing' – a focus on the hands-on, DIY, crafting and materials (Crawford, 2009). Fast becoming affordable and workable, desk-top 3D printers take manufacturing from industrial and mass commercial production to micro, one-off amateur creations and also do away with unnecessary consumption (Anderson, 2012). Rather than a lively economy being met by industrial and large enterprises, 3D printers are the modern David to corporate Goliaths (Sennet, 2009).

Technocamps, is a three-year European-funded project based in Wales with four hubs across the Convergence regions of Aberystwyth, Bangor, South Wales, and Swansea. Technocamps aims to enthuse young people, aged 11 to 19 years, to engage with computing (programming and electronics). Technocamps operates both within schools with workshops and Technoclub, and outside of school with holiday Bootcamps and has a range of activities, tools, hardware and educational resources designed to give the participants a hands on approach to computer science. .

Graphical programming such as Scratch, S4A, and App Inventor is popular for introducing young people to programming. The graphical interfaces are much more intuitive for those who do not understand the complex syntax of written code. These tools allow learners to program by drag and dropping blocks of code thereby eliminating the frustration of learning and debugging syntax (text-based) programming language. Learning writing and debugging syntax can be a barrier to learning programming and can stifle creative thinking. That said, recognizing the importance of learning syntax Technocamps offers, and has successfully used, programming languages such as Greenfoot, HTML and Python as well as Arduino.

Technocamps aims to encourage young people to be producers, as well as consumers, of technology. In order to encourage young people to do-it-themselves Technocamps has spearheaded out-of-the-box activities to engage them with computing *and* electronics and thus to move away from the usual screen and keyboard. This has been focused around the Arduino microcontroller: wearables technology, using the Lilypad, where young people develop their own circuit diagrams on paper before transferring them to cloth using conductive thread and sensors; and using S4A (Scratch for Arduino) or the Arduino IDE to control tethered and untethered self-built robots. More recently we have utilised the Raspberry Pi, a credit-card sized computer. With its connection to the internet the Pi has been useful creating networks and exploring the possibilities offered by the World Wide Web.

**3. Minecraft and Printcraft as learning tools**

Minecraft (Mojang, 2014) is a hugely popular, multiplayer sandbox game environment where participants can build with others online. It attracts a massive number of users of all ages and has proven efficacy as an educational tool (Short, 2012) (Webster, 2011) (Duncan, 2011). Most often, Minecraft is compared to LEGO™ for the style of play. Whilst Minecraft is far from the first game with educational potential, the abundance of modern screen-based computing and an awareness of Minecraft amongst young people, has made it one of the most popular. One of the exciting aspects of Minecraft as an educational tool, is that is that it brings with it a culture of collaborative learning and knowledge sharing. Mojang, the creators of Minecraft, have never published instructions to their complex multiplayer game. Instead, children the world over are using chat, YouTube, and wikis to teach themselves, and each other, to play the game they enjoy.

Players interact with a randomly generated world consisting of simple building blocks that can be dismantled and reconstructed. At a basic level Minecraft encourages the building of structures from modest houses to magnificent castles, but the supporting physics system enables players to build complex mechanical devices and circuitry changing the way they interact with the environment. There are real benefits to using Minecraft which they are already familiar with as consumers, providing an opportunity to quickly engage with them in learning.

3D printing is a fast-growing commercial and hobbyist technology and teaching young people about it familiarises them with many of the essential technologies and processes of modern manufacturing, from design through to delivery. Printcraft is a plug-in, which allows users to print out their Minecraft creations on a 3D printer (Harter, 2014). Printcraft translates structures within a Minecraft world into an STL file for use by 3D printers. 3D printing is a process, also known as Fused Deposition Modelling, in which 3D structures are made through the extrusion of a molten material at precise locations. As the extruding tool moves and the material cools and hardens, a solid

structure is formed. There are a number of publications that explain the 3D printing process and applications in greater detail (Lipson, 2013) (Dimitrov, Schreve, & de Beer, 2006). The path of a 3D printer's extruder is controlled with a series of low-level machine instructions. The generation of the instructions can be a complex problem as most efficient paths for travel and details of interior support structure are calculated and so they are usually generated automatically from computer aided design (CAD) software.

Whilst the flexibility and diverse building options in Minecraft encourages creativity, Printcraft's 3D printing option provides a means for teaching fundamental computational, science, technology and engineering concepts without the need to become familiar with complex CAD software. For example, when working with a 3D printer a number of aspects must be considered. As in Minecraft, it is not possible to place a block in mid-air, necessary support structures are required. Similarly, bridge gaps will often collapse and necessitate a series of steps to form an adequate arch (as seen in real world architecture).
Drawing similarities from the virtual world of Minecraft and the physical world enables students to experiment with engineering concepts and design to develop an appreciation of issues going from concepts to implementation.

**4. Technocamps Printcraft Bootcamp Findings**

Technocamps has run a series of two-day workshops both in and around the Technocamps hubs. Known as Bootcamps, these workshops run during the school holidays with young people voluntarily booking places on the course. Since Easter 2013 the Aberystwyth and South Wales hubs offered 5 Bootcamps in Printcraft which were extremely popular and generally over subscribed.
Since Easter 2013 Technocamps has run two-day 'Bootcamps', holiday workshops which young people who attend voluntarily – the Printcraft bootcamps are always over-subscribed. Technocamps ran 5 Printcraft Bootcamps with a total of 85 participants.

The Bootcamps were designed so as to meet the following learning outcomes:

1. Appreciate CAD/CAM and the individuals who have contributed to its development.
2. Explain the role 3D printers have in engineering.
3. Plan, design and print collaboratively both on and off line within teams.
4. Understand some limitations when designing real world objects using 3D printing.
5. Use Printcraft to understand the specific computing and electronics involved in the design to manufacturing process using 3D printing.

**4.1 Results of Printcraft Feedback Questionnaire**

Each participant completed a specific feedback questionnaire as part of this study (see *Appendix I: Printcraft Bootcamp Research Questionnaire)*. The questions were based specifically on Specific Learning Outcomes listed above.

There were a number of questions raised in respect to each learning outcomes with multiple-choice answers and some open-ended questions. The statistical results from the questionnaire with summaries are given below.

**4.1.1 Learning Outcome 1**

| **Appreciate CAD/CAM, its role has in modern engineering and the individuals who have contributed to its development.** | | | |
|---|---|---|---|
| What do you understand CAD/CAM? | Daytime/nighttime<br>1.20% | A washing machine<br>1.20% | Computer-aided design/computer-aided manufacturing<br>97.59% |
| Who is Ada Lovelace? | A crochet shawl<br>2.47% | A computer programme<br>14.81% | The world's first computer programmer<br>82.72% |

The students were given a presentation on the history of 3D printing and CAD\CAM. The participants were extremely engaged which is reflected in their results showing that they not only understand CAD/CAM (which some might already have had experience with in school) but also its development.

#### 4.1.2 Learning Outcome 2

| **Explain the role 3D printers have in engineering.** | | | |
|---|---|---|---|
| Have you started looking online for things to do in relation to Printcraft or CAD/CAM? | Yes<br>22.89% | No<br>77.11% | |
| What can 3D printers help build? | Small one-off complex objects or parts<br>91.46% | Films<br>2.44% | Hand-made items<br>6.10% |

Though the participants were using Printcraft and 3D printers for fun they understood what these tools are used for in real life situations with a few students looking at websites such as http://www.thingiverse.com or other structures which can be built using 3D printers.

#### 4.1.3 Learning Outcome 3

| **Plan, design and print collaboratively both on and off line within teams.** | | | |
|---|---|---|---|
| What methods did you use to communicate to your design team? | In Minecraft only<br>29.27% | In Minecraft, across the table and using sketches<br>36.59% | In Minecraft and across the table<br>34.15% |
| Have you built something 3D in Minecraft and exported it to print on a 3D printer? | Yes<br>91.57% | B.<br>8.43% | |

Minecraft is designed for collaborative play. The participants worked extremely well in teams both across the table and within the application. Students were asked to work in teams to develop a team "badge" which they designed on paper and then build collaboratively within Minecraft. All participants participated in this (though to different levels as their comfort dictated).

#### 4.1.4 Learning Outcome 4

| **Understand some limitations when designing real world objects using 3D printing.** | | | |
|---|---|---|---|
| Too much overhang on a 3D design can cause it to do what when printing in 3D? | The edges to droop<br>92.68% | The nozzle to get jammed<br>6.10% | The layers to become multi-coloured<br>1.22% |
| Do you think you will use Printcraft again? | Yes<br>66.25% | No<br>33.75% | |

The participants all built models on the 3D printer and almost all were designed with the abilities of the printed in mind. In the questionnaires almost all the student understood the issues around overhang. Though the students seem engaged in the subject and enthused by Printcraft 33.75% said that they would not use Printcraft again, this seem contradictory to their engagement in the workshop and could be due to the cost of the application and availability.

#### 4.1.5 Learning Outcome 5

| **Use Printcraft to understand the specific computing and electronics involved in the design to manufacturing process using 3D printing** | | | |
|---|---|---|---|
| What moves the build platform and print head? | Controllers and motors<br>85.19% | A nozzle<br>9.88% | Molten plastic<br>4.94% |

| | | | |
|---|---|---|---|
| How is plastic filament forced through the extruder? | Using a hammer<br>1.22% | Using a heating element<br>75.61% | Via a syringe<br>23.17% |

All participants were able to see the 3D printer in operation and therefore understand how it operated. Although 91% repeated that they had exported an item to be printed during the workshops the 3D printers were accessibly to all student (with three 3D printers running simultaneously in USW). Their general understanding of the manufacturing process was high though the specifics to how 3D printers work was slightly lower (with only 75% knowing how the plastic filament is extruded). This result is consistent in Aberystwyth and the University of South Wales even though the Cubify Cube 3D printer at the University of South Wales Bootcamps was enclosed and therefore the heating filament less visable than that of the Makerbot used in Aberystwyths Bootcamps.

**4.1.6 Open-ended Questions**

The students were asked what other things they would like to see included in the Bootcamps their suggestions can be summarized as follows:

- Other design packages then Minecraft.
- Scriptcraft (python was included in USW)
- Raspberry Pis
- Designed with overhangs (only possible with 3D printers which create supports)

The students were asked if the Bootcamps could have been structured differently. Their suggestions can be summarized as follows with most students requesting that the Bootcamps run for more days:

- Longer Bootcamps (suggestions for 3 days)
- More Minecraft
- More space/more/different laptops (there seems to have been a problem with equipment at Tregaron secondary School)
- Some other different activities

How do you think Printcraft might benefit other areas of your learning?

- Design (DT), Art and ICT (also mentioned Maths, and coding)
- Introductions to Engineering
- Homework (but I'm not sure how)

**4.2 Result of Technocamps Pre and Post Questionnaires**

As well as the Printcraft questionnaires, the partitipants were asked to rate how they enjoyed the Bootcamps and whether they would like to learn more about Computing, Engineering or Science. This data has allowed for an analysis of the engagement of the students on the Bootcamps.

Technocamps collects feedback from pre and post-questionnaires which are issued to each participant at every workshop, Bootcamp and club and this study drew additional data from these questionnaires – see *Appendix II and III: Technocamps Pre and Post-Questionnaire*.

78% of participants rated the workshop as being Great or Good, and 68% of students saying they would come to another Technocamps workshop. 84% said they definitely would, or may return.

The graph in Figure 1 shows the number of participants who would like to learn more about Technology, Engineering and Computing following the Printcraft workshop.

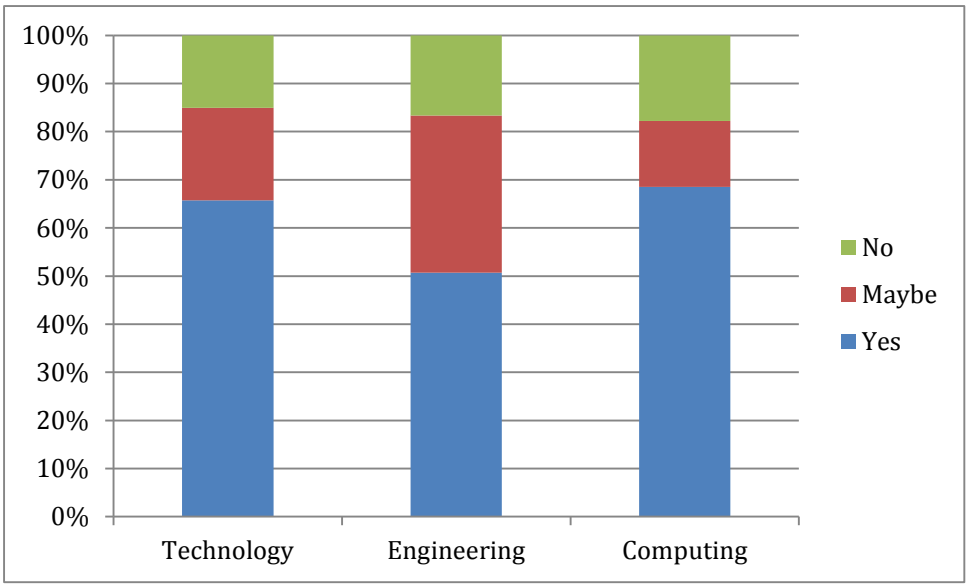


*Figure 1: Participant interest in Technology, Engineering and Computing after the workshop.*

**5. General Findings, Recommendations, Conclusions**

**5.1 Findings**

The Bootcamp was successful in its intentions: to give pupils an understanding of manufacturing (using 3D printers), prototype design with computer software (in this case, with Minecraft); and collaboration. This study demonstrates that the Printcraft Bootcamp is able to meet the Specific Learning Outcomes.

Printcraft is a good 'gateway' tool offering an approach to increasing understanding in computational thinking, Computer Aided Design and manufacturing in a way that is engaging and stimulating for pupils.

**5.2 Recommendations**

The popular low-cost Raspberry Pi computer designed for teaching and learning led to the release of a free edition of Minecraft Pi geared towards teaching programming to young people. This edition can be manipulated with Python at a level accessible to novice programmers. Although some coding was introduced in to some of the Printcraft Bootcamps using either Scriptcraft or Minecraft Pi, further research could specifically explore the benefits or otherwise of using the Minecraft environment to program. This study predominately explored Computer Aided Design and manufacturing.

Although computational thinking is inherent in the Printcraft Bootcamp - problem solving, moving from one environment to another involving various levels of abstraction – this was not identified as a specific learning outcome and therefore was not directly tested in this study. Further enquiry would include computational thinking as a learning outcome.

Printcraft bridges the disciplines of Computer Science and Design & Technology, especially in terms of understanding manufacturing concepts. Further enquiry could explore ways of linking aspects of the Programmes of Study of each discipline.

Minecraft's popularity as a gaming environment over a educational tool has encouraged participation in events such as the Technocamps Bootcamps. However, in order to identify whether Minecraft is a preferred environment in which to explore computational thinking, it should to be directly compared to other environments such as Scratch and Greenfoot which has been designed to be educational (but which have attracted fewer users). By being flexible and complex, Minecraft has inadvertently met challenges that were never intended by the creators, Redstone.

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*Appendix I: Printcraft Bootcamp Research Questionnaire*



# PRINTCRAFT Bootcamp Feedback Questionnaire

**i** **How old are you?**

**ii** **Are you male or female?**

○ Male ○ Female

**iii** **Where are you?**

i.e. are you doing Printcraft at a Technocamps Bootcamp or a Printcraft workshop?







Page 1

The purpose of this feedback session is to find out what you got out of using Printcraft and to help us understand the impact it has with young people such as yourselves. The information you provide may be used in reports and academic papers, but at no point will the information you provide be linked to you, and you will not be named in anything we publish.

This feedback session will take approximately 20 minutes, and the information you provide will really help us.

**1a What do you understand by the term CAD/CAM?**

- ○ Daytime/nighttime
- ○ A washing machine
- ○ Computer-aided design/ computer-aided manufacturing

**1b Who is Ada Lovelace?**

- ○ A crochet shawl
- ○ A computer programme
- ○ The world's first computer programmer

**2a What can 3D printers help build?**

- ○ Small one-off complex objects or parts
- ○ Films
- ○ Hand-made items

**3a Have you built something 3D in Minecraft and exported it to print on a 3D printer?**

- ○ Yes
- ○ No

**3b What methods did you use to communicate to your design team?**

- ○ In Minecraft only
- ○ In Minecraft, across the table and using sketches
- ○ In Minecraft and across the table

**4 Too much overhang on a 3D design can cause it to do what when printing in 3D?**

- ○ The edges to droop
- ○ The nozzle to get jammed
- ○ The layers to become multi-coloured

**5a What moves the build platform and print head?**

- ○ Controllers and motors
- ○ A nozzle
- ○ Molten plastic

| | |
|---|---|
| 5b | How is plastic filament forced through the extruder? |

○ Using a hammer ○ Using a heating element ○ Via a syringe

| | |
|---|---|
| 6 | Have you started looking online for things to do in relation to Printcraft or CAD/CAM? |

○ Yes ○ No

| | |
|---|---|
| 7 | Do you think you will use Printcraft again? |

○ Yes ○ No

| | |
|---|---|
| 8 | What would you have liked to see that wasn't covered? |

| | |
|---|---|
| 9 | Could the Bootcamp/workshop have been structured differently? |

| | |
|---|---|
| 10 | How do you think Printcraft might benefit other areas of your learning? |

| | |
|---|---|
| 11 | Now that you've done the Printcraft would you consider working in computing after you leave school? |

And, that's it! Thanks for participating in this session.

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*Appendix II: Technocamps Pre-Questionnaire*

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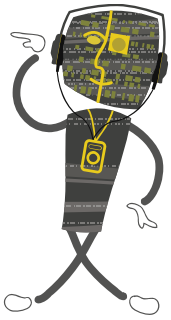
# Pre-day Questionnaire



**Participant ID:**

Q1 **How old are you?**

Q2 **Have you completed your...**

| | | |
|---|---|---|
| GCSEs | ☐ Yes | ☐ No |
| AS and A levels | ☐ Yes | ☐ No |

Q3 **Are you studying any courses outside of GCSEs & AS and A levels?**
If yes, what courses?

Q4 **Have you been to a Technocamps workshop before?** ☐ Yes ☐ No

Q5 **Have you been to a Technoclub before?** ☐ Yes ☐ No

Q6 **Would you like to learn more about computing?** ☐ Yes ☐ No
If not, why...?

Q7 **How interested are you in the following subjects?**

| | | | |
|---|---|---|---|
| Science | ☐ Very Interested | ☐ Interested | ☐ Not Interested |
| Technology | ☐ Very Interested | ☐ Interested | ☐ Not Interested |
| Engineering | ☐ Very Interested | ☐ Interested | ☐ Not Interested |
| Maths | ☐ Very Interested | ☐ Interested | ☐ Not Interested |

Q8 **Do you think computing is important to the following subjects at school?**

| | | | |
|---|---|---|---|
| Science | ☐ Yes | ☐ Maybe | ☐ No |
| Technology | ☐ Yes | ☐ Maybe | ☐ No |
| Engineering | ☐ Yes | ☐ Maybe | ☐ No |
| Maths | ☐ Yes | ☐ Maybe | ☐ No |

# Pre-day Questionnaire

Q9 **Do you think computing is important to any other subjects at school?**
If yes, which...?

Q10 **How do you use computers at school or college?**

Q11 **How do you use computers at home?**

Q12 **What jobs do you think you could do if you studied computer science?**

Q13 **Would you like to study or work in computing?**

☐ Yes ☐ Maybe ☐ No

Q14 **Why did you attend this Technocamps workshop?**

technocamps
Inspiring | Creative | Fun
Ysbrydoledig | Creadigol | Hwyl

*Appendix III: Technocamps Post-Questionnaire*

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# Post-day Questionnaire

**Participant ID:**

Q1 **What is the most exciting thing you learnt today?**

Q2 **Do you think computing is important to the following subjects at school?**

| | | | | | |
|---|---|---|---|---|---|
| Science | ☐ | Yes | ☐ | Maybe | ☐ No |
| Technology | ☐ | Yes | ☐ | Maybe | ☐ No |
| Engineering | ☐ | Yes | ☐ | Maybe | ☐ No |
| Maths | ☐ | Yes | ☐ | Maybe | ☐ No |

Other subjects...

Q3 **What do you think *computing* means...?**

Q4 **What jobs do you think you could do if you studied computer science?**

Q5 **Would you like to learn more about...**

| | | | | | |
|---|---|---|---|---|---|
| Science | ☐ | Yes | ☐ | Maybe | ☐ No |
| Technology | ☐ | Yes | ☐ | Maybe | ☐ No |
| Engineering | ☐ | Yes | ☐ | Maybe | ☐ No |
| Maths | ☐ | Yes | ☐ | Maybe | ☐ No |
| Computing | ☐ | Yes | ☐ | Maybe | ☐ No |

# Post-day Questionnaire

Q6 **How would you rate today?**

Bad ☐ Poor ☐ OK ☐ Good ☐ Great ☐

Q7 **Why did you give this rating...?**

Q8 **How would you rate the following...**

| | (Very Good) 5 | 4 | 3 | 2 | (Very Bad) 1 |
|---|---|---|---|---|---|
| Teaching | ☐ | ☐ | ☐ | ☐ | ☐ |
| Facilities | ☐ | ☐ | ☐ | ☐ | ☐ |
| Subject Content | ☐ | ☐ | ☐ | ☐ | ☐ |

Q9 **Would you attend a Technocamps workshop again?**

☐ Yes ☐ Maybe ☐ No

Q10 **Are you interested in joining a Technoclub?**

☐ Yes ☐ Maybe ☐ No

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Inspiring | Creative | Fun
Ysbrydoledig | Creadigol | Hwyl