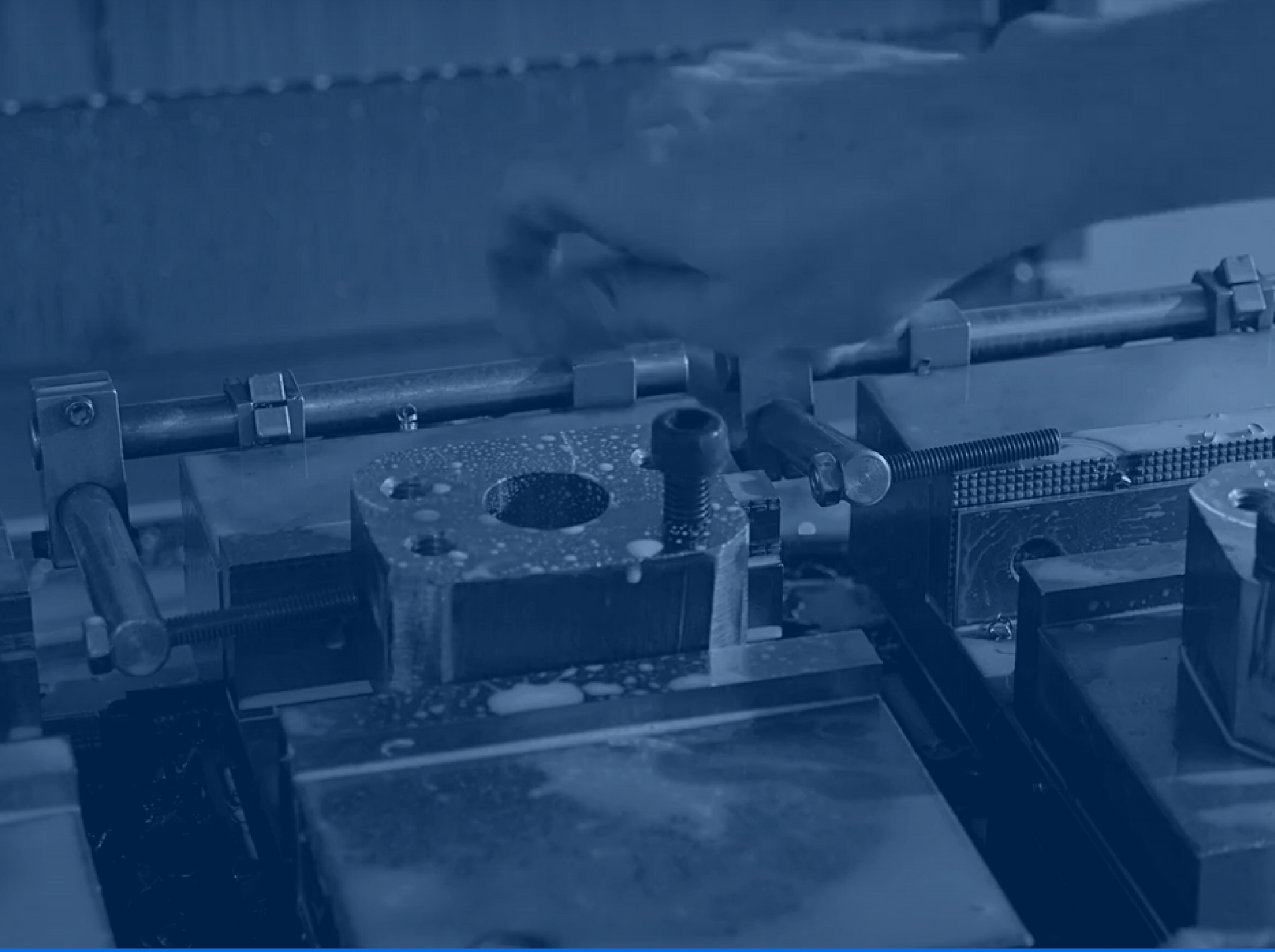

Teaching Advanced Manufacturing

Learn more:
bitlink.com.au

Acknowledgements

This workshop has been developed by Bitlink in collaboration with the Tasmanaian Minerals, Manufacturing and Energy Council.

TMEC

Tasmanian Minerals, Manufacturing & Energy Council

How to Use This Guide

This guide provides an overview of a workshop that Bitlink has developed to teach high-school students about the advanced manufacturing sector. The workshop has been designed to give students an understanding of how a part is designed, and then manufactured. It will teach them how to analyse the costs of production of a part and understand the importance of documentation to ensure that the part is reproducible through a manufacturing process.

This workshop has been designed to run in two halves. The first half covers an introduction to advanced manufacturing and a prototyping design activity. The second half focuses on documenting the prototype and a manufacturing simulation.

While we have presented this as two workshop sessions, it may suit your class to run this lesson as a longer-term project over multiple weeks. Suggestions for precursor and extension activities can be found in the next steps section.

Resources

To support this workshop, Bitlink has developed the following materials:

- Lesson slide deck
  - Slide deck includes embedded video profiles
- Student Handouts
  - Requirements Handout
  - Pricelist Handout
  - Bill of Materials Template
  - Manufacturing Instructions Template

The resources can be accessed at:
bitlink.com.au/advanced-manufacturing

Additional resources that you might find useful include:
- What is LEAN manufacturing (TWI Global)
- The 8 Wastes of Lean (Leanscape)

Curriculum Links

Investigating and defining
AC9TDI8P04 - Define and decompose real-world problems with design criteria and by creating user stories.

Generating and designing
AC9TDI8P07 - Design the user experience of a digital system.
AC9TDI8P08 - Generate, modify, communicate, and evaluate alternative designs

Evaluating
AC9TDI8P10 - Evaluate existing and student solutions against the design criteria, user stories, and possible future impact.

What is Advanced Manufacturing?

Manufacturing is an important industry sector that focuses on the production of goods. Manufacturing starts with a raw material and through a series of processes transforms it into a product or a part of a product. What we traditionally think of as manufacturing is a labour-intensive process, with a single part often needing to be processed multiple times, by multiple people in order to arrive at a finished part.

Advanced manufacturing represents a shift in manufacturing that involved more sophisticated techniques for designing, producing, and delivering products. Advanced manufacturing focuses on new technologies like robotics, automation, 3D printing, and data analytics to make the manufacturing process more efficient. This unlocks the ability to produce parts that can't be created by traditional manufacturing techniques, as well as enabling smaller manufacturing runs that may not have been economical before. It also promotes sustainability and efficient resource use, eliminating waste and improving manufacturing yield.

Why do we want to teach it in schools?

There are a number of reasons why we should be teaching students about the advanced manufacturing industry.

- **Jobs of the Future** - Advances in manufacturing are leading to new jobs being created that blend traditional manufacturing expertise with computer-aided design and operation. The skills involved in advanced manufacturing will be in demand in the future.
- **Digital skills and literacy** - The advanced manufacturing sector needs employees with digital literacy. Some roles require basic knowledge, whereas others will require more proficiency. Developing these skills will help students in future employment.
- **Sustainability and efficiency** - Advanced manufacturing is also about increasing efficiency, in terms of materials and resource utilization, but also in creating more efficient work practices. Being able to analyse processes and focus on efficiency are important skills for students to develop.
- **Real-world projects** - Focusing on real-world examples give students a great hook for engagement, giving them a creator understanding of how the skills they are learning can be applied.

Learning Intentions

We will be simulating the process of manufacturing to show students how important documentation is in the manufacturing process and how to analyse the costs of producing a part.

Success Criteria

You will be successful when:

- Students have completed a prototype and documented how to recreate it.
- Completed a manufacturing simulation based on the documentation.
- Analysed the costs of producing a part and investigated ways to make the process more efficient.

Safety First!

While running this workshop, we want to model the importance of safety in manufacturing. To do this, we ask students to complete a safety induction before using some pieces of equipment. Even though we trust that students of this age are responsible with sharp (scissors) and hot (glue gun) equipment, we ask them to complete a safety induction as this would be a requirement in industry. It also simulates the time taken for training in a workplace, which has time and cost implications for businesses.

The induction is only brief. We basically talk through the safety implications of the equipment (potential for cuts or burns, safe ways to handle them, how to store them safely). You might like to do these safety inductions yourself or assign one or more students as safety leaders who conduct training. You will need a way to keep track of who has been inducted into the use of which equipment and it is important to stress that everyone on a team who is using the equipment must complete an induction (ie. someone who has been inducted for scissor use should not hand a pair of scissors to someone who has not completed that training).

Additional Resources Required

To run this workshop, you will need access to crafting supplies for students to use when constructing their prototypes. Below is a list of suggested materials, however, you should feel free to use this only as a guide and you may substitute materials you have on hand. There are no right or wrong materials, the goal is to provide students with a number of options so that they can explore different solutions to meet the requirements. Please note if you make substitutions, it is a good idea to update the price list handout document. You should also feel free to adjust the pricing as you like.

Suggested materials:

- Paper
- Cardboard
- Sticky Tape
- String
- Blu Tack
- Glue sticks
- Paddle Pop Sticks
- Rubber Bands
- Lamination Pouch
- Staples

Suggested Equipment:

- Hole Punch
- Stapler
- Scissors
- Paper Cutter (Guillotine)
- Hot Glue Gun
- Ruler
- Laminator

Lesson Sequence (Workshop 1, Prototyping)

Preparation (15 Minutes)

- Lay out the crafting materials and equipment at the front of the room.
- Print all required handouts, or prepare access to digital versions of the documents.
  - Requirements Handout
  - Price List Handout
  - Bill of Materials Template

Introduction (15 Minutes)

- Introduce some of the concepts surrounding advanced manufacturing by using the video profile from Harbro Engineering **(Slide 4)**. Use the discussion questions **(Slide 5)** to ask students about what manufacturing is, how it has changed, and what some of the advantages of advanced manufacturing are.
- Discuss the concept of additive versus subtractive manufacturing **(Slides 6 - 11)**.
  - This has been foregrounded in the Harbro video
  - More information about these approaches can be found in the glossary at the end of this document.
- Explain the concept of LEAN manufacturing **(Slides 12 - 14)**.
  - More information about LEAN manufacturing can be found in the resources section of this document.

Prototype manufacturing (45 - 60 Minutes)

- Form Teams **(Slide 15)** - Ask students to form small groups of 2 - 3.
- Introduce the activity
  - Students will be asked to build a prototype for an enclosure for an electronic device used for measuring soil moisture. This device is based on the hardware from the Bitlink IoT kits. There is no requirement for students to create a working device. They do not need to program the micro:bit, however, if you have worked with the IoT kits before, then this can be done prior to this lesson as an extension activity **(Slides 16-18**)
  - Explain to students that they should focus on building a prototype that meets the requirements that have been outlined in the requirements document. Students should also focus on building a device that's cost-effective and easy to reproduce **(Slides 20 - 21).**
  - Explain to students that they will require a safety induction for particular pieces of equipment **(Slide 19)**
- Distribute the worksheets to students
  - The requirements handout document outlines what features and design considerations students should think about while designing their prototypes.
  - The pricelist handout gives them a handy reference for the cost of materials.
  - The Bill of Materials handout gives students a template for creating their own Bill of Materials and calculating the cost of their prototype.

Prototype manufacturing (continued)

- Start the prototyping phase
  - Start a timer and give students time to work on their prototypes.
  - Remind them to keep track of materials they have used and generate their bill of materials as they go.
  - Conduct safety inductions for students that require them while the rest of the prototyping is being conducted.

Reflection (5 - 15 Minutes)

- When the time is up, ask students to quickly show their prototypes to the class.
- Ask students to explain any design features and evaluate how well their prototype meets the design requirements **(Slides 22-23)**.
- Ask students to calculate their bill of materials to arrive at a cost for their prototype. Try to find the most expensive and inexpensive prototypes. Ask other students to evaluate whether the cost of these prototypes is reasonable and whether they meet the requirements.
- Store all prototypes for the next workshop session.

Prototype manufacturing (45 - 60 Minutes)

- Form Teams **(Slide 15)** - Ask students to form small groups of 2 - 3.
- Introduce the activity
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  - Explain to students that they will require a safety induction for particular pieces of equipment **(Slide 19)**
- Distribute the worksheets to students
  - The requirements handout document outlines what features and design considerations students should think about while designing their prototypes.
  - The pricelist handout gives them a handy reference for the cost of materials.
  - The Bill of Materials handout gives students a template for creating their own Bill of Materials and calculating the cost of their prototype.

Lesson Sequence (Workshop 2, Manufacturing)

Preparation (15 Minutes)

- Lay out the crafting materials and equipment at the front of the room.
- Print all required handouts, or prepare access to digital versions of the documents.
  - Manufacturing Instructions Template

Recap (5 Minutes)

- Watch the Maltec Engineering video to quickly recap advanced manufacturing **(Slide 25)**.

Documentation (30 Minutes)

- Discuss with students the importance of a Bill of Materials, which they generated in the previous workshop. A Bill of materials is like the ingredients of a recipe. (Slides 26-29)
- Discuss the importance of clear instructions. Other students will be asked to recreate the prototype based on their instructions.
- Ask students to document their prototypes **(Slides 30-31)**
  - Distribute the Manfacturing Instructions Template.
  - They should focus on instructions that are clear and easy to follow.
  - They should think about the most efficient order to construct the prototype.
  - Ask students to analyse their Bill of Materials for efficiencies as they go - are there any materials that can be reduced, or replaced with cheaper alternatives without compromising the design requirements.

Manufacturing (30 Minutes)

- Students will now give their instructions to another group **(Slide 22)**.
- Working from the instructions, students will try to manufacture 2 copies of the device based on the instructions provided **(Slides 33 - 34)**.
  - The original prototypes should be put away so that they are not referred to.
  - Students should focus on following the instructions as provided, but they should be making notes about how to improve the instructions to provide constructive feedback to the original group.
  - You should conduct new safety inductions for all students, even if they received the respective induction in the previous workshop - this is to add a time constraint.

Reflection (10 - 15 Minutes)

- When the time is up, ask students to quickly show their reproductions to the class.
- Ask students to reflect on how easy it was to build the reproductions **(Slide 36)**.
    - Compare the prototypes to the reproductions - how similar are they?
    - Reflect on the quality of the instructions provide - how useful where they? What feedback could they give other groups to improve their instructions?
    - Discuss any feedback on the design - would teams change anything to make manufacturing easier?
- Ask students to reflect on the prototyping and manufacturing process **(Slide 37)**.
    - What materials or equipment were the most efficient?
    - What were some of the common mistakes that groups made?
    - What opportunities are there for more efficiency in the process?

Next Steps and Extension

We have designed this activity to be able to run in approximately half a day, but there are lots of opportunities to extend this activity beyond the workshops we've described. Below are a few ideas on how this could be extended.

More Iteration

The initial prototyping activity will arrive at an initial prototype for an enclosure design. More time can be spent iterating on this design and moving towards a more polished prototype. We would recommend getting students to score their designs against the original requirements and look to address anything they might have missed. They can also do another iteration to try to improve efficiency either in production time or materials used.

Mass manufacturing exercise

We simulate manufacturing by building a few reproductions of the original prototype. To extend this activity, you could have the students choose a prototype for mass production. You can then get them to organise the classroom into a production line, with different stations set up for different processes and stages of production. You can have them create a work order, or documentation to track the journey of a piece of material through the production chain. Then they can reflect on how they could use LEAN manufacturing principles to increase the efficiency of their production process.

Formulas in Excel
Rather than doing the maths themselves, your students can learn how to use formulas in Excel to create a Bill of Materials (BOM) template that is responsive to changes. They can then use this to experiment with different approaches to building a prototype enclosure and rapidly determining how those changes would impact their total cost of materials. Incorporating this idea is as simple as providing a printed BOM example and then asking students to create their own smart digital version in Excel and teaching them some basic formulas and Excel formatting techniques.

Programming the device
While there is no requirement for the device to function, the soil moisture sensor is based on a Bitlink project that is available on our website. If you want students to learn how to program the device to create a working soil moisture sensor, look at Lesson 3.1, Soil Moisture Sensor.

This lesson culminates in students creating their own soil moisture sensor. Our resources presume you have a basic understanding of the micro:bit and attaching sensors. At a minimum, it would be valuable to have completed our first module (Meet Micro:bit), and Lesson 2.2, which introduces the use of sensors, prior to tackling Lesson 3.1.

Computer-aided design and 3D printing

This activity is designed to be ‘unplugged’, and can be completed without students needing to use a computer. A good follow-up activity to this workshop will be to move it to a computer-aided process. Students can create a 3D model of their enclosure for 3D printing, focusing on the same requirements as before. The printed parts can be compared to the paper prototypes and the efficiencies of both processes can be discussed.

Risk Assessment

The workshop features safety inductions to highlight the importance of safety in the workshop. This activity can be expanded to get students to consider the risks present, even with relatively safe items such as scissors. Students can create a risk matrix and look at mitigation strategies to improve safety.

Glossary of terms

Subtractive manufacturing - a term that covers a range of traditional manufacturing processes that start with a large piece of material and machine away the areas that are unwanted ie: CNC milling and lathing.

Additive manufacturing - a term for new production processes that start with nothing and add material to create a finished part ie: 3D printing and casting.

Industry 4.0 - a term that refers to the so-called fourth revolution of industrial production. This refers to the growing use of new manufacturing techniques and the growth of automation, including data-driven analysis of manufacturing processes.

Lean manufacturing - This term refers to the process of making production more efficient by optimising not just the use of materials, but also the skills of workers, and transportation and reducing the number of processes required to complete a part.

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