Stage 5 – Industrial Technology Engineering – Under pressure

## Summary

In this unit students will develop a fundamental understanding of engineers' work and the underlying scientific principles and practices that form the foundation of engineering. Students will take on the role of the engineer and apply theoretical engineering principles learned throughout this unit to prototype, test, and then build a water tower within a set of applied constraints.

## Duration

10 weeks – 2.5 hours/week

## Outcomes

* **IND5-1** identifies, assesses, applies and manages the risks and WHS issues associated with the use of a range of tools, equipment, materials, processes and technologies
* **IND5-2** applies design principles in the modification, development and production of projects
* **IND5-6** identifies and participates in collaborative work practices in the learning environment
* **IND5-7** applies and transfers skills, processes and materials to a variety of contexts and projects
* **IND5-8** evaluates products in terms of functional, economic, aesthetic and environmental qualities and quality of construction

## Unit overview

Students are to work in pairs to design and construct a water tower out of hoop pine that is prepared and cut to 4 x 4mm. The water tower must stand a minimum of 300mm high and weigh no more than 50g. To be successful the tower must hold a minimum of 50kg (1000x its weight). Students will need to apply their knowledge of forces and structures gained through theory components in this unit. Once towers are complete they will be tested until failure and filmed in slow motion to document and analyse the failure of the tower.

Students are required to keep a log of their construction timeline, as well as any successes and failures they faced whilst constructing their prototype and final build, and use this information to prepare an engineering report on the tower addressing aspects such as its design, successes/failures, ultimate hold weight at failure, where/why it failed and an evaluation of the overall project.

Students must also research a landmark structure of their choosing and report on its construction and the challenges that engineers faced at the time as well as how they were able to overcome these challenges to complete the project.

## Resources overview

The resources and links listed below are referenced within the program but is not an exhaustive list of resources available. Teachers can add to these resources as needed.

###  Physical resources

* Workshop access (for building or testing tower)
* Occasional computer room access
* Electronic balance (to weigh tower and ensure it is under 50g)
* General measuring and marking equipment (rules, squares, pencils etc.)
* Tenon saws
* Disc sander
* Hot glue guns and sticks
* PVA glue (for joining methods test)
* 15mm nails (for joining methods test)
* Paddle pop sticks
* Thumb tacks
* Fettucine or spaghetti
* Hoop pine (prepared 4mm x 4mm)
* Force gauge (for testing fettucine under load, small measured weights could also be used)
* 100kg (or more) of calibrated weights (to test final tower design)

### Websites

* SI derived units [physics.nist.gov/cuu/Units/units.html](https://physics.nist.gov/cuu/Units/units.html)
* 2D Truss Simulator [jfmatrix.com/Analysis](http://www.jfmatrix.com/Analysis)
* SafeWork safety signs in the workshop (poster) [safework.sa.gov.au/resources/free-resources](https://www.safework.sa.gov.au/resources/free-resources)
* SafeWork Australia first aid in workshops [safework.sa.gov.au/workers/health-and-wellbeing/first-aid](https://www.safework.sa.gov.au/workers/health-and-wellbeing/first-aid)
* SafeWork NSW safe work method statement (templates) [safework.sa.gov.au/industry/construction/safe-work-method-statements](https://www.safework.sa.gov.au/industry/construction/safe-work-method-statements)
* Sample SOPs [worksafe.tas.gov.au/safety/advisors/sample\_safe\_work\_procedures](https://www.worksafe.tas.gov.au/safety/advisors/sample_safe_work_procedures)
* The difference between JSA and SWMS [safetyaction.com.au/blog/quick-tip-the-difference-between-a-jsa-and-swms](https://www.safetyaction.com.au/blog/quick-tip-the-difference-between-a-jsa-and-swms)
* Basic PPE [safetyculture.com/topics/ppe-safety](https://safetyculture.com/topics/ppe-safety/)
* NSW WHS legislation (PPE) [legislation.nsw.gov.au/#/view/regulation/2017/404/chap3/part3.2/div5](https://www.legislation.nsw.gov.au/#/view/regulation/2017/404/chap3/part3.2/div5)
* Common engineering terminology [.strucalc.com/the-most-used-engineering-terminology-defined](http://www.strucalc.com/the-most-used-engineering-terminology-defined/)
* Burj Khalifa Design and Construction [burjkhalifa.ae/en/the-tower/design-construction](https://www.burjkhalifa.ae/en/the-tower/design-construction/)
* Structures [burjkhalifa.ae/en/the-tower/structures](https://www.burjkhalifa.ae/en/the-tower/structures/)
* Composite materials [science.org.au/curious/technology-future/composite-materials](https://www.science.org.au/curious/technology-future/composite-materials)

**YouTube:**

* [Genetic engineering will change everything forever – CRISPR](https://www.youtube.com/watch?v=jAhjPd4uNFY&t=3s) – duration 16:03
* [The Burj Khalifa: how to build higher?](https://www.youtube.com/watch?v=niVguabIhTs) – duration 7:37
* [Heat treatment: the science of forging](https://www.youtube.com/watch?v=6jQ4y0LK1kY&t=35s) – duration 11:22
* [What is prestressed concrete?](https://youtu.be/P13Mau2VUWw) – direction 8:46

[Industrial Technology 7-10 Syllabus](https://educationstandards.nsw.edu.au/wps/portal/nesa/k-10/learning-areas/technologies/industrial-technology-2019) © NSW Education Standards Authority (NESA) for and on behalf of the Crown in right of the State of New South Wales, 2019

|  |  |  |  |
| --- | --- | --- | --- |
| **Content** | **Teaching and learning** | **Evidence of learning** | **Adjustments and registration** |
| **Week 1**investigate a range of career paths in the engineering industry | **Teacher:*** Introduces the course and outlines the content covered in 'under pressure' and the aligned assessment activities.

**Students:*** Brainstorm in small groups the processes that a civil/structural engineer would go through if they were to design a water tower at full scale.
* Using civil/structural engineers as the example consider the role engineers play in the design and production of structural projects.
* Complete page 8 in student workbook.

**Teacher and students:*** Discuss the work of engineers in general, looking at the potential careers and career pathways available.
* Discuss engineers work as part of a dynamic team due to projects requiring experienced engineers from multiple disciplines of expertise to work alongside one another cohesively.
 | * Students articulate the roles and responsibilities of the professional engineer.
* Students identify various fields that engineers specialise in and the unique skills and knowledge required for each.
* Students demonstrate understanding of why structures need to be engineered.
 |  |
| explore ethical, social and legal issues that apply to engineered solutions | **Teacher:*** Leads discussion regarding the importance of ethics in the engineering industry.
* Shows [Genetic engineering will change everything forever – CRISPR](https://www.youtube.com/watch?v=jAhjPd4uNFY&t=3s) – duration 16:03.

**Students:*** Complete page 9 & 10 in student workbook.

**Teacher and students:*** Discuss ethical, social and legal issues that apply to the construction of new engineered structures and demolition of old engineered structures (for example ethical considerations for the building of new structures could include ensuring that the building is energy efficient and is made from recyclable material, considerations for demolishing old structures could include ethical waste disposal and management of noise pollution and so on.)
* Watch "genetic engineering will change everything forever - CRISPR", as CRISPR is a very current and emerging technology there is heavy debate in the medical and engineering communities around what is ethically acceptable or unethical in relation to genetic engineering, discuss this with students.
 | * Students articulate the importance of ethics in the engineering industry.
* Students actively participate in discussion regarding ethics in engineering.
 |  |
| **Week 2**investigate the reasons for engineered structuresexplore the elements and design of structures | **Teacher:*** Draw links between bridge truss and frame design and the design of students' water tower.
* Use student identified structures to introduce the components of trusses and their role within the truss (for example truss members, pin joints, rollers joints etc.)

**Students:*** Explore the range of engineered structures and their application or importance in society
* Identify structures within their local area such as bridges, water towers, electrical transmission towers etc.
* Investigate the rigidity of triangles in truss and frame design (to demonstrate this create a pin jointed triangle and a pin jointed quadrilateral out of timber and demonstrate how the quadrilateral is not completely rigid.)
* Complete pages 11, 12 & 13 in student workbook.

**Optional extension activity:**Investigate I beams and their application in structures.[Why are I beams shaped like an I?](https://www.youtube.com/watch?v=zSz0kV0BPDY) – duration 3:46 | * Students articulate the impact of engineered structures on peoples’ lives.
* Students identify elements of why engineered structures are designed the way they are.
* Students justify the use of triangles in trusses and frames through completion of the practical activity on page 13.
 |  |
| select correct International System of Units (SI) and Australian Standards for designidentify fundamental quantities, derived quantities and their units | **Teacher:*** Explains the use of SI units as the standard units in the engineering (and all scientific) industries.

**Students:*** Explore the seven base SI units (metre (m) for distance/displacement, kilogram (kg) for mass, second (s) for time, ampere (A) for electrical current, Kelvin (K) for temperature, candela (cd) for luminous intensity, mole (mol) for amount of substance.)
* Analyse how all other metric units can be derived from the base SI units (for example, a force measured in Newtons (N) is equal to mass (kg) x acceleration (m/s2), therefore a force is derived from three of the base SI units.)
* Calculate the average density of the timber and utilise this information to estimate how much material should be able to be used in the construction of the water towers so that the tower does not exceed 50g.
* Complete pages 14-16 in student workbook.

**Resources:*** [SI derived units](https://physics.nist.gov/cuu/Units/units.html)

**Optional adjustments:**If students display difficulty in analysing unfamiliar SI derived units, have them identify common SI derived units such as the 'speed' (velocity) in a car, even if identified as km/hr.**Optional adjustments:**If students display difficult in calculating the average density of timber and manipulating that information to gain the total amount of useable material, instead have them weight a piece of material cut to the correct dimensions (4 x 4mm at any length) and divide the length by the weight (in grams) then multiply by 50g to get an estimate of the total useable length. | * Students identify the SI units and can articulate why they are used due to the accuracy in which they can be measured.
* Students successfully calculate the density of hoop pine and manipulate that information to estimate how many linear metres of material can be used in their design.
 |  |
| **Week 3**identify the forces that act on structuresexplore the effects of forces on structures | **Students:*** Identify the different types of loads that act on structures (for example, static loads - weight of a building; dynamic loads - environmental forces(rain, wind, earthquake); uniform distributed loads.)
* Explore how forces affect structures and investigate how engineers can use calculations to find the net force that an object is experiencing (for example objects in equilibrium use Σmoments = 0 to calculate the effort required to balance a lever effected by perpendicular moments, use Σforces = 0 to calculate reaction forces of simple concurrent force systems, calculate resultants of basic concurrent force systems.)
* Complete a stress test on fettucine testing it under various types of loads (for example, tension, compression, shear, torsion and so on.) until failure and utilise this information to aid in the design of their water tower (experiment with joined pieces of pasta and pieces of different length etc.)
* Complete pages 17-22 in student workbook.

**Optional extension:**Investigate the Tacoma narrows bridge collapse due to uncalculated wind[Tacoma Narrows Bridge collapse](https://www.youtube.com/watch?v=j-zczJXSxnw) – duration 5:56 | * Students identify the types of loads that engineers need to consider when designing structures.
* Students articulate how truss members behave when subjected to various types of loads.
* Students articulate the effect of moment creating forces as they move farther away from the point they are creating a moment about.
 |  |
| **Week 4**demonstrate safe workshop practices and proceduresrecognise and comply with WHS signage | **Teacher:*** Explains what workshop safety is, and how it is to be applied during the completion of practical projects including the use of powered tools and machinery.

**Students:*** Complete general workshop safety test as well as a tool/machine specific test for each piece of equipment they are going to use in the production of the project (for example, hand tools, hot glue gun, disc sander.)
* Investigate the colour and shapes associated with safety signs and discuss the importance of safety signs in a workshop.
 | * Students demonstrate safe work practices at all times whilst working in workshop environment.
* Students comply with applicable workplace signage.
* Students successfully complete workshop safety test.
 |  |
| explore design construction sequencing and collaborative processesdesign and construct simple structures for specific purposesconduct experiments, produce prototypes and practical projects using appropriate tools, equipment, machinery | **Students:*** Divide into teams of two or three and allocate themselves roles within the design group.
* Have their design approved and begin to measure, mark and cut material for prototyping.
* Work in their teams to begin construction of their prototype water tower design using fettucine joined with hot glue.
* Complete pages 23-26 in student workbook.
 | * Students contribute to team discussion about design of the water tower structure.
* Students apply basic principles of engineering to the design of their engineered structure.
 |  |
| **Week 5**safely use and maintain hand, power and machine toolsuse and adjust a wide range of hand tools in the production of practical projectsselect and use personal protective equipment (PPE) when working with tools, materials and machinesapply measuring standards and methods | **Teacher:*** Demonstrates the safe use and maintenance of all equipment related to the project (tri-square, vice, bench hook, tenon saw, hot glue gun, disc sander and bench chisel.)
* Demonstration on how to accurately measure and cut pasta and timber for the construction of the tower.

**Students:*** Identify PPE and identify link to appropriate tools, materials and equipment.
* Demonstrate safe use to teacher on first use of the equipment to prove they are safe and competent with the equipment.
* Complete their pasta prototype and test it under load to failure.
* After testing their prototype students can record any observations and use slow motion filming to analyse the failure of their prototype tower whilst it was subject to loading and utilise this information to make changes to their original design before constructing their tower from timber.

**Teacher and students:*** Discuss PPE and which PPE is appropriate for specific tools, materials and equipment that will be used during the construction of the project.
* Discussion and demonstration about how to achieve project goals with tools and resources available (teacher constrained tools and equipment to limit those which students have access to.)
* Discuss the success or failure of the prototype towers and consider what changes will need to be made by the designs in order to improve their success for the final design.

**Resources:*** [Basic PPE](https://safetyculture.com/topics/ppe-safety/)
* [NSW WHS Legislation PPE](https://www.legislation.nsw.gov.au/#/view/regulation/2017/404/chap3/part3.2/div5)
 | * Students demonstrate safe use of tools and equipment whilst producing their engineered structure.
* Students select and use appropriate PPE whilst working on their engineered structure.
* Students accurately measure and prepare materials for their structure, and the structure closely resembles their design.
 |  |
| describe elementary first aid proceduresapply the principles of risk management | **Teacher:*** Identifies the location of first aid kits in the workshop, the first aid supplies available within kits and how to use supplies.

**Students:*** Complete a safe work method statement related to the production of the project (students to identify risks associated with particular tasks and demonstrate understanding of how to manage risk.)
* Students complete workshop risk assessment and hazard analysis worksheet.

**Teacher and students:*** Discuss basic first aid appropriate for the workshop (for example, how to clean and dress minor cuts and abrasions, how to treat first degree burns.)
* Discuss risk management and hazard analysis, and its importance in the workshop environment.
* Discuss the purpose of safety documents in industry and in the workshop such as SOP, SWMS and JSA.
 | * Students identify the location and contents of the first aid kit.
* Students treat minor injuries appropriately using the principles of first aid.
* Students identify hazards in the workshop and apply appropriate risk management techniques.
 |  |
| **Week 6**produce freehand sketches of project components and/or projects | **Teacher:*** Demonstration of basic technical drawing techniques appropriate for designing a single side of the water tower.

**Students:*** Use freehand sketching/basic technical drawing to design their structure, keeping in mind that the tower can only weigh 50g.
* Use calculation of the average density of the timber and their technical drawing to estimate final weight of the tower.
* Once students have created a design they can use an online 2D truss simulator to find areas within the truss that will experience the most load, and modify their design accordingly.
* Complete pages 27 & 28 in student workbook.
* Design one side of the water tower and then replicate this three or four times during construction depending on whether they want their tower to have a triangular or square base (advantage of the triangular base is that you can dedicate more material to withstanding weight force, and the advantage of the square base is that it is more balanced.)

**Resources:*** [2D Truss Simulator](http://www.jfmatrix.com/Analysis)
 | * Students accurately produce a scale drawing of their intended structure.
* Students reproduce their structure in an online truss simulator and use the data from the simulator to inform decisions regarding their final design.
 |  |
| **Week 6**produce freehand sketches of project components and/or projects | **Teacher:*** Demonstration of basic technical drawing techniques appropriate for designing a single side of the water tower.

**Students:*** Use freehand sketching/basic technical drawing to design their structure, keeping in mind that the tower can only weigh 50g.
* Use calculation of the average density of the timber and their technical drawing to estimate final weight of the tower.
* Once students have created a design they can use an online 2D truss simulator to find areas within the truss that will experience the most load, and modify their design accordingly.
* Complete pages 27 & 28 in student workbook.
* Design one side of the water tower and then replicate this three or four times during construction depending on whether they want their tower to have a triangular or square base (advantage of the triangular base is that you can dedicate more material to withstanding weight force, and the advantage of the square base is that it is more balanced.)

**Resources:*** [2D Truss Simulator](http://www.jfmatrix.com/Analysis)
 | * Students accurately produce a scale drawing of their intended structure.
* Students reproduce their structure in an online truss simulator and use the data from the simulator to inform decisions regarding their final design.
 |  |
| **Week 7 - 8**develop and produce practical projects allowing for the characteristics and properties of materials, systems, components, tools and equipment available (ACTDEK046)construct engineering projects | **Students:*** Work in their teams to begin construction of their final design.
* Apply the knowledge they have gained from constructing their prototypes to consider how timber behaves in tension and compression.
* Manage their project within applied constraints by teacher (for example, tower must be 300mm tall and weigh less than 50g.)
 | * Students work collaboratively to produce their structure.
* Students’ final structure conforms to tolerances and constraints.
 |  |
| apply project management techniques and follow a planned sequence through to project completionevaluate the impact of design and work practices/processes on the quality of finished projects | **Teacher:*** Reinforces the criteria for success that students need to design and produce a water tower that can support a load of at least 1000 x its own weight.

**Students:*** Document the process undertaken to design and construct their prototype and final designs in a record of production that they maintain alongside the manufacture of their tower.
* Report on their observations and once again use slow motion filming to analyse the failure of their tower, to see whether the design changes they implemented had an effect whilst the tower was under load.
* Analyse how the material/design ultimately failed, and evaluate if the design could have been improved further.
 | * Students complete their structure, it conforms to constraints and is able to be tested.
* Students articulate which processes worked well and which did not and what would they change if they were to produce the project again.
 |  |
| **Week 9**evaluate work practices and practical projects in terms of qualityprepare engineering reports to describe the management and processes undertaken in the production of practical project | **Students:*** Evaluate their final design in regards to its ultimate weight held before failure, the means by which it failed and possible improvements in design
* Use their record of production, including a timeline of production and successes/challenges that they faced, observations from their prototype and final observations after loading their timber tower, to prepare an engineering report that addresses aspects such as design, successes/failures, ultimate hold weight at failure, where/why it failed and an evaluation of the overall project
 | * Students investigate their tower after testing and try to diagnose why it failed.
* Students evaluate tower in terms of its performance and articulate what worked well and what could be improved.
 |  |
| select and use specialist terminology in context | **Students:*** Use specialist terminology related to the engineering industry and engineered structures (e.g. the nature of forces such as tension, compression, linear, concurrent and types of structures such as truss, cantilever, suspension.)
* Students complete glossary of terms in student workbook as they progress through the unit of work.

**Resources:*** [Common engineering terminology](http://www.strucalc.com/the-most-used-engineering-terminology-defined/)
 | * Students use engineering terminology appropriately throughout the completion of the project.
 |  |
| **Week 10**investigate innovative design solutions appropriate to engineered structures | **Students:*** Investigate the Burj Khalifa and the developments in engineering throughout the history of sky scrapers that inevitably lead to its creation (safety elevators, steel frames, air conditioning, cast in place walls using kangaroo cranes, bessemer process for example.)
* Research and add to their report information regarding a landmark structure of their choosing, addressing the construction and the challenges that engineers faced at the time, as well as how they were able to overcome these challenges to complete the project.

**Resources:*** Burj Khalifa websites below:
	+ [Design and Construction](https://www.burjkhalifa.ae/en/the-tower/design-construction/)
	+ [Structures](https://www.burjkhalifa.ae/en/the-tower/structures/)
	+ [The Burj Khalifa: how to build higher?](https://www.youtube.com/watch?v=niVguabIhTs) – duration 7:37
 | * Students describe engineering innovations that needed to be used in order to build the Burj Khalifa.
* Students articulate the unique challenges that engineers face when working on projects at this scale.
 |  |

## Evaluation

Evaluation of learning activities should be an ongoing process that happens throughout the delivery of this unit. Teachers should document their evaluation of learning activities throughout the program. The space provided below is to evaluate the overall unit of work.