Engineering subject report

2023 cohort

February 2024

Queensland Government

QCAA
Queensland Curriculum & Assessment Authority

240042

For all Queensland schools

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Introduction

Throughout 2023, schools and the Queensland Curriculum and Assessment Authority (QCAA) continued to improve outcomes for students in the Queensland Certificate of Education (QCE) system. These efforts were consolidated by the cumulative experience in teaching, learning and assessment of the current General and General (Extension) senior syllabuses, and school engagement in QCAA endorsement and confirmation processes and external assessment marking. The current evaluation of the QCE system will further enhance understanding of the summative assessment cycle and will inform future QCAA subject reports.

The annual subject reports seek to identify strengths and opportunities for improvement of internal and external assessment processes for all Queensland schools. The 2023 subject report is the culmination of the partnership between schools and the QCAA. It addresses school-based assessment design and judgments, and student responses to external assessment for this subject. In acknowledging effective practices and areas for refinement, it offers schools timely and evidence-based guidance to further develop student learning and assessment experiences for 2024.

The report also includes information about:

- how schools have applied syllabus objectives in the design and marking of internal assessments
- how syllabus objectives have been applied in the marking of external assessments
- patterns of student achievement.

The report promotes continuous improvement by:

- identifying effective practices in the design and marking of valid, accessible and reliable assessments
- recommending where and how to enhance the design and marking of valid, accessible and reliable assessment instruments
- providing examples that demonstrate best practice.

Schools are encouraged to reflect on the effective practices identified for each assessment, consider the recommendations to strengthen assessment design and explore the authentic student work samples provided.

Audience and use

This report should be read by school leaders, subject leaders and teachers to:

- inform teaching and learning and assessment preparation
- assist in assessment design practice
- assist in making assessment decisions
- help prepare students for internal and external assessment.

The report is publicly available to promote transparency and accountability. Students, parents, community members and other education stakeholders can use it to learn about the assessment practices and outcomes for senior subjects.

Report preparation

The report includes analyses of data and other information from endorsement, confirmation and external assessment processes. It also includes advice from the chief confirmer, chief endorser and chief marker, developed in consultation with and support from QCAA subject matter experts.

Subject highlights

102
schools offered Engineering

82.71%
of students completed 4 units

93.77%
of students received a C or higher

Subject data summary

Subject completion

The following data includes students who completed the General subject.

Note: All data is correct as of January 2024. Where percentages are provided, these are rounded to two decimal places and, therefore, may not add up to 100%.

Number of schools that offered Engineering: 102.

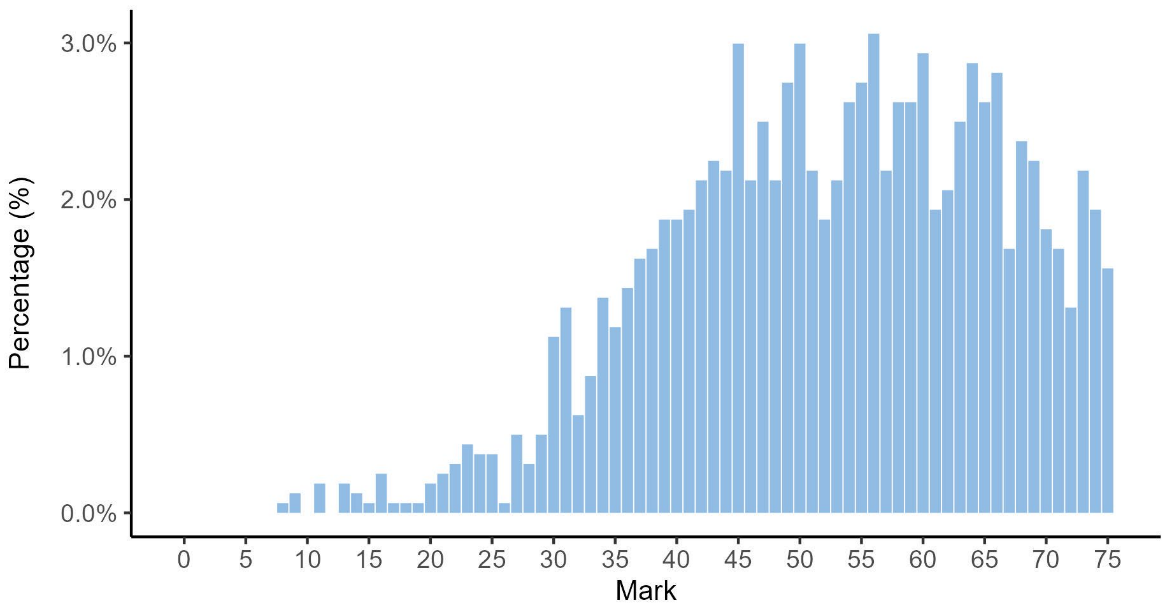
Completion of units	Unit 1	Unit 2	Units 3 and 4
Number of students completed	1,920	1,765	1,588

Units 1 and 2 results

Number of students	Satisfactory	Unsatisfactory
Unit 1	1,711	209
Unit 2	1,626	139

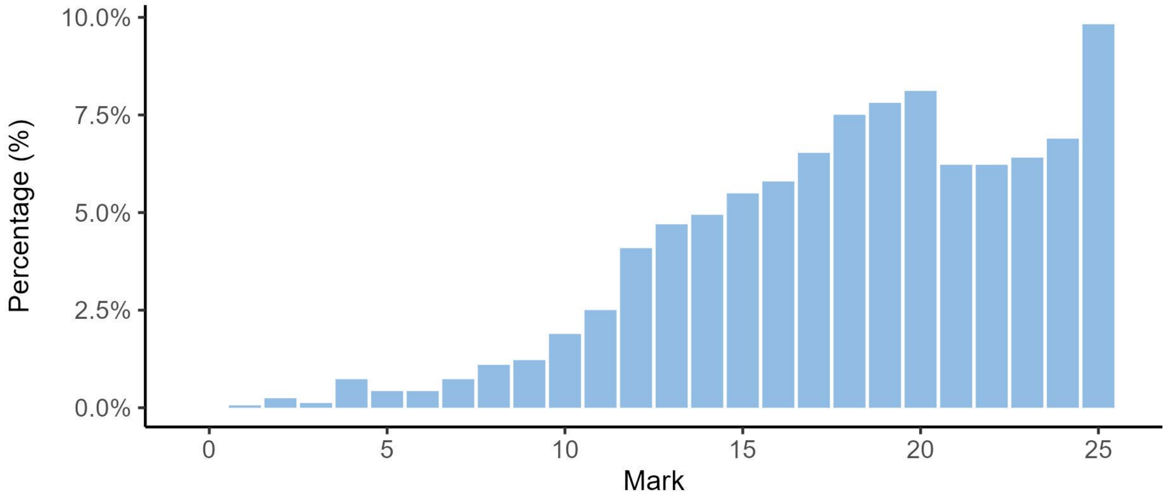
Units 3 and 4 internal assessment (IA) results

Total marks for IA

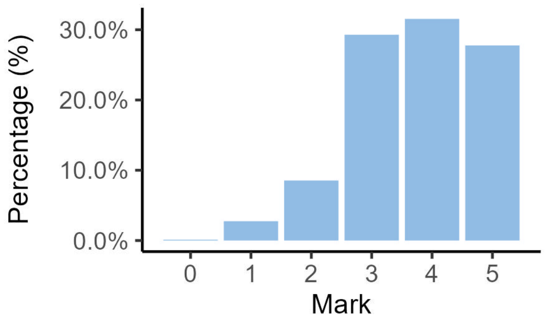


IA1 marks

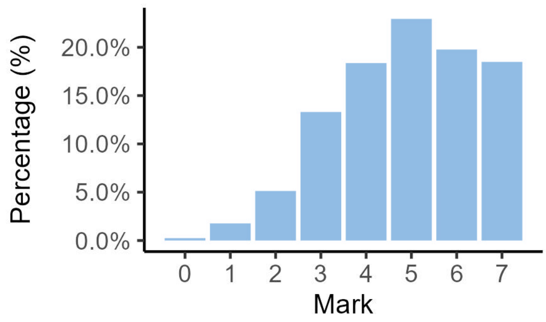
IA1 total



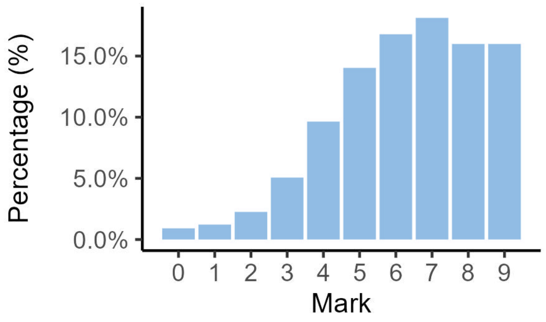
IA1 Criterion: Retrieving and comprehending



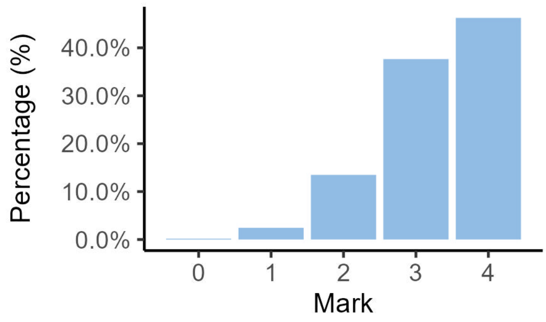
IA1 Criterion: Analysing



IA1 Criterion: Synthesising and evaluating

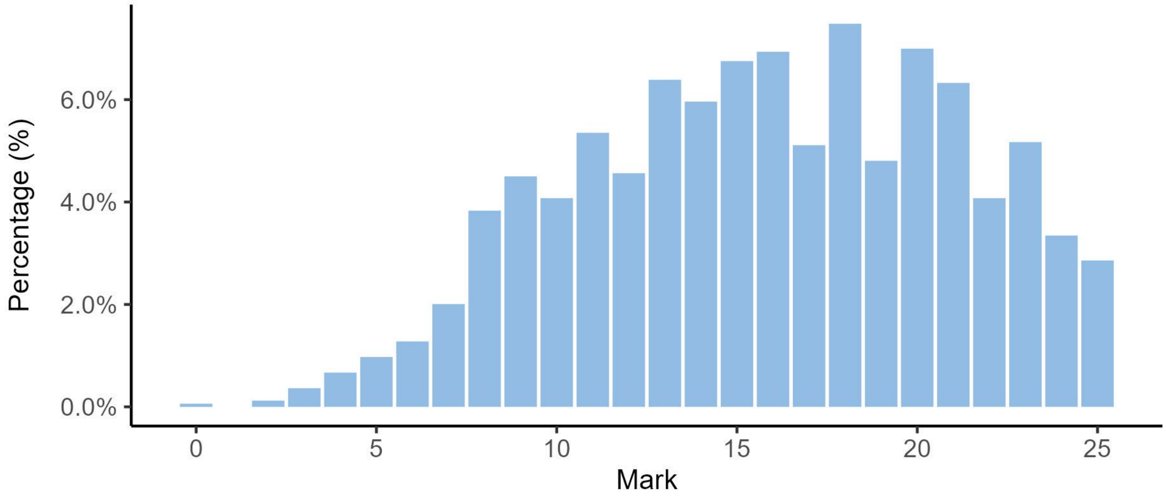


IA1 Criterion: Communicating

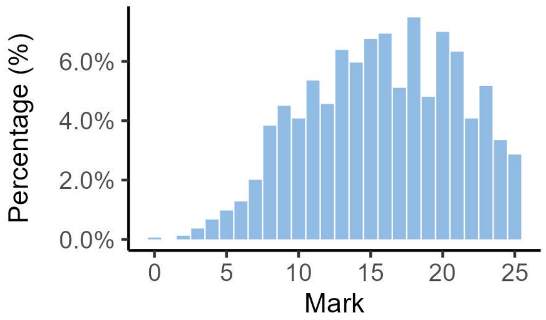


IA2 marks

IA2 total

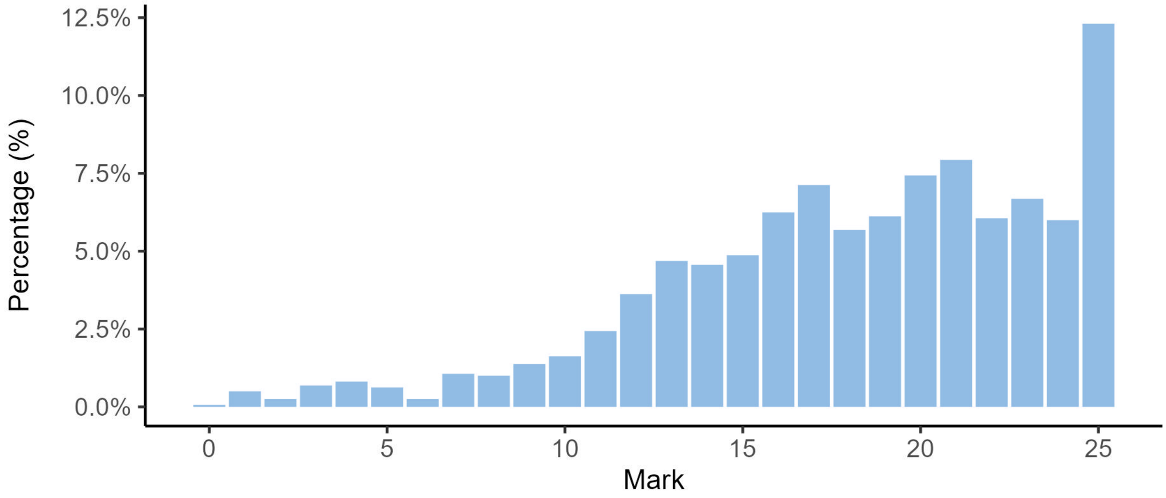


IA2 Criterion: Engineering knowledge and problem-solving

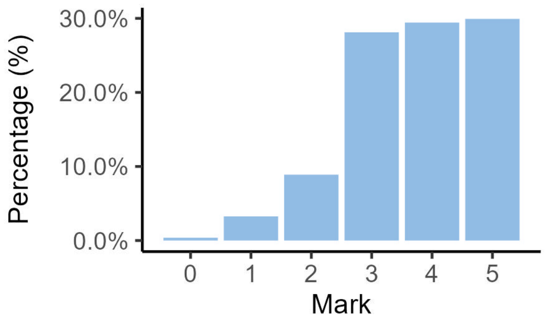


IA3 marks

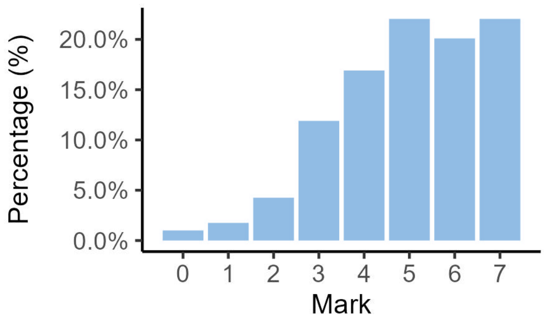
IA3 total



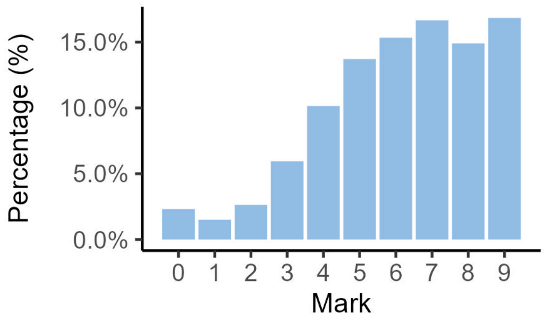
IA3 Criterion: Retrieving and comprehending



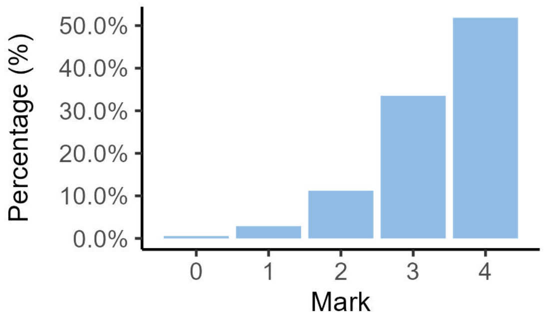
IA3 Criterion: Analysing



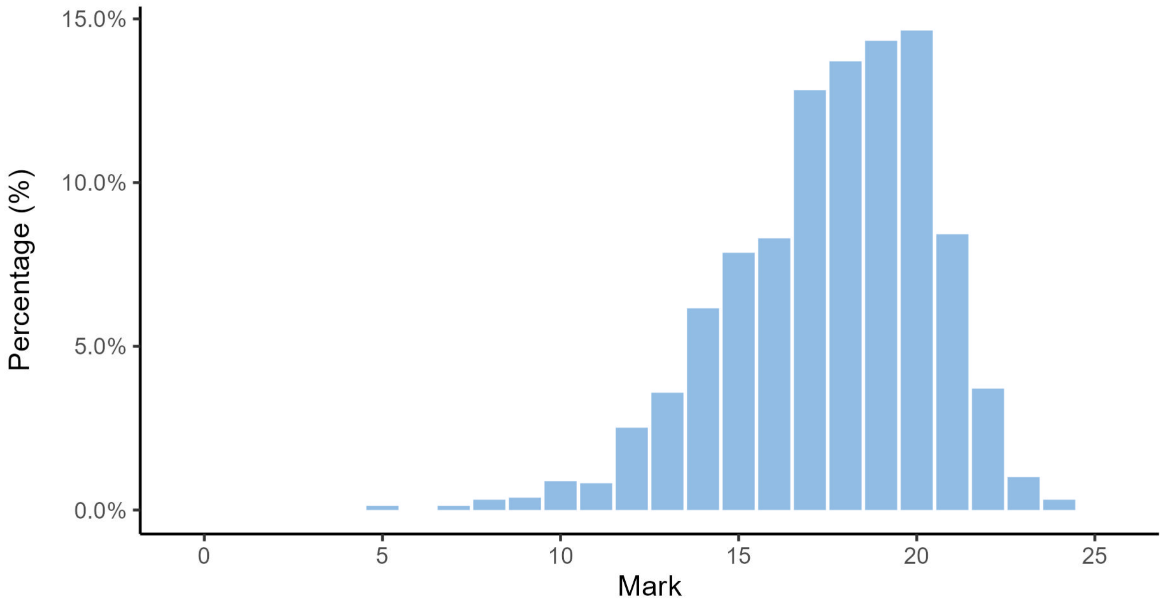
IA3 Criterion: Synthesising and evaluating



IA3 Criterion: Communicating

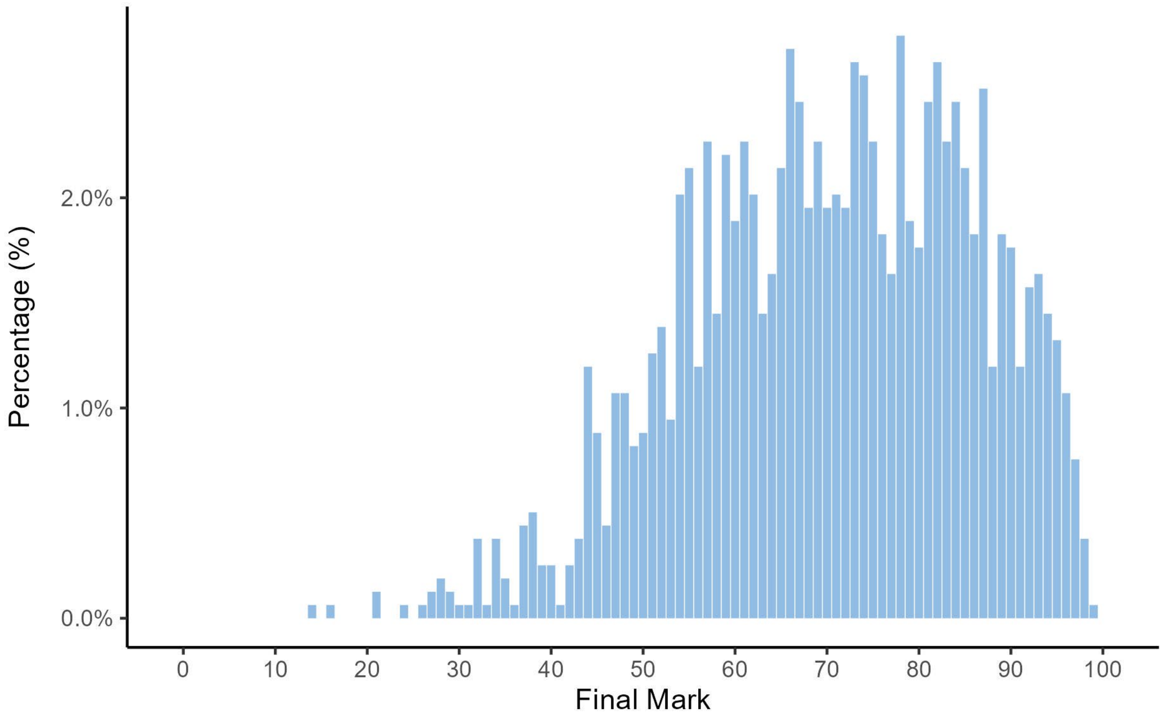


External assessment (EA) marks



Final subject results

Final marks for IA and EA



Grade boundaries

The grade boundaries are determined using a process to compare results on a numeric scale to the reporting standards.

Standard	A	B	C	D	E
Marks achieved	100–83	82–68	67–46	45–19	18–0

Distribution of standards

The number of students who achieved each standard across the state is as follows.

Standard	A	B	C	D	E
Number of students	404	518	567	97	2

Internal assessment

The following information and advice relate to the assessment design and assessment decisions for each IA in Units 3 and 4. These instruments have undergone quality assurance processes informed by the attributes of quality assessment (validity, accessibility and reliability).

Endorsement

Endorsement is the quality assurance process based on the attributes of validity and accessibility. These attributes are categorised further as priorities for assessment, and each priority can be further broken down into assessment practices.

Data presented in the Assessment design section identifies the reasons why IA instruments were not endorsed at Application 1, by the priority for assessments. An IA may have been identified more than once for a priority for assessment, e.g. it may have demonstrated a misalignment to both the subject matter and the assessment objective/s.

Refer to *QCE and QCIA policy and procedures handbook v5.0*, Section 9.6.

Percentage of instruments endorsed in Application 1

Number of instruments submitted	IA1	IA2	IA3
Total number of instruments	102	102	101
Percentage endorsed in Application 1	56%	14%	69%

Confirmation

Confirmation is the quality assurance process based on the attribute of reliability. The QCAA uses provisional criterion marks determined by teachers to identify the samples of student responses that schools are required to submit for confirmation.

Confirmation samples are representative of the school's decisions about the quality of student work in relation to the instrument-specific marking guide (ISMG), and are used to make decisions about the cohort's results.

Refer to *QCE and QCIA policy and procedures handbook v5.0*, Section 9.7.

The following table includes the percentage agreement between the provisional marks and confirmed marks by assessment instrument. The Assessment decisions section of this report for each assessment instrument identifies the agreement trends between provisional and confirmed marks by criterion.

Number of samples reviewed and percentage agreement

IA	Number of schools	Number of samples requested	Number of additional samples requested	Percentage agreement with provisional marks
1	101	677	112	57.43%
2	101	525	0	96.04%
3	101	672	7	77.23%

Internal assessment 1 (IA1)

Project — folio (25%)

This assessment focuses on a problem-solving process that requires the application of a range of cognitive, technical and creative skills and theoretical understandings. The response is a coherent work that documents the iterative process undertaken to develop a solution to a problem. It may include written paragraphs and annotations, diagrams, sketches, drawings, photographs, tables, spreadsheets and prototypes.

This assessment occurs over an extended and defined period of time. Students may use class time and their own time to develop a response.

Assessment design

Validity

Validity in assessment design considers the extent to which an assessment item accurately measures what it is intended to measure and that the evidence of student learning collected from an assessment can be legitimately used for the purpose specified in the syllabus.

Reasons for non-endorsement by priority of assessment

Validity priority	Number of times priority was identified in decisions*
Alignment	16
Authentication	2
Authenticity	3
Item construction	13
Scope and scale	17

*Each priority might contain up to four assessment practices.

Total number of submissions: 102.

Effective practices

Validity priorities were effectively demonstrated in assessment instruments that:

- provided clear instructions about how the authenticity of individual student responses would be checked with appropriate authentication strategies identified and suitable checkpoints established
- included a considered, detailed and authentic real-world context that provided students with the opportunity to develop a unique response demonstrating their understanding of Unit 3 subject matter in relation to
  - engineering technology knowledge, e.g. instruments that included a context with geographic location specifications and relevant detail, allowing students to consider the
    - impacts of the local environment on their material selection for their solution
    - life cycle analysis of materials mitigating or limiting the environmental and sustainability impacts of the solution, such as corrosion, habitat loss and erosion

  - the development of a truss structure, e.g. instruments that explicitly stated that students were to develop a solution that is a truss structure.

Practices to strengthen

It is recommended that assessment instruments:

- are constructed using a scaffolding section that
  - describes the folio and referencing conventions that must be used in the response for headings, the table of contents, reference list and in-text referencing (Syllabus section 4.6.1)
  - may include the Engineering problem-solving process diagram (this is not a mandatory requirement)
  - avoids over-scaffolding and referring to working as a team to ensure students are able to provide a unique response
- align to the assessment specifications, e.g. include *all* the assessable elements listed in the syllabus from Part A and Part B (Syllabus section 4.6.1) unchanged
- include an appropriate scale when physical prototypes are to be produced to provide students the opportunity to generate a prototype that can be used to
  - obtain data through testing
  - evaluate aspects of the truss solution to the real-world problem within the assessment conditions, including evaluating the size of the physical prototype and the load expectations (if these are specified in the task) and recommending an appropriate scale.

Accessibility

Accessibility in assessment design ensures that no student or group of students is disadvantaged in their capacity to access an assessment.

Reasons for non-endorsement by priority of assessment

Accessibility priority	Number of times priority was identified in decisions*
Bias avoidance	4
Language	5
Layout	0
Transparency	2

*Each priority might contain up to four assessment practices.

Total number of submissions: 102.

Effective practices

Accessibility priorities were effectively demonstrated in assessment instruments that:

- included relevant layout features, such as bold, italics, underlining and other formatting features, e.g. to draw student attention to important information
- included transparency of information by providing clear instructions to students, with cues aligned to information shared before administering the assessment, e.g. the assessment objectives, specifications and ISMG (Syllabus section 4.6.1).

Practices to strengthen

It is recommended that assessment instruments:

- avoid bias and inappropriate content, e.g. placing students in professional roles beyond their capabilities. The task should allow students to demonstrate their knowledge of Unit 3 subject matter in developing a solution to a real-world context without the pretence of being an engineer, e.g. students should not be referred to as engineers or as working for an engineering firm
- avoid the use of jargon or inappropriate language. The task should use the Engineering syllabus language when referring to problem-solving, solutions and solution development. Instruments are required to use terms such as ‘develop’, ‘ideas’ and ‘engineered solutions’ rather than ‘design’, ‘designs’ or ‘design concepts’ etc. The task should not use design-related concepts and principles as these are not included in syllabus subject matter and are not defined in the Engineering syllabus.

Assessment decisions

Reliability

Reliability is a judgment about the measurements of assessment. It refers to the extent to which the results of assessments are consistent, replicable and free from error.

Agreement trends between provisional and confirmed marks

Criterion number	Criterion name	Percentage agreement with provisional	Percentage less than provisional	Percentage greater than provisional	Percentage both less and greater than provisional
1	Retrieving and comprehending	84.16%	12.87%	1.98%	0.99%
2	Analysing	62.38%	34.65%	1.98%	0.99%
3	Synthesising and evaluating	71.29%	26.73%	0.99%	0.99%
4	Communicating	92.08%	6.93%	0.99%	0%

Effective practices

Accuracy and consistency of the application of the ISMG for this IA was most effective when:

- for the Retrieving and comprehending criterion upper performance levels
  - to explain ideas and a solution
    - sketches and drawings demonstrated proficient use of basic drawing and dimensioning conventions
    - annotations demonstrated thoughtful and astute choices about the additional information required and were related to the structural problem
  - information was selected for its value or relevance to the structural problem in relation to engineering technology, materials science and mechanics, and extended beyond the context information that was provided in the instrument

- for the Communicating criterion upper performance levels
  - visual features (e.g. PMI charts, sketches, drawings, diagrams, graphs, tables, schemas or spreadsheets) were selected for their value or relevance and used to provide an articulate and thoughtful presentation of information
  - a reference list and a recognised system of in-text referencing was applied.

Samples of effective practices

The following excerpts have been included to provide examples of the Retrieving and comprehending criterion at the 4–5 performance level.

Excerpt 1 provides an accurate account of the materials, mechanics and engineering technology concepts with information selected for its value or relevance in relation to the problem. It demonstrates evidence of thoughtful and astute choices when distinguishing between the identification of the known and unknown characteristics of the problem, the assumptions made, and the boundaries defined. The use of annotated sketches effectively demonstrates how the characteristics are related to the problem.

Excerpt 2 demonstrates proficiency with engineering drawing and includes valuable and relevant annotations that follow drawing conventions and display intellectual perception when providing additional information about the prototype solution.

Excerpt 1

INTRODUCTION

Brisbane City Council has requested for an upgrade to train stations across Brisbane as part of the new Cross River Rail project. This folio aims at designing a truss bridge design in order to accommodate pedestrians and users of Dutton Park train station. This folio will research, test, develop and evaluate various truss bridge designs that suit the guidelines given by Brisbane City Council.

KNOWNS

- The structure of choice from city planners is a two- span truss bridge. (only one span needs to be designed and replicated).
- The required dimensions of the bridge are 18m length x 3m width. (One span)
- The deck at the bottom of the bridge must have a height clearance of at least 5.5m from the ground.
- Bridge must be mounted on concrete pads of width 0.5m at the ends of the structure.
- The bridge must have a factor of safety of between 2 and 3.
- The materials used for the truss structure and deck need to be included in the solution.
- The section type and dimensions are to be included in the solution based on commercially available stock.
- The pedestrian load of 4kPa is present as per AS1170.
- The structure must account for a roof/canopy for the bridge which needs to be set at a minimum height of 2.5m.
- The structure must be designed for Brisbane's wind conditions in region B with wind speeds of 180km/h.
- The structure must have a life span of 50 years and must have low maintenance requirements.
- The maximum mass of the bridge is to be limited to 26t.
- A virtual model of the structure needs to be designed and tested using the Performance Index (PI).

UNKNOWNS

- The best factor of safety for the truss structure between 2 and 3
- The lateral loads applied on the truss structure as a result of 180km/h winds.
- The vertical loads applied on the structure as a result of pedestrians, the deck and the roof.
- The type of truss structure that would appropriately suit the given problem.
- The most appropriate materials that would be suitable for the truss structure, the deck, and the roof/canopy.
- The type of section that will be sufficient to handle the loads applied on the structure.
- The most suitable height and angle of internal members of the truss.

ASSUMPTIONS

- Assuming that the lateral loads and vertical loads are all distributed evenly among the structure.
- Assuming that the wind load is only applied on either one side of the bridge at any given time and is directly perpendicular.
- Assuming that the materials used for the bridge must be environmentally friendly and sustainability.
- Assuming that the loads from the roof and deck are approximately 8000N.(only for testing)
- Assuming that the area of the deck is 18m x 3m= $54m^2$.

BOUNDARIES

- The total cost of building the structure will not be taken into account in this folio.
- The design of entry/exit ramps, stairs and lifts to the bridge will not be considered in this solution.
- The details of the deck on the bridge will not be considered in this solution and only the material of the deck will be explored.

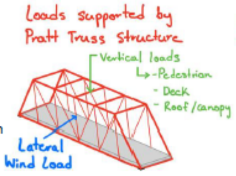
MATERIAL SELECTION CRITERIA

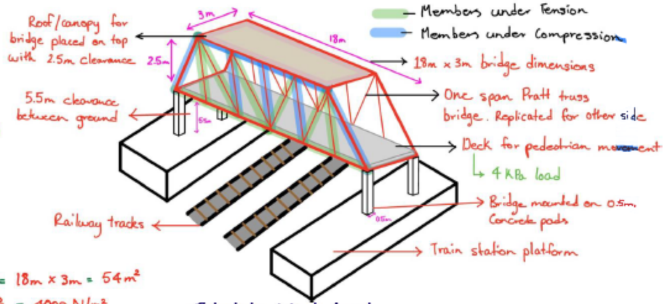
The materials required for the truss structure, roof and deck have to be efficient and appropriate to the conditions of the problem in order to reach an effective solution. The materials used for the solution must abide by the following criteria:

- High tensile and compressive strength in order to withstand the horizontal and vertical loads applied by the pedestrians, roof and deck.
- Durable and corrosion resistant as it is placed outdoors and exposed to all weather conditions.
- Sustainable and reusable in order to reduce environmental impact.
- Needs to have low maintenance requirements and a 50-year life span as it is frequently used by public.

***NOTE: One span bridge will be designed and replicated for other side**

SKETCH OF KNOWNS





Calculate Vertical Loads

* Assumed area of deck = 18m x 3m = $54 m^2$
* Pedestrian load = 4 kPa = 4000 N/m^2

$\therefore$ Force exerted by Pedestrians =

$$\text{Stress} = \frac{\text{Force}}{\text{Area}}$$

$$\therefore \text{Force} = 4000 \times 54 = 216\,000 \text{ N}$$

* Assumed load of Deck + Roof = 8000 N

$\therefore$ Total Vertical load = Pedestrians + Deck + Roof

$$= 216000 + 8000$$
$$= 224000 \text{ N}$$

$\therefore$ Total vertical load = $\boxed{224000 \text{ N}}$

Calculate Wind Load

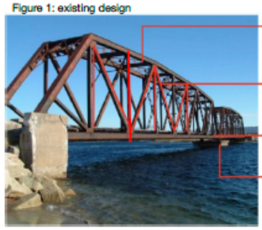
* Average air density in Brisbane = 1.2 Km/m^3
* Area of bridge where wind is loaded ≈ 12 m^2
* Acceleration of wind = 180 Km/h = 50 m/s

Force exerted by wind:

$$F = \text{density} \times (\text{wind speed})^2 \times \text{Area}$$
$$F = 1.2 \times (50)^2 \times 12$$
$$F = 36000 \text{ N}$$

$\therefore$ Total horizontal Force needed to Support = $\boxed{36000 \text{ N}}$

Figure 1: existing design



Truss made from stainless Steel → oxidised due to low maintenance

Warren truss structure with vertical supports

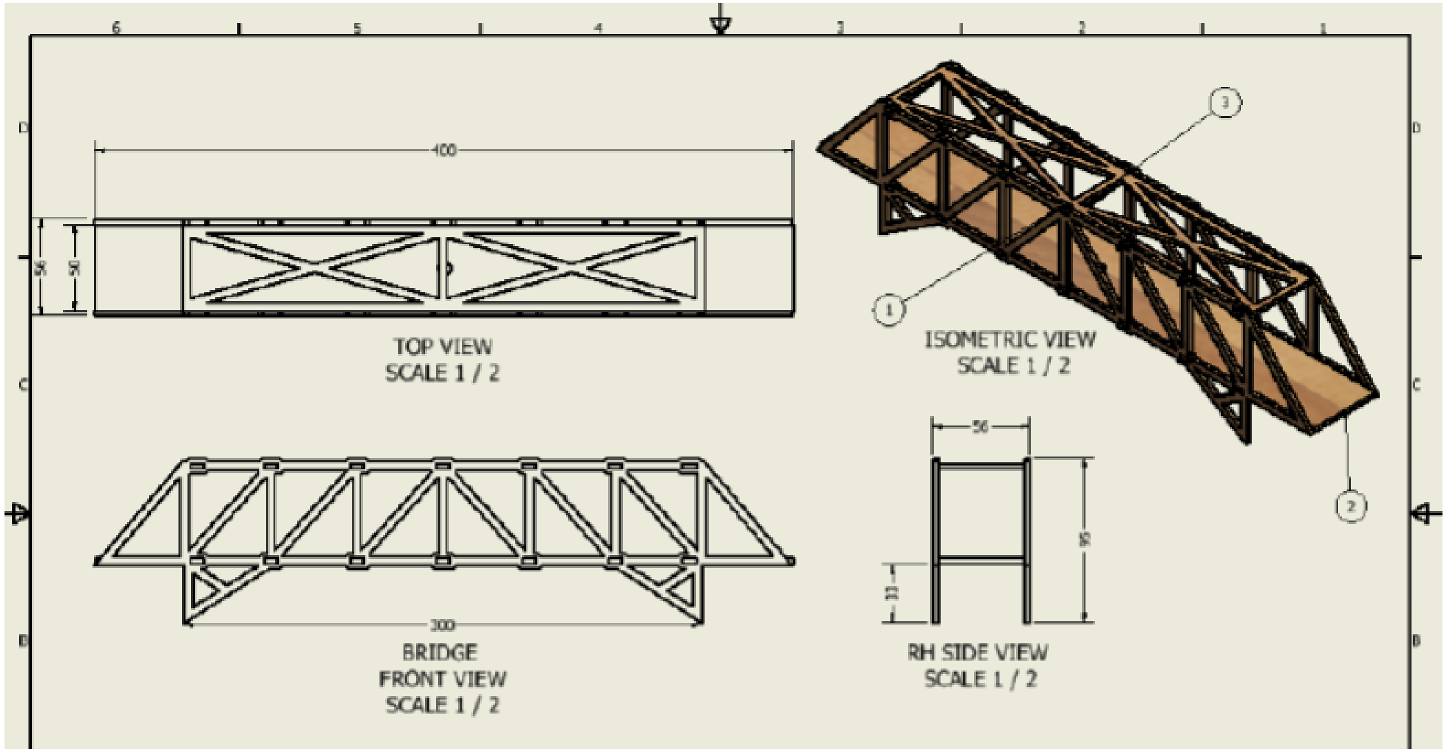
Two-Span truss bridge

Edge of truss mounted on concrete pads

***NOTE:** This wind load and vertical load is specifically for this truss design only. These values will be used for testing. However, the loads of the final solution would be different to these values and will be calculated when the final solution is designed, and the section sizes and type of roof, wall and floor are determined.

Fig 1 Bridge photo source: Garner, Morgan (2015) 'Analyzing a Simple Truss by the Method of Joints', Instructables, www.instructables.com/Analyzing-a-Simple-Truss-by-the-Method-of-Joints

Excerpt 2



The following excerpts have been included to provide examples of the Communicating criterion at the 3–4 performance level.

Excerpt 1 demonstrates articulate use of in-text referencing conventions.

Excerpt 2 provides evidence of articulate use of folio conventions. The contents page shows the folio structure used to demonstrate that good judgment. Thoughtful and astute choices have been made in selecting the most relevant headings and subheadings to organise and communicate the iterative phases of the problem-solving process used to respond to the structural problem. This structure is also sufficiently different from the QCAA sample response.

Note: The characteristic/s identified may not be the only time the characteristic/s has occurred throughout a response.

Excerpt 1

	Task name	Week 5	Week 6	Week 7	Week 8	Week 1	Week 2	Week 3	Week 4
Explore the Problem	Find knowns, unknowns, assumptions, constraints, environmental considerations and preliminary research								
	Clarify unknowns								
	Create success criteria								
Analyse	Analyse existing solutions								
	Analyse sketches of potential solutions								
Generate a solution	Sketch final solution								
	Calculations and simulations								
	Orthographic presentation								
Evaluation	Assess performance								
	Propose refinements and recommendations								
	Compare to other designs								
	Summary Report								

Clarifying Unknowns:

Size and Shape of the Tank:

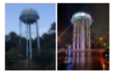
Water tanks are often cylindrical because they remove the weak points rectangular tanks would observe in the seams (W.C.A.M.E., 2021). The optimal volume of a cylinder is maximised when the diameter is equal to the height.

$$volume = \frac{\pi d^2}{4} \times h$$
$$assuming: d = h \text{ and } 1000L\ water = 1m^3$$
$$v = \frac{\pi d^3}{4}$$
$$d = \sqrt[3]{\frac{4v}{\pi}}$$
$$= \sqrt[3]{\frac{4(55)}{\pi}}$$
$$\approx 4.12m$$

To allow for expansion of the water in raised temperatures, 4.12 was rounded up.

$$\therefore d = 4.2m$$

Width of the support tower (Wikipedia, 2022):



Preliminary research suggests that the support tower's base can be exactly the diameter of the water tank. With a 4.2m diameter cylindrical water tank, the support tower would have a square base of 4.2m x 4.2m.

Wind speed:

Wind speeds can reach 52m/s at Thursday Island during a 1 in 100 years event (SkyCiv Engineering, 2021).

Density of the Air On Thursday Island:

The temperature of Thursday Island varies minimally throughout the year, with an annual average of approximately 30°C (Weatherzone, 2022). At 30°C, the average air density is 1.164kg/m^3 (Engineering ToolBox, 2003).

Coefficient of Drag on the Tank:

Assuming wind acts from one direction horizontally, the cylindrical water tank has a coefficient of drag of 1 (Heddleson, 1957).

Materials used in Tank Construction and its Density:

Polyethylene Plastic

- Lightweight
- Produced as one piece
- Recycled plastic cannot be used to construct the tank because of potable water regulations
- Difficult to recycle as the degraded plastic can only be repurposed into a limited selection of products, so the polyethylene tanks are often thrown into landfill
- Non-corrosive
- Reliably stores up to 50 000L of water
- Must be UV stabilised to prevent damage from sun exposure
- Can melt and buckle under extreme heat (e.g. fire)

Stainless Steel

- Often pre-fabricated and constructed onsite
- Typically has a longer life span
- Reliably stores up to 250,000L of water
- Can be coated to protect it from environmental conditions (e.g. water, sea spray)
- Requires a liner to ensure the water is potable for the hospital
- Very strong and will not bulge or warp when filled
- Fire-resistant
- Once reaching the end of the tank's life span, the steel alloys can be melted down again and recycled

Thus, a stainless steel water tank was selected. It's density was recognised as 7850kg/m^3 (Spira, 2021). However, stainless steel is expensive. Stainless steel truss towers are extremely uncommon.

Truss Material:

An economic option for the truss structure's material is galvanised steel. In a marine environment, galvanised steel adds a protective layer over standard mild steel. This protects the structure from reacting with the saltwater to produce rust. However, this layer can corrode or fade over time. Thus, surface protection is still recommended, but galvanised steel should be used for the main truss component of the structure.

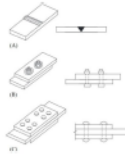
Surface Protection for Steel:

The steel solution must endure coastal environmental conditions, entailing sea salt spray and constant contact with water. A lining inside of the water tank would also ensure the potability of water for the hospital's usage by preventing rusting of the stainless steel. A possible surface protectant is an epoxy coating, specifically intended for drinking water tanks. As a water and sea spray resistant material, epoxy is often used for stainless steel tanks (杨耀辉, 2014; Darya Tamin, 2021). Epoxy can also be applied onto the galvanised steel truss.

Joining Method of the Members:

Welding (Norther Weldarc Ltd., 2018; Lowry, 2021)

- Connections have low-stress concentrations as the members are not penetrated
- Requires advanced and large equipment that is difficult to transport and use in a rural environment
- Would require the truss to be transported as a whole after being assembled in a factory
- High temperatures threaten the surrounding environment if performed onsite



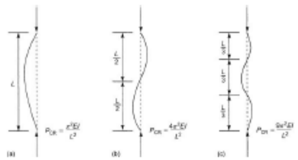
Bolting (Norther Weldarc Ltd., 2018; Lowry, 2021)

- Easy to transport and install onsite as the prefabricated parts only require a handheld torque wrench for onsite assembly
- Assembling the truss would be a controlled operation with minimal risks to the environment
- Any unexpected issues are quicker and cheaper to repair than welding
- The bolts are subject to corrosion, and should be prepared with an appropriate protectant coating prior to installation

Thus, bolting was chosen as the most appropriate joining method. Gusset plates are also to be installed at the joints to promote an even transfer of stress and increase the strength of the joint (Designing Buildings Ltd., 2021).

Tension and Compression Forces That 3 x 3 mm Balsa Can Withstand:

Slender members do not reach the material yield strength in compression due to the slenderness ratio (Nazir, Arshad, & Jeng, 2019). The maximum load of Figure b is four times greater than the magnitude of the critical load of Figure a (Megson, 2019).



Tensile forces were assumed negligible in the simulation process, as members under compression were significantly more susceptible to failure through buckling.

As balsa is an organic material, each member can vary significantly in strength due inconsistent growths. To ensure the safety of the solution, the minimum test value was selected as the maximum force that a balsa member of that length could withstand.

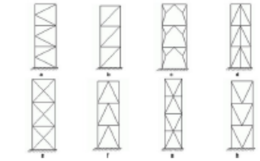
Length	Test 1 (g)	Test 2 (g)	Test 3 (g)	Test 4 (g)	Test 5 (g)	Test 6 (g)	Test 7 (g)	Test	
150 mm	2395	2090	2300	2890	2890				
125 mm	5000	3200	5000+	3600	2900	4100	4400	3700	2700
112.5 mm	3700	3750	5000+	5000+	4700	5000+			
90 mm	5000+	5000+	5000+	4700	5000+	5000+			
The highlighted values were the minimums. These were used in the design process.									

Each mass was converted to a force for the corresponding lengths of balsa. These were halved to consider the factor of safety of two.

Real Length	Prototype Length	Mass Withstood	Force Withstood	Force With FOS of 2
3m	150mm	2090g	20.48N	10.24N
2.5m	125mm	2700g	26.46N	13.23N
2.25m	112.5mm	3700g	36.26N	18.13N
1.8m	90mm	4700g	46.06N	23.03N

Type of Truss for the Support Tower (Graitec, 2022):

Vertical truss towers are constructed with a variety of solutions. This image depicts some common truss solutions, with K, X and Z shaped bracings frequently observed.



Drag Force on the Tank:

$$CSA = l^2 = 4.2^2 = 17.64m^2$$

$$tank's\ surface\ area = wall + top + base = \pi dh + \frac{\pi d^2}{4} \times 2 = \pi \times 4.2^2 + \frac{\pi \times 4.2^2}{4} \times 2 \approx 83.13N$$

$$volume\ of\ tank = thickness \times surface\ area = 0.002 \times 83.13 = 0.17m^3$$

$$mass\ of\ tank = volume \times density = 0.17 \times 7850 = 1305.14kg$$

$$Real\ F_d = 0.5\rho \times v^2 \times C_d \times A = 0.5 \times 1.164 \times 52^2 \times 1 \times 17.64 = 27760N$$

$$F_d = \frac{Real\ F_d}{20^3} = \frac{27760}{20^3} = 3.47N$$

$$\frac{F_d}{2} = \frac{3.47}{2} = 1.74N$$

$$Real\ F_s = F_{tank\ weight} + F_{water\ weight} = 9.8(1305.14 + 55000) = 551790.37N$$

$$F_s = \frac{551790.37}{20^3} = 68.97N$$

$$\frac{F_s}{4} = \frac{68.79}{4} = 17.24N$$

The tank endured a drag force of 27,760N horizontally from one direction. Scaled, the prototype with endure one horizontal force of 1.74N at the centre of the tank.

The weight of the stainless steel tank and the 55,000L of water is a force of 551,790N acting downwards on the support tower. Scaled, the prototype experiences a force of 69N on each of the top nodes.

Excerpt 2

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Practices to strengthen

To further ensure accuracy and consistency of the application of the ISMG for this IA, it is recommended that:

- when matching evidence to the descriptors in the Analysing criterion, attention should be given to
  - understanding the relationships that exist between the characteristics of the structural problem and the relevant information about materials science, engineering mechanics and

engineering technology that is developed through research and testing, e.g. physical or virtual testing of a truss to analyse the relationship between the properties of the identified material and the mechanics of the structure in relation to the problem

  - determining solution success criteria that are focused primarily on the most important and relevant, measurable characteristics of the real-world solution, so that they can be used to judge the suitability of the solution

- when matching evidence to the characteristics in the Synthesising and evaluating criterion, attention should be given to
  - ensuring engineering mechanics, materials science, technology, research information and data from the testing of the prototype solution are combined in a well-structured and logical way to develop a structural solution
  - weighing up the merit or worth of ideas and a solution against the solution success criteria and the data obtained from the testing of the prototype to make thoughtful and astute judgments about their suitability and to inform improvements and recommendations.

Additional advice

- For the Project — Folio, responses should
  - adhere to the assessment conditions, which state that Part A should be 7–9 A3 pages and Part B should be 2–3 A4 pages (Syllabus section 4.6.1). During the drafting process, or when providing feedback, students must be supported to develop skills in appropriately managing the length of their responses within the syllabus conditions. (Refer to Sections 8.2.4: Feedback and 8.2.5: Drafting of the *QCE and QCIA policy and procedures handbook v5.0* for further guidance.)
  - avoid including appendixes as they are not assessable evidence. (Refer to the Determining word length and page count of a written response table in Section 8.2.6 of the *QCE and QCIA policy and procedures handbook v5.0.*)
- Assessment responses that exceed syllabus length conditions must be accompanied by clear annotations to show how the school's assessment policy has been applied and which evidence was used to make a judgment. Further information about managing assessment response length is in Section 8.2.6 of the *QCE and QCIA policy and procedures handbook v5.0*. Schools are responsible for ensuring that students are aware of the school-based assessment policy and procedures, particularly regarding the management of response length.

Internal assessment 2 (IA2)

Examination — short response (25%)

The examination assesses the application of a range of cognitions to multiple provided items — questions, scenarios and problems.

Student responses must be completed individually, under supervised conditions, and in a set timeframe.

Assessment design

Validity

Validity in assessment design considers the extent to which an assessment item accurately measures what it is intended to measure and that the evidence of student learning collected from an assessment can be legitimately used for the purpose specified in the syllabus.

Reasons for non-endorsement by priority of assessment

Validity priority	Number of times priority was identified in decisions*
Alignment	70
Authentication	0
Authenticity	20
Item construction	14
Scope and scale	16

*Each priority might contain up to four assessment practices.

Total number of submissions: 102.

Effective practices

Validity priorities were effectively demonstrated in assessment instruments that:

- included appropriately constructed items, e.g. multiple choice questions had plausible responses with mutually exclusive options and avoided options such as 'all of the above' and 'none of the above' (*QCE and QCIA policy and procedures handbook v5.0*, Section 9.6.1)
- provided items that were of an appropriate scope and scale, including
  - items that enabled students to demonstrate the assessment objectives
    - across the range identified in the syllabus, including Assessment objective 3 (analyse) and 5 (synthesise) (Syllabus section 4.6.2)
    - using an appropriate balance of multiple-choice, single-word, sentence, short-paragraph and calculation items across the range of subject matter from Topics 1, 2 and 3 of Unit 3
  - a sufficient quantity of items for students to demonstrate their knowledge of Unit 3 subject matter to sufficient depth within the assessment conditions, and included items that were allocated marks based on the
    - required cognitions as per the assessment specifications

    - evidence in the student response, e.g. complex unfamiliar questions included a number of elements, processes and/or Unit 3 subject matter, and all information required to solve the problem was not immediately identifiable in the item (Syllabus section 4.6.2).

Practices to strengthen

It is recommended that assessment instruments:

- provide authentic opportunities for students to provide unique responses, including
  - avoiding diagrams that lead students to a response for another item, e.g. a diagram of a simply supported beam should not specify where horizontal and vertical components of reactions can be found if this information provides students with the response to another item within the instrument
  - avoid the use of items that are too similar to those in the QCAA sample assessment instrument. Schools should provide opportunities for students to demonstrate authentic responses to assessment (*QCE and QCIA policy and procedures handbook v5.0*, Section 8.2.8)
- align with Unit 3 subject matter, e.g. interpreting stress–strain diagrams is Unit 3 subject matter and may be included in the instrument. Calculating stress or strain is Unit 2 subject matter and cannot be included in the instrument.

Accessibility

Accessibility in assessment design ensures that no student or group of students is disadvantaged in their capacity to access an assessment.

Reasons for non-endorsement by priority of assessment

Accessibility priority	Number of times priority was identified in decisions*
Bias avoidance	23
Language	22
Layout	12
Transparency	13

*Each priority might contain up to four assessment practices.

Total number of submissions: 102.

Effective practices

Accessibility priorities were effectively demonstrated in assessment instruments that:

- were formatted to allow appropriate space for responses to sentence, short-paragraph and calculation questions, and were aligned to the expected responses as indicated in the marking scheme
- included clear instructions within items, using cues that aligned with the cognitions in the assessment objectives to achieve transparency, e.g. items that required students to discriminate between different engineering concepts and principles like dry, wet and stress corrosion used instructions such as ‘explain’, ‘compare’ or ‘contrast’ to clearly inform students about the cognition involved and the type of response required.

Practices to strengthen

It is recommended that assessment instruments:

- use Unit 3 syllabus language and cognitions that align to the unit objectives to structure items, e.g.
  - items that require students to solve truss analysis problems include terms, concepts and principles taken directly from the syllabus, such as 'roller and pin support', 'actions', 'loads' and 'reactions'
  - instructions such as 'explain', 'compare' or 'contrast' that clearly inform students about the cognition involved and the type of response required
- avoid bias by including
  - diagrams in items only where appropriate. When diagrams are included, they should be accurate, clear, legible and accessible to all students
  - items that avoid the use of jargon or language that does not relate to Unit 3 subject matter, e.g. 'culverts' or references to inappropriate contexts such as 'Mars'.

Assessment decisions

Reliability

Reliability is a judgment about the measurements of assessment. It refers to the extent to which the results of assessments are consistent, replicable and free from error.

Agreement trends between provisional and confirmed marks

Criterion number	Criterion name	Percentage agreement with provisional	Percentage less than provisional	Percentage greater than provisional	Percentage both less and greater than provisional
1	Engineering knowledge and problem-solving	96.04%	0.99%	2.97%	0%

Effective practices

Accuracy and consistency of the application of the ISMG for this IA was most effective when:

- for the Engineering knowledge and problem-solving criterion
  - responses to short-paragraph questions included correct recall of relevant characteristics of structural problems by
    - demonstrating thoughtful and astute choices in the selection and description of mechanics, materials science and engineering technology knowledge
    - using key terms and ideas that were clearly identified in the marking scheme
  - responses to short-paragraph questions included an understanding of the situation or process to ascertain the essential characteristics to interpret the relationships that exist between the pertinent components of the problem.

Samples of effective practices

The following excerpt has been included to provide an example of the Engineering knowledge and problem-solving criterion at the upper performance level.

The excerpt provides evidence of a well-structured response to a short-response written question. The question asked student to compare the properties of a stated building material to other suitable building materials within the context of civil construction to justify why it is the most suitable material choice. The response demonstrates insightful and accurate analysis of an industrial application to justify the suitability of one material in preference to another and a discerning description of mechanics, materials science, environment and sustainability, using key terms that align to the focus of the question. Marks are clearly annotated on the written response and the total mark for the question is included with the response.

Note: The characteristic/s identified may not be the only time the characteristic/s has occurred throughout a response.

Question 22 (8 marks) Mark/s: 5

Redacted
for
copyright

laminated timber is easier ~~to~~ & cheaper to source
than other building materials such as steel. It is
also more environmentally friendly & sustainable than steel.
Although sourcing Timber from the environment requires cutting
down trees which can lead to deforestation, ~~timber~~ manufacture companyss
have become more sustainable. Once the timber reaches
the end of its life, it can be recycled or biodegraded.
Steel has a stronger compressive & tensile strength
compared to timber, hower timber can resist corrosion
& rusting. laminated Timber is a lightweight material compared
to steel but can still hold a large load.
When under stress, steel can hold a larger load.

Practices to strengthen

To further ensure accuracy and consistency of the application of the ISMG for this IA, it is recommended that:

- the marking scheme is applied consistently across all samples in the cohort. Awarding half marks is not recommended as there is a risk that their allocation can seem indiscriminate and is often not explained in the marking scheme. If, however, half marks have been allocated, these must be clearly indicated on the marking scheme to show how they have been awarded consistently (*QCE and QCIA policy and procedures handbook v5.0*, Section 9.6.1)
- the ISMG is used accurately to determine a mark out of 25, i.e. schools should provide the mark awarded out of the total marks for the paper, the percentage to at least one decimal place, and the mark out of 25 awarded using the ISMG cut-offs, e.g. 48.5/76 = 63.8% > 60% but not > 64% so the correct cut-off score would be 15.

Additional advice

- For the examination
  - the marking scheme
    - must support the confirmation process and clearly indicate the mark allocations for all examination questions in the one document (*QCE and QCIA policy and procedures handbook v5.0*, Section 9.6.1)
    - could include notes to clarify the mark allocation or feature clearly defined and well-laid out expected student responses and acceptable alternative responses, where applicable, as a useful addition to support the confirmation process
    - should be amended to reflect any errors found when marking student responses to ensure the accurate and consistent allocation of marks for each question. An amended marking scheme can be updated in the Endorsement application (app) at any time, or could be uploaded with the confirmation samples
    - should state where follow-through errors are permitted in calculation questions
  - clearly identify in student responses where follow-through errors have been permitted
  - ensure that the totals for the instrument and marks allocated are added correctly so that cut-off scores can be accurately applied.

Internal assessment 3 (IA3)

Project — folio (25%)

This assessment focuses on a problem-solving process that requires the application of a range of cognitive, technical and creative skills and theoretical understandings. The response is a coherent work that documents the iterative process undertaken to develop a prototype solution to a problem, situation or need. It includes written paragraphs and annotations, diagrams, sketches, drawings, photographs, tables, spreadsheets and prototypes.

This assessment occurs over an extended and defined period of time. Students may use class time and their own time to develop a response.

Assessment design

Validity

Validity in assessment design considers the extent to which an assessment item accurately measures what it is intended to measure and that the evidence of student learning collected from an assessment can be legitimately used for the purpose specified in the syllabus.

Reasons for non-endorsement by priority of assessment

Validity priority	Number of times priority was identified in decisions*
Alignment	12
Authentication	6
Authenticity	2
Item construction	6
Scope and scale	5

*Each priority might contain up to four assessment practices.

Total number of submissions: 101.

Effective practices

Validity priorities were effectively demonstrated in assessment instruments that:

- included authentic, real-world contexts that
  - were selected and developed to provide sufficient detail about the mechanical and/or mechanisms problem while allowing for unique student responses
  - facilitated student engagement with Unit 4 syllabus subject matter, e.g. the contextual statement and/or task required the use of control technologies concepts and principles in relation to machines and mechanisms in the development of a real-world solution
- used the assessment specifications, objectives, ISMG and Unit 4 syllabus subject matter to develop the context statement and task requirements
- clearly detailed the scope of subject matter that students were required to demonstrate in their response, e.g. task descriptions that clearly identified what needed to be addressed in terms of control technologies (Syllabus section 5.6.1).

Practices to strengthen

It is recommended that assessment instruments:

- require students to demonstrate unique responses, clearly indicating that responses should be completed individually and use authentication strategies that reflect QCAA guidelines for student authorship, e.g. for generation of prototypes and performance data
- follow the conventions for item construction by including scaffolding that provides clear instructions informing students of the processes they can use to complete the response, e.g. describe the folio and referencing conventions for headings, the table of contents, reference list and in-text referencing that must be included in the response (Syllabus section 5.6.1)
- are aligned to the syllabus specifications, objectives and unit subject matter to
  - include all Part A and Part B assessable evidence (Syllabus section 5.6.1)
  - allow students to demonstrate knowledge of Unit 4 content across all three topics, not only focusing on Topic 1 or Topic 3, e.g. a task should require the control component of a machine or mechanism and the development or improvement of the machine or mechanism, including mechanics from Topic 1 and materials science from Topic 2. The instrument should ensure that, within the description of the task, it is clear that Unit 4 content (including control technologies, mechanics, and materials science) should be included in the student response.

Accessibility

Accessibility in assessment design ensures that no student or group of students is disadvantaged in their capacity to access an assessment.

Reasons for non-endorsement by priority of assessment

Accessibility priority	Number of times priority was identified in decisions*
Bias avoidance	1
Language	13
Layout	0
Transparency	0

*Each priority might contain up to four assessment practices.

Total number of submissions: 101.

Effective practices

Accessibility priorities were effectively demonstrated in assessment instruments that:

- contained stimulus images only when required and, when included, met with task requirements, e.g. an image or images were often not required as stimulus because the context and task included sufficient contextual information to promote student exploration of the real-world problem in the development of unique responses.

Practices to strengthen

It is recommended that assessment instruments:

- avoid bias and inappropriate content that can disadvantage students, such as placing students in professional roles, e.g. students should not be referred to as engineers or as working for an engineering firm
- use the Engineering syllabus language when referring to problem-solving, solutions and solution development and avoid jargon. Instruments are required to use terms such as ‘develop’, ‘ideas’ and ‘engineered solutions’ in preference to ‘design’, ‘designs’ or ‘design concepts’, etc. Design-related concepts and principles are not included in syllabus subject matter, are not defined in the Engineering syllabus, and should not be used.

Assessment decisions

Reliability

Reliability is a judgment about the measurements of assessment. It refers to the extent to which the results of assessments are consistent, replicable and free from error.

Agreement trends between provisional and confirmed marks

Criterion number	Criterion name	Percentage agreement with provisional	Percentage less than provisional	Percentage greater than provisional	Percentage both less and greater than provisional
1	Retrieving and comprehending	92.08%	7.92%	0%	0%
2	Analysing	83.17%	16.83%	0%	0%
3	Synthesising and evaluating	82.18%	16.83%	0.99%	0%
4	Communicating	99.01%	0.99%	0%	0%

Effective practices

Accuracy and consistency of the application of the ISMG for this IA was most effective when:

- for the Retrieving and comprehending criterion
  - responses showed adept symbolisation and discerning explanation of ideas and a solution to convey additional information in a clear and succinct way by
    - demonstrating a high degree of proficiency in the use of sketches, drawings that adhere to basic drawing standards, logic and/or electrical circuit diagrams, Gantt charts, graphs, tables and/or schemas, e.g. mind maps
    - using annotations to support the visual representations of information and demonstrate intellectual perception about their value and relevance to the machine and mechanism problem
  - responses showed accurate and discriminating recognition and discerning description of a machine and/or mechanism problem by providing information in relation to engineering technology knowledge, mechanics, control technologies and materials science fundamentals that extended beyond the context information provided in the instrument. The information included was also relevant to the specific machine and/or mechanism problem.

Samples of effective practices

The following excerpts have been included to provide examples of the Retrieving and comprehending criterion at the 4–5 performance level.

Excerpt 1 includes the accurate identification of the materials, mechanics and engineering technology characteristics of the machine and/or mechanism problem, through the use of a schema, to discriminate between the known and unknown characteristics of the problem, the assumptions made, and the boundaries defined. The supporting annotations demonstrate evidence of thoughtful and astute choices, with information selected for its value or relevance in relation to the problem.

Excerpt 2 includes representations of ideas that demonstrate highly proficient sketching and include valuable and relevant annotations that display intellectual perception when providing additional information.

Note: The characteristic/s identified may not be the only time the characteristic/s has occurred throughout a response.

Excerpt 1

requested the development of unique pieces that connect to existing LEGO Technic parts.

It is my task to use the problem-solving process in engineering to determine these unique Lego pieces that can inspire students about machines in society, whilst adhering to the safety requirements for the LEGO system A/S team.

Explore

CHARACTERISTICS

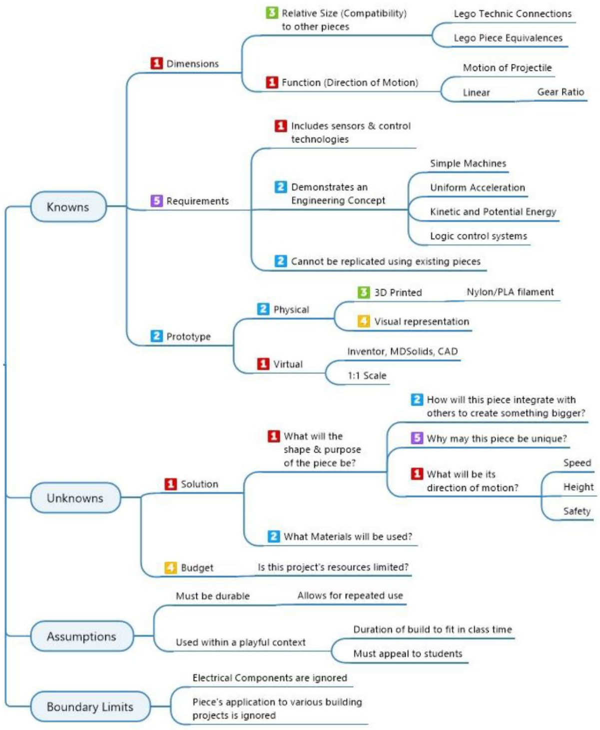


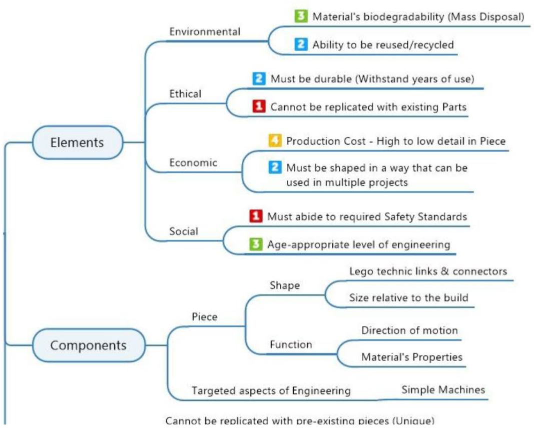
Figure 1 - Characteristics of the task

The characteristics of the problems were explored and represented in Figure 1. These characteristics were analyzed to identify the key concepts that will have the most impact on the solution.
The 'Known' information consists of dimensional data and the restrictions of the task. Of this, the purpose and uniqueness of the pieces has the greatest impact on the solution. This is because it defines the LEGO Technic Kit's ability to appeal toward a targeted audience (Students) whilst exhibiting aspects of engineering. The 'Unknowns' will be resolved. The key unknowns have been identified as the following:

1. The direction of motion will be calculated with safety in mind (i.e. projectiles).
2. The budget/resources will be somewhat ignored as the task does not identify any financial limit.
3. The duration of the build is assumed to fit within a period of class time with respect to the target audience – Students.

The priority of these aspects are ranked from 1-5 (1 being the most important). For example, the prototype side of this report has been assigned a 2 since the material will be made from the exact same as pre-existing LEGO piece. Whilst the prototype will show certain features that need to be fixed for the final solution, it will be 3D printed out of PLA, Nylon, PET etc. Thus it will not be the exact same as the final solution and is assigned a 2 because of this dissimilarity.

ENGINEERING TECHNOLOGY



The Engineering technology was explored and represented in Figure 2. Critical to the solution are the elements identified, with the following points in particular.

1. Must be durable to withstand years of repeated use
2. Environmental damage (due to mass production and disposal) must be minimized – i.e. amount of material used
3. Cannot be replicated using existing pieces and must abide to the required safety standards.

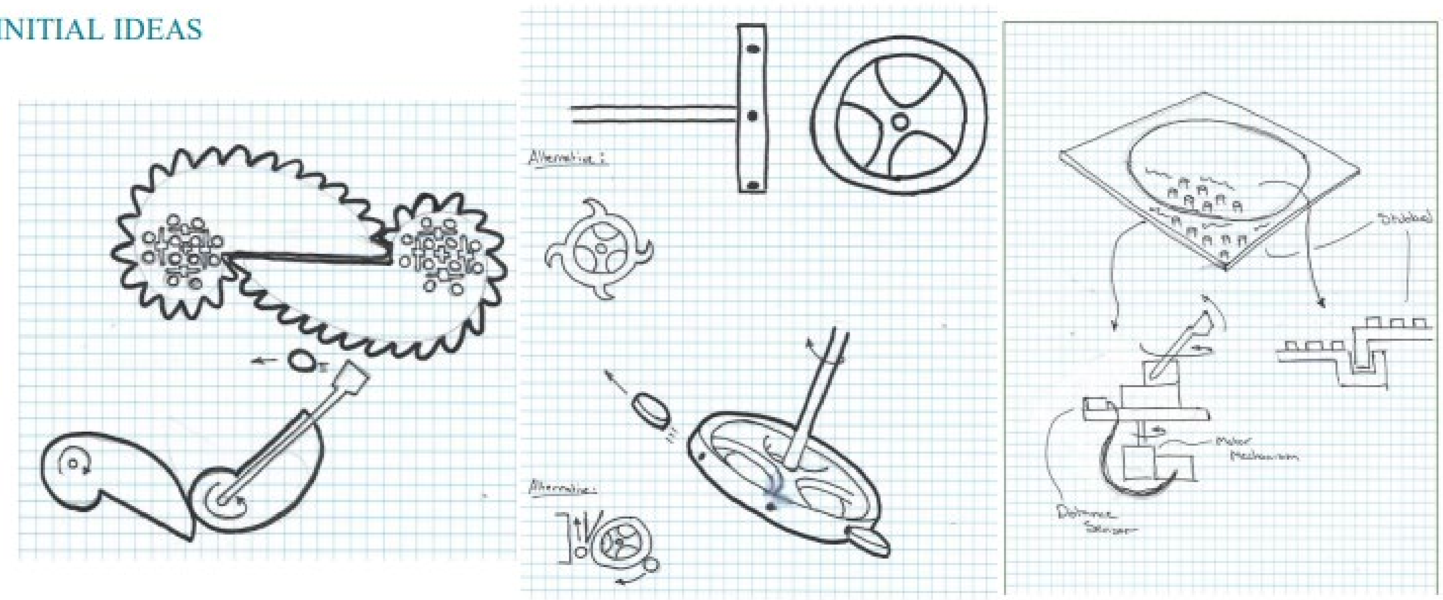
Note that these safety standards will following the following resources:

- LEGO Product Standards (LEGO System A/S n.d.):
    - Compression tests (pressing with a 15 kg force)
    - Drop tests (1.5m and 1m)
- Australian Standard AS/NZS ISO 8124.1:2019:
    - Projectile Properties – shape, range and force

Excerpt 2

Develop

INITIAL IDEAS



Solution A	Solution B	Solution C

Figure 4 – Initial Ideas for the final solution

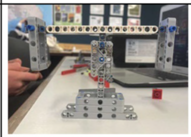
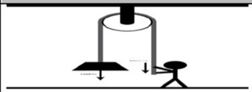
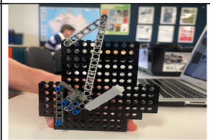
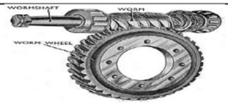
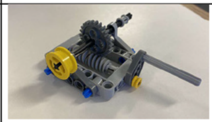
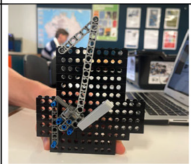
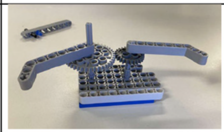
The Figure 5 sketches illustrate the initial ideas for unique LEGO pieces. Solution A is a nautilus gear, which can use its unique shape and subsequent varying gear ratio to launch a projectile in a catapult-like movement – solving the challenge set for students through variable motion. Solution B is a rotary piece that resembles a flywheel. This piece exercises centripetal forces to overcome magnetic forces to launch a disk projectile. Other alternative features of solution B involve using a simple hook system (rather than magnets) and additional Lego pieces to separate the projectiles if the centripetal forces are unsafe or not enough. However, these alternatives may prove harmful when spinning at a certain RPM. Since this unique piece utilizes centripetal and magnetic force, it solves the challenge set for students through simple harmonic motion. Solution C is also a rotary piece which can fix moveable parts to other stationary pieces. This mechanism consists of a rotatable circle in the center of a flat plane, with both features involving stubs. This solution can also use a distance sensor, in which can rotate the movable piece using logic

The following excerpt has been included to provide an example of the Analysing criterion at the 6–7 performance level. It provides evidence of an understanding of machines and mechanisms relevant to the problem. Testing is used to examine the mechanics of the problem to ascertain the essential characteristics and to determine the reasonableness of information and its relationship to the problem.

Note: The characteristic/s identified may not be the only time the characteristic/s has occurred throughout a response.

Researching the Problem and Testing Systems

In order to establish an appropriate mechanism, several systems will undergo trials and testing to ascertain the optimal combination that aligns with the mechanism's operational process.

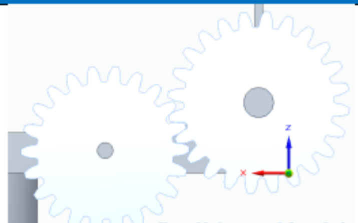
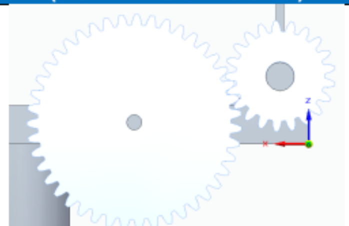
Mechanical Systems	Image	LEGO Build	Pros and Cons	Conclusions and Links to Task
Lever	Redacted for copyright		**Pros** - Uses $w = F \times d$ to produce more turning force by extending the distance. Which increases the mechanical advantage. - As mechanical advantage is greater than velocity ratio the efficiency will be greater than 1. - Low friction in a lever system due to the fact it has low internal resistance. - The lever system is very **easy to build** and **use** as it works on a basic concept using a rigid beam and a fulcrum. - Requires little maintenance just greasing and inspection. **Cons** - For levers with a longer reach on one side of the fulcrum they have a poor velocity ratio and for those with even reach it is neutral or 1:1. - Takes up large space especially if lifting heavy load with low effort. - Lever wears over time from contact and friction with fulcrum.	A model lever was constructed using ABS plastic and the findings where that its mechanical advantage and velocity ratio where very similar, this gave an efficiency of close to 1 due to no frictional forces. A lever will be utilized in the design as it increases the mechanical advantage greatly. The lever system in the bin tipping machine is designed to minimize friction. However, it is important to note that there is a fixed frictional component present at the fulcrum, which gradually leads to wear over time. To mitigate the impact of friction, it is recommended to apply grease to the tipping mechanism. This greasing procedure is an integral part of the straightforward maintenance process aimed at ensuring optimal performance and longevity of the machine.
Pulley	 https://www.instructables.com/Basic-Pulley-Mechanisms/		**Pros** - Has a velocity ratio of 1 as the distance moved from the effort is the distance moved by the load. - Effective way of moving a load vertically up and thus utilized in many mechanical bodies. - When using a compound pulley, the mechanical advantage increases with the number of loops and pulleys. **Cons** - Mechanical advantage is poor due to frictional forces experienced by the rope on the wheel and the wheel spinning which means more effort is required to overcome the weight force of the load. - The efficiency will be less than 1 as the mechanical advantage is less than the velocity ratio. - Rope wears over time against the wheel increasing the required maintenance. - The system necessitates an overhead "wheel" for operation, which requires additional space and materials during construction, leading to an increase in design costs.	A pulley system was constructed using ABS plastic and kevlar rope. Its mechanical advantage increases with the more pulleys and loops that are added but will likely not be used in the final design. The task doesn't require a direct vertical lift and although they could be paired with gears, pulley's offer no locking system and have high friction. A single fixed pulley provides minimal mechanical advantage, and to enhance it, additional loops and pulleys are needed. However, this results in increased weight on the tipping machine and introduces additional friction. While the pulley effectively facilitates vertical movement of the bin, repeated lifting can cause wear and eventual breakage of the ropes. Consequently, regular maintenance and repair become necessary to address the increased strain on the ropes.
Worm Gear	 https://en.wikipedia.org/wiki/Worm_drive		**Pros** - The high mechanical advantage of a worm gear system is due to the ratio of the number of teeth on the worm wheel to the number of threads on the worm gear, resulting in a large output force from a relatively small input force. - Ability to prevent reverse motion and act as a mechanical locking system. **Cons** - Due to frictional forces between the worm and the worm wheel the system is relatively inefficient. - Expensive to manufacture. - Velocity ratio is poor as the movement of the wormshaft (effort) is less than the movement of the worm wheel (load).	A worm gear system was built using ABS plastics and it was deduced that a worm gear offers great mechanical advantage when paired with a lever. It produces high friction, which is inhibits the efficiency, but it provides a locking system increasing safety within the system. The worm gear possesses the ability to transfer force in various directions with the inclusion of only a few additional components. Moreover, it incorporates a mechanical locking system, resulting in a higher mechanical advantage for the bin tipping machine. However, these advantages come with a distinct maintenance routine that must be carried out accurately. Failure to do so may increase the likelihood of requiring repairs for the bin tipping machine.
Linkage	Redacted for copyright		**Pros** - Low amount of friction as the crank is directly connected to the link via screw, which is lubricated, smooth and circular to allow ease of movement. - Velocity ratio is low as the crank will require less movement to move the link components further upwards if components are placed in long-long-short formation. - The system is easy to build as requires two same length components plus one smaller length crank. - The linkage system could move in a circular motion around the top link member. **Cons** - Less mechanical advantage as crank system requires a similar amount of force to use as to push the link system upwards. However, by implementing a winch system in the crank, the mechanical advantage could be increased, thus increase the efficiency. - Difficult to repair as the system will need to be taken apart to fix each individual component. - Absent of a locking system, however through the use of bite gears in the crank, the system could be locked in place when lifting the load.	The linkage system enables the circular motion necessary to lift, discard, and return the bin load to its initial position within the mechanism. Furthermore, its low velocity ratio and minimal friction contribute to higher efficiency. Additionally, the ease of construction allows for multiple mechanisms to be built simultaneously. However, this system has a lower mechanical advantage, making it less suitable for low-effort environments. It is also more challenging to repair due to its design, and the absence of a locking system can be considered a disadvantage when compared to other systems.
Traditional Gear	Redacted for copyright		**Pros** - Building a simple traditional gear system is easy with basic hand tools. - Traditional gears offer a large velocity ratio in minimal space, which is beneficial for machines with limited space. - A locking mechanism can be incorporated into the gear system to prevent accidental shifting between forward and reverse gears. - The gear ratio determines the mechanical advantage of the system, with the input gear requiring less force but rotating at a higher speed than the final gear. **Cons** - The interface of tooth contacts in traditional gears can experience combined sliding and rolling motions, which can cause friction. This can be minimized through lubrication of the teeth. - Gear operation can produce a significant amount of noise pollution. However, as the machine will be operated in an educational institution, it is essential to limit the noise level. - The engagement of gears can cause excessive loading on the machine parts, which may lead to permanent damage.	Traditional gears offered very similar properties to that of a worm gear. Although no locking system is offered, it can be easily implemented, and traditional gears can be utilized to offer extremely high mechanical advantage to a system. In saying this, the more gears, the more friction inhibiting the overall efficiency of the system and affecting the true mechanical advantage. The gear system can be constructed using simple building processes with basic hand tools. It is primarily limited to rotational movements, which align perfectly with the requirements of the bin tipping process. However, friction is generated by the gears, which can be mitigated by applying lubrication as part of the maintenance routine. The maintenance process itself is relatively straightforward and does not necessitate extensive training or specialized equipment. However, repairs may pose a challenge as the machine component of the bin load machine needs to be disassembled to replace any gears. Despite this limitation, the gear system offers numerous advantages and can be readily combined with other systems.

Conclusions: Based on the mechanism testing, the lever, worm gear, and traditional gear emerged as the most suitable mechanisms for the prototype solution. Extensive research indicates that these three mechanisms are characterized by ease of construction and user-friendly operation, minimizing complexity in both building and operating processes. The utilization of multiple gear systems opens up opportunities for various developments, as they can readily accommodate the incorporation of additional components such as the lever. Conversely, the pulley and linkage system were not chosen due to their larger space requirements and construction difficulties, outweighing the mechanical advantage they offer to the system. In contrast, all three selected mechanisms provide a mechanical advantage while occupying minimal space.

The following excerpts have been included to provide examples of the Synthesising and evaluating criterion at the 8–9 performance level. Excerpts 1 and 2 provide evidence of a well-structured, rational and valid combination of engineering mechanics, control technologies, materials science, technology, research information and ideas to predict a possible machine and/or mechanism solution to the problem. Various components of the ideas have been prototyped using physical and virtual prototyping to produce legitimate and defensible performance data that supports an evaluation of the strengths and limitations of the prototype solution to determine the feasibility of the predicted real-world solution.

Note: The characteristic/s identified may not be the only time the characteristic/s has occurred throughout a response.

Excerpt 1

Theoretical Prototyping Data	Prototype 1 (REDUCING GEAR SYSTEM)	Prototype 2	Prototype 3 (MULTIPLYING GEAR SYSTEM)
	 Figure 28- Prototype 1 Gears Ratio	 Figure 29- Prototype 2 Gears Ratio	 Figure 30- Prototype 3 Gears Ratio
Gear Ratio (No. of Teeth of Driven/No. of Teeth of Driver)	44/22 = 2:1 = 2	22/22 = 1:1 = 1	22/44 = 1:2 = 1
Mechanical Advantage (Assume 100% Efficient)	MA = VR = 2	MA = VR = 1	MA = VR = 0.5
Output Torque (Torque (0.7906 Nm) x Gear Ratio)	0.7906 x 2 = 1.5812 Nm	0.7906 x 1 = 0.7906 Nm	0.7906 x 0.5 = 0.3953
RPM (Revolutions Per Minute)	55 ÷ 2 = 27.5 RPM (Driven Gear is Twice as Big)	55 RPM (Both Gears are Equal)	55 ÷ 0.5 = 110 RPM (Driven Gear is Twice as Small)
How Far Driven Gear Needs to Rotate for the Can to Rotate 90° Clockwise Back Up onto the Platform	Small Driver 1/2 Big Driven 1/4	Both Driver and Driven 1/4	Big Driver 1/8 Small Driven 1/4
Theoretical Time it Would Take for the Can to Reset	55/60 x 2 = 1.8333 seconds	55/60 x 1 = 0.9167 seconds	55/60 x 0.5 = 0.4583 seconds
Analysis of Prototype and Improvements for Next Prototype	Prototype 1 provides a reducing gear system where there is a 2:1 gear ratio between the driver gear and the driven gear. This system would produce an output torque of 1.5812 Nm and complete the reset in 1.8333s, which would be considered as slower than the time it would take the host to manually reset the can at 1 second, disregarding SC5. This gear system could be used in this game; however, it is not the most appropriate system to implement in order maximise the efficiency of the system. Decreasing the amount of torque and increasing the speed of the system will lead to a faster reset, and the system would be able to lift the can as easy as this Prototype.	Prototype 2 provides an equal gear system where there is a 1:1 gear ratio between the driver gear and the driven gear, as illustrated by the gears being the same size. This a more suitable and efficient and gear system to use, as the torque has decreased, and the speed of the can reset has increased to 0.9167s, reaching SC5 in this requirement, however, the gears are not a multiplying system, hence, better efficiency can be reached through implementing a multiplying system. Both the maximum output torque and the time taken to reset the can have halved from Protype 1, and as a result the system will be able to lift the can just as easy as in Prototype 1, but it will be done in half the time decreasing the time it takes to prepare for the next game. However, to really maximise the system, a multiplying system can be implemented to further decrease the speed, with a reduction of output torque.	Prototype 3 provides a multiplying gear system where there is a 1:2 gear ratio between the driver and the driven gear. This system would produce the least output torque out of the three prototypes, and as a result it would take the least amount of time and be the quickest to reset the cans in a time of 0.4583. These multiplying gears are the most efficient and appropriate system for this game, approving, both the requirements of SC5, as a can resetting system like this is only being implemented into the game to make resetting the cans quicker using simple machines, than the time it would take the host of the game to pick them up manually and reset them. With this system having a resetting time of 0.4583s, it is definitely quicker than a human, justifying the reason for implementing this.

Physical Prototyping Data – Time Taken for Cans to Reset Using Different Gear Ratios

Prototype	Trial 1 (s)	Trial 2 (s)	Trial 3 (s)	Trial 4 (S)	Trial 5 (s)	Average Time (s)
1	1.86	1.84	1.79	1.81	1.87	1.834
2	0.94	0.89	0.96	0.90	0.93	0.924
3	0.49	0.51	0.44	0.47	0.46	0.474

How and Was the Physical Prototype Built and Why?

This physical structure was created using a combination of Lego, gears, and a specific motor. The main reason for building this structure was to physically show how the simple machines (lever and gears) would fit together with the can and the platforms to create a fully functional automated resetting system, and to be able to physically move and play around with the system. The measurements used to build this structure were determined based off ratios surrounding the can (represented by the tyre), the levers, and the gears, and resemble what the measurements would most likely be in the real game.

The different gear ratios were fitted onto the structure, the input gear connected to the motor, and the output gear connected to the axle that rotates the lever. This motor specifically spun at 55rpm and was turned on when the can was pushing down and touching the button (indicating the can had been knocked over). Using a stopwatch 5 trials were recorded for each gear ratio, timing how long it took the can to reset (testing speed of reset). The purpose of collecting this physical data was to prove and support the theoretical data.

Images of Physical Lego Build:

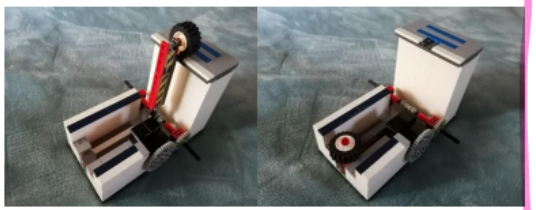
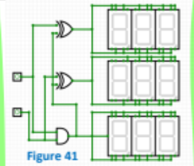
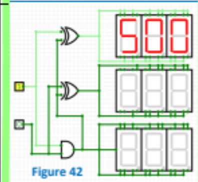
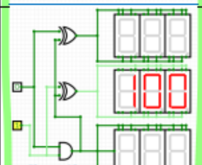
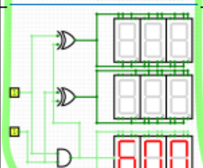


Figure 31 and 32- Physical Lego Build

Excerpt 2

EVALUATION: ANALYSIS

Analysis of Logic Gates:

SCENARIO (Can 1 500 Points) (Can 2 100 Points)	LOGIC GATE ILLUSTRATION	ANALYSIS OF WHAT WOULD HAPPEN
NO CANS KNOCKED DOWN	 Figure 41	When none of the cans get knocked over, the buttons don't get pressed, therefore, no signals are sent through the logic gate circuit, resulting in no points being scored and nothing going up on scoreboard.
ONLY CAN A GETS KNOCKED DOWN	 Figure 42	When the can that is worth 500 points is the only can to get knocked over, the can will hit the button and send through the logic gate circuit, a signal that will only light up that can's scoreboard, showing 500 points have been scored, and this amount will also get added to the bigger scoreboard, where the player will be able to see the points which will get added their total points.
ONLY CAN B GETS KNOCKED DOWN	 Figure 43	When the can that is worth 100 points is the only can to get knocked over, the can will hit the button and send through the logic gate circuit, a signal that will only light up that can's scoreboard, showing 100 points have been scored, and this amount will also get added to the bigger scoreboard, where the player will be able to see the points which will get added their total points.
BOTH CANS GET KNOCKED DOWN	 Figure 44	When either the can worth 500 points or the can worth 100 points gets knocked over a signal will light up their individual scoreboard, however, if then the second can gets knocked over, equalling to both cans now being knocked over, both buttons will get pressed. Instead of both the can's individual scoreboards lighting up, the signals that get sent through the logic gate circuit will result in the lit up individual scoreboard switching off, and the summative scoreboard lighting up due to the implementation of the two NOR gates, showing the sum of those two cans, equally to 600 points. These points will be sent through and added to the bigger scoreboard for the player's view.

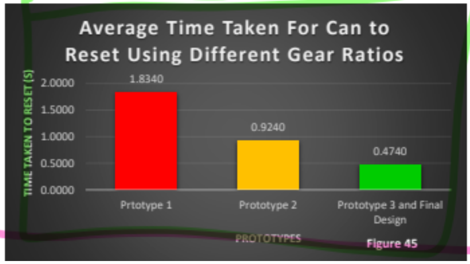


Figure 45

Analysing Success Criteria:

Code	Criteria	Justification	Rating
SC1	The knocked down cans will automatically reset and come back up successfully after the game is finished and in preparation for the next game with the implementation of levers and gears.	The simple machines of a lever and gears have proven to work together to as shown by the physical Lego build and Solid Edge simulation, creating an automated can resetting system that reduced the overall labour cost of the game with the host no longer needed to manually pick up the cans, as a result of this system.	5/5
SC2	A scoring system will be implemented into the game to digitally calculate the scoring based off the cans that get knocked over using the most efficient logic gate circuit possible.	After the creation of three prototypes, the most efficient and effective logic gate system, that was still able to produce the required outcome, was created. This system was made with a total of two NOR gates and one AND gate, with three connecting memory cells, representing the scoreboard.	5/5
SC3	The logic gate circuit will have the quantity of at least three different logic gates and at least two different types of gates.	The prototypes and the final design of the logic circuit created for the point scoring system, met this requirement in terms of the quantity, of having at least three gates, and variety, of having at least two of them being different, showing variety and depth.	5/5
SC4	The measurements of the gear sizes of the prototypes will be to scale and resemble the measurements that of the real-world game.	Although, the prototypes and final design of the gear ratios and overall structure of the can resetting system, were in scale, using measurements that would be represented and used in the real world, these measurements are not exactly precise, as factors including; spacing have not been accounted for, which could impact the measurements of the structure.	4/5
SC5	The can resetting system will have a velocity ratio of less than 1 to be able to reset can in less than 1 second as this was the recorded time that it took to manually pick up the can and place it back on the platform into its starting position, without any simple machines.	After the creation of three prototypes, the most suitable gear ratio was determined to produce the most efficient and effective result. Using a 0.5 gear ratio, this led to a decrease in mechanical advantage and an increase in speed. In this scenario, the maximising the torque wasn't the priority, but more so, maximising the speed. Ultimately, the cans reset in about 0.474 s, justifying the implementation of this system as it was done in less than 1 s.	5/5
SC6	The can knock game will be made of specific materials that are corrosion resistant, preventing any chance of corrosion rusting the parts of the game, and damaging the functioning of it.	The majority of this game including the lever, gears, motor, and can, were all made using corrosion free metals of stainless steel, and zinc plated steel except for the platforms and poles, that were just made from unprotected black metal. The reason for this was because these parts of the structure were solid, and deemed as unlikely to corrode and rust. The baseballs were made of leather, and had a risk of getting water logged with rain.	4/5

Sustainability and Cost of Final Design:

(Strengths and Limitations)

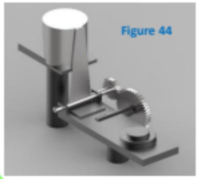


Figure 44

The materials of both stainless steel zinc plated steel that are used in this game are special types of steel that prevent corrosion over time, are more expensive than normal unprotected steel (jain, 2023). This leads to more money going towards creating the game, with lower grades of stainless steel costing around $800 per ton, and higher grades costing around $2500 per ton, whereas, normal steel costs about $400 for lower grades and around $1200 for higher grades (jain, 2023).

This motor is a specific type of motor that has been chosen because it was determined to be the most efficient and effective, based off its maximum output torque and overall size. However, they cost around $120 each (RS Components Pty Ltd, 2023), and if there are 30 cans, 30 motors are needed, resulting in around $3600 needing to be spend on the motors.

Although in order to build this game, a lot of money is being spent, with the types of motors being implemented, and the decision to use higher quality steel that is corrosion resistant rather than using normal steel that costs half the price, by using these types of materials and spending the extra dollar, this will result in the significant increase of the sustainability of the game, with less maintenance needing to be done, as the steel will last longer due to it prohibiting any corrosion that would damage the game. Ultimately spending more in the building process will be compensated over time, with less money needing to be spent on maintenance and repairs of the steel.

As a result of the Final Design being the same as Prototype 3, which was a 0.5 gear ratio, the hypothesis will be supported and backed up by the Final Design testing that would occur in the real world when building this game. Based off the theoretical data this gear ratio should perform at the speed whereby over a number of trials, the average reset time should theoretically be 0.4583 seconds, with there being some variance in the data in either direction, as can be seen with the results of Prototype 3, where there was a slightly slower sample, with the experimental time going over the theoretical time.

Each prototype increased in speed as it decreased in the maximum output torque, with Prototype 1 being a reducing gear system, which prioritised torque over speed, all the way to Prototype 3 and the Final Design being a multiplying gear system, which is the opposite and prioritised speed over torque which was most suitable and appropriate for this game.

Practices to strengthen

To further ensure accuracy and consistency of the application of the ISMG for this IA, it is recommended that:

- when matching evidence to descriptors for the Analysing criterion at the upper performance level, attention should be given to ensuring the solution success criteria
  - primarily relate to the real-world machine and/or mechanism problem
  - are based on research and analysis of materials science, mechanics, engineering technology and control technology that extends beyond the information that has been provided in the instrument
  - includes measurable aspects that will facilitate a critical evaluation
- when matching evidence to descriptors for the Synthesising and evaluating criterion at the upper performance level, attention should be given to ensuring evaluations are based on the solution success criteria and include justified recommendations for further enhancement and refinement of ideas and a real-world solution throughout the problem-solving process.

Additional advice

- Schools should use the correct ISMG when making judgments about the response (*QCE and QCIA policy and procedures handbook v5.0*, Sections 7.3.3 and 8.3). While assessing the same objectives, the ISMG for IA1 and IA3 assess different characteristics as Unit 3 focuses on structures, while Unit 4 focuses on machines and mechanisms.
- Each summative internal assessment instrument should be printed directly from the Endorsement application for use with students.
- Schools should check that the pages are orientated correctly when scanning samples for confirmation. This ensures confirmers do not need to rotate each page to review the response. The *Confirmation submission information* for Engineering is available in the Resources section of the Syllabuses app in the QCAA Portal.

External assessment

External assessment (EA) is developed and marked by the QCAA. The external assessment for a subject is common to all schools and administered under the same conditions, at the same time, on the same day.

Examination — short response (25%)

Assessment design

The assessment instrument was designed using the specifications, conditions and assessment objectives described in the summative external assessment section of the syllabus.
The examination consisted of one paper:

- Paper 1, Section 1 consisted of 10 multiple choice questions (10 marks)
- Paper 1, Section 2 consisted of 5 short response written questions (30 marks)
- Paper 1, Section 3 consisted of 6 short response calculation questions (45 marks).

The examination assessed subject matter from Unit 4. Questions were derived from the context of

- Topic 1: Machines in society
- Topic 2: Materials
- Topic 3: Machine control.

The assessment required students to respond to multiple choice and short response questions.

Assessment decisions

Assessment decisions are made by markers by matching student responses to the external assessment marking guide (EAMG). The external assessment papers and the EAMG are published in the year after they are administered.

Multiple choice question responses

There were 10 multiple choice questions.

Percentage of student responses to each option

Note:

- The correct answer is **bold** and in a blue shaded table cell.
- Some students may not have responded to every question.

Question	A	B	C	D
1	24.51	**57.61**	9.99	7.57
2	4.39	6.11	**67.54**	21.07
3	**59.13**	13.56	16.42	10.5
4	40.17	14.19	12.03	**33.35**
5	5.16	**75.43**	5.16	13.69
6*	**16.36**	**44.81**	21.77	16.74
7	6.62	10.95	8.72	**73.14**
8	5.03	23.87	**60.28**	9.93
9	**79.76**	12.92	4.2	2.86
10	9.87	20.43	**59.96**	8.4

*The multiple-choice scrutiny panel reviewed the question and determined that there were two keys for Item 6.

Effective practices

Overall, students responded well to:

- simple familiar, complex familiar and complex unfamiliar calculation questions that required knowledge of mechanical advantage, velocity ratio, work, power, kinetic and potential energy, equations of motion and inclined planes
- simple familiar, complex familiar and some complex unfamiliar written questions that required them to identify or explain concepts, principles and situations using knowledge of mechanics and materials science subject matter
- simple familiar and complex familiar questions that required the use of logic control subject matter knowledge.

Samples of effective practices

Short response

The following excerpt is from Question 12. It required students to explain the concepts of mechanical advantage and work done in the context of a bicycle and to support the explanation with an annotated sketch.

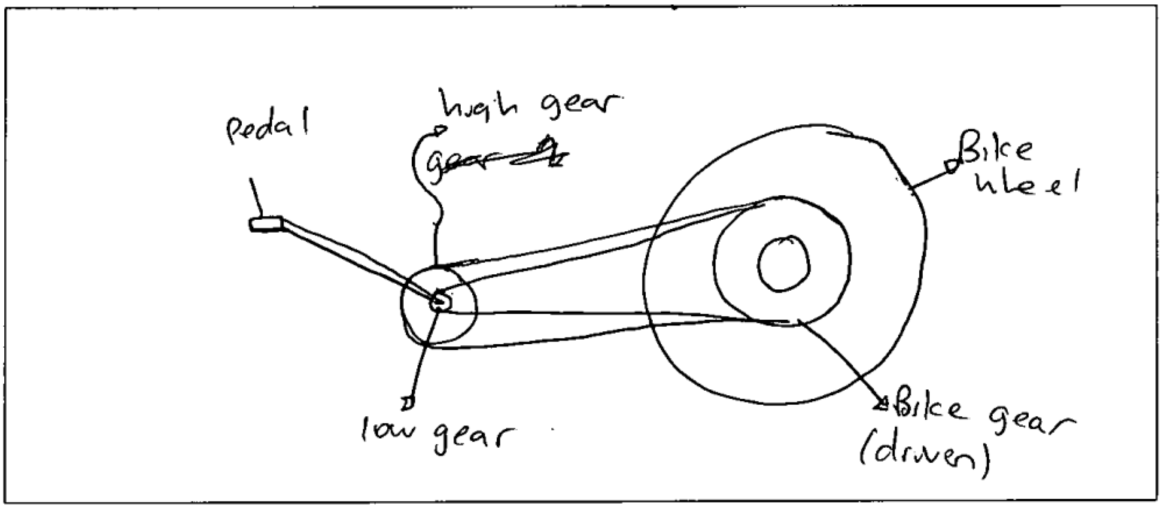
Effective student responses:

- provided a clear written explanation of mechanical advantage that indicated that less force was required to move the pedals
- provided a clear written explanation that indicated that work done remained the same
- provided an annotated sketch that clearly indicated the large rear wheel gear was linked to the smaller pedal gear to support the response.

This excerpt has been included:

- to provide a high-level response that shows an understanding of how a bicycle provides mechanical advantage through the use of gears, and demonstrates how an annotated sketch may be used to reinforce key points highlighted in an appropriate explanation concerning the concepts of mechanical advantage and work done.

Gears on a bicycle increase the mechanical advantage when going up hills. By going down a gear, the cyclist has the amount of force (effort) to pedal up the hill decreased as the gear ratio is larger, meaning it must complete more revolutions. The work remains the same as the pedals must complete more revolutions to move a certain distance, despite the reduced force. For example, if ~~sa~~ in gear 4, the ratio of driven : driver is 2:1, and then lower gear is 3:1, it means 3 revolutions of the pedals are required to move the ~~bike~~ wheel (driven component) once, rather than 2 revolutions to move it once. Assuming no ~~fo~~ force is lost due to decreased efficiency, the MA is also increased from 2 to 3, as MA = VR for 100% efficiency. Overall, gearing makes it easier as less force is required over a larger time.



The following excerpts are from Question 13. It required students to interpret a logic circuit to complete a truth table and explain the operation of the logic circuit within a familiar context.

Effective student responses:

- included a completed truth table that demonstrated accurate interpretation of the logic circuit and correct identification of logic gate symbols and their operation
- included a clear, written explanation of how the logic circuit determines which power source drives the motor under different conditions.

These excerpts have been included:

- to illustrate a high-level response that clearly shows an understanding of how logic gates function.

Excerpt 1

A	B	C	D	E	F	Q
0	0	0	0	0	0	0
0	0	1	0	0	0	0
0	1	0	0	0	0	0
0	1	1	0	1	1	1
1	0	0	0	0	0	0
1	0	1	0	0	0	0
1	1	0	1	0	1	1
1	1	1	1	1	0	1

Excerpt 2

The logic ~~Co~~ circuit determines the source or power based on the 3 inputs. For an output to the electric motor (Q) the timer must be on as two and ~~or~~ gates (A and C separately) result in an output of 0 if the timer is 0.

- If the timer is on and the A or C (solar or wind) is 1, then the circuit outputs ~~a~~ 1 at Q, ∴ driving the motor with the power source currently active.
- If ~~both~~ A and C are on, on (output of 1) and B, then the motor is driven (output of 1) but ~~a~~ the solar panel is prioritised due to the direct connection to the or gate at Q.

∴ if A, B, C are ~~one~~ 1, then A drives motor.

The following excerpts are from Question 15. It required students to:

- explain how the microstructures of medium carbon steel demonstrate mechanical properties that make it a suitable material for train rails
- support their explanation with an annotated sketch of the microstructure of medium carbon steel.

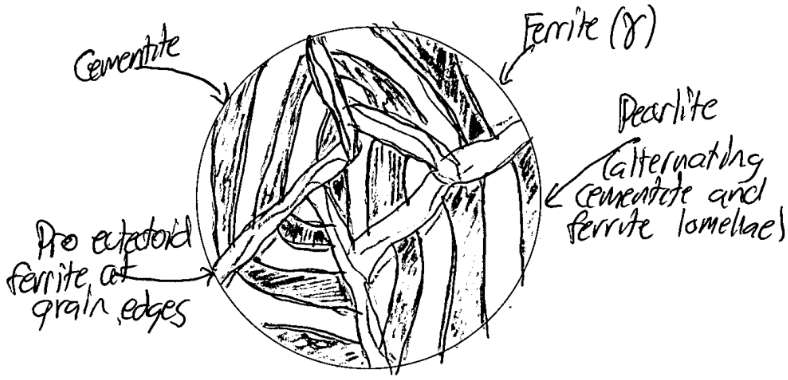
Effective student responses:

- included an appropriate sketch of the microstructure of medium carbon steel that correctly identified ferrite and pearlite, including
  - a clear distinction between ferrite and pearlite
  - clearly identifying the laminar structure of pearlite
- included an appropriate explanation of the suitability of medium carbon steel for the application of train rails with reference to mechanical properties interpreted from the microstructure.

These excerpts have been included:

- to illustrate a high-level response that explains the suitability of the material using knowledge of mild carbon steel microstructure and two relevant mechanical properties to justify why mild carbon steel is the preferred option in the given industrial context
- an appropriate sketch that illustrates an understanding of the microstructure of the material.

Excerpt 1



Excerpt 2

Medium carbon steel is before the eutectoid composition of 0.76 WT. carbon and has 0.3 to 0.6 WT. ~~as~~ 0.3 to 0.6 WT carbon. Thus ~~the~~ medium steel has pearlite (alternating ferrite and cementite lamellae) and also proeutectoid at grain edges, it has more soft ductile ferrite than brittle had cementite. The cementite in medium steel causes it to be ~~very~~ hard and strong, and the ferrite causes it to be very tough and not brittle, This makes it useful for train rails which require a strong material, but also a tough material that can withstand repeated loads...

The following excerpt is from Question 16. It required students to determine the total mechanical energy of a crane lowering system used for offloading storage containers from a truck.

Effective student responses:

- accurately determined the total mechanical energy of the crane lowering system, including correctly determining the
  - mass of the storage container
  - potential energy.

This excerpt has been included:

- to illustrate a high-level response that is well-structured to clearly show the steps used to determine the mechanical energy to the correct whole unit.

$KE = \frac{1}{2}mv^2$ Mechanical Energy = KE + PE

$850 = \frac{1}{2} m (1.5)^2$

$850 = \frac{1}{2} \times m \times 2.25$ $PE = mgh$

$1700 = 2.25m$ $PE = 755.56 \times 9.8 \times 2$

$m = \frac{1700}{2.25}$ $\therefore PE = 14808.98\ J$

$\therefore m = 755.56\ kg$

Mechanical Energy $= 850 + 14808.98\ J$

$= 15658.98\ J = 15659\ J$

∴ the total mechanical energy of the lowering system is 15659 J.

The following excerpts are from Question 19. It required students to analyse written and graphical information to determine the distance a box slides along a horizontal surface before coming to a complete stop after having slid down a ramp where there was a constant coefficient of kinetic friction between the box and all surfaces.

Effective student responses:

- correctly determined the resultant force down the incline, including identifying the
  - frictional force on the incline
  - parallel force down the incline
- correctly determined the distance the box slid along the horizontal surface before coming to a complete stop to the nearest whole unit, including identifying the
  - acceleration down the incline
  - velocity of the box at the bottom of the ramp
  - deceleration of the box on the horizontal surface.

These excerpts have been included:

- to illustrate a high-level response that is well-structured to clearly show the steps used to determine the answer to the correct whole unit.

Excerpt 1

$$F_{NET} = F_{\parallel} - F_F$$
$$= 2 \times 9.8 \sin 25 - 0.35 \times 2 \times 9.8 \cos 25$$
$$= 8.28 - 6.22$$
$$F_{net} = 2.06\,N$$
$$F_{net} = ma$$
$$2.06 = 2 \times a$$
$$a = \frac{2.06}{2}$$
$$a = 1.03\,m/s^2 \text{ down incline}$$

Excerpt 2

$s = 4$ $\qquad$ $v^2 = u^2 + 2as$

$u = 0.5\,m/s$ $\qquad$ $v^2 = 0.5^2 + 2 \times 1.03 \times 4$

$v = \cancel{0\,m/s}\ ?$ $\qquad$ $= 0.25 + 8.25$

$a = 1.03\,m/s^2$ $\qquad$ $v = \sqrt{8.49}$

$v = 2.91\,m/s$

$$F_{net} = F_f$$
$$F_f = 0.35 \times 2 \times 9.8$$
$$F_f = 6.86\,N$$
$$F = ma$$
$$6.86 = 2 \times a$$
$$a = 3.43\,m/s^2$$

Excerpt 3

$a = -3.43 m/s^2$

$v = 0 m/s^2$ $\quad s = \frac{v^2 - u^2}{2a}$

$u = 2.91 m/s^2$

$s = ?$ $\quad s = \frac{0^2 - 2.91^2}{2 \times -3.43}$

$s = 1.23 m$

distance until complete stop = ~~1.23~~ 1m

The following excerpt is from Question 20. It required students to determine the coefficient of friction between a trolley and an incline if the trolley was travelling at a uniform velocity up the incline.

Effective student responses:

- correctly identified that the system is in equilibrium
- identified the three forces acting on the trolley, parallel to the incline
- correctly determined the coefficient of friction to two decimal places.

This excerpt has been included:

- to illustrate a high-level response that is well-structured to clearly outline the steps used to determine the coefficient of friction to two decimal places.

if $a = 0$, $\therefore F_f + F_g$ down slope $= -F_{applied}$

$-(F_n \mu + 20 \times 9.8 \times \sin(10)) = -160N$

$-(20 \cdot 9.8 \cos(10) \mu + 20 \times 9.8 \sin(10)) = -160$

$193.022 \mu + 34.035 = 160$

$193.022 \mu = 125.965$

$0.65 = \mu$

$20 \times 9.8 \cos(10) \times 0.65 + 20 \times 9.8 \times \sin(10)$

$= 159.499 \approx 160$

$\therefore \mu = 0.65$

The following excerpts are from Question 21. It required students to interpret complex written information to determine the rate at which a pump system can lift water into a reservoir.

Effective student responses:

- correctly determined the input power of two pump systems, including identifying the
  - work done
  - power
  - efficiency
- correctly determined the output power of the new pump system
- correctly determined the rate the new pump system will lift the water into the reservoir to the nearest whole unit.

These excerpts have been included:

- to illustrate a high-level response that is well-structured to clearly show the steps used to determine the answer to the nearest correct whole unit.

Excerpt 1

$P = \frac{E}{t}$ $E = w = F \times d$ S, R / main 6m Holding tank 6m 10m

S/ pump 1.

$E = F \times d$

$= 500 \times 9.8 \times 6$

$= 29400\ J$

$P = \frac{E}{t} = \frac{29400}{60} = 490W$

$\eta = \frac{\text{usable power}}{\text{input}} = \frac{490}{\text{input}} = 0.8$ ∴ input $= \frac{490}{0.8}$

$= 612.5W$

pump 2. $E = F \times d$

$= 500 \times 9.8 \times 4$

$= 19600\ J$

$P = \frac{E}{t} = \frac{19600}{60} = 326.66\ W$

input power $= \frac{326.66}{0.75} = 435.55W$

∴ total power $= 435.55 + 612.5 = 1048.05W$

Excerpt 2

S_2 / $P = 1048.05W$

Usable power $= 1048.05 \times 0.9 = 943.245W$

$P = \frac{E}{t}$, $943.245 = \frac{E}{60}$

$\therefore E = 56594.7J$

$E = F \times d$

$56594.7 = F \times 10$

$F = 5659.47N$

$F = ma$

$m = F/a = \frac{5659.47}{9.8} = 577.497kg$

$1L = 1kg$ $\therefore$ $577.497L$

$= 577L$ ~~every minute~~

$\therefore$ 577 L/min in system 2.

Practices to strengthen

When preparing students for external assessment, it is recommended that teachers consider:

- further development and application of Unit 4, in particular
  - Topic 1 subject matter knowledge in complex familiar and complex unfamiliar situations, including
    - using mechanical advantage and velocity ratio including gears and gear ratio
    - inclined planes, e.g. the parallel and perpendicular components of the weight vector
  - Topic 2 subject matter knowledge in complex familiar and complex unfamiliar situations, including the
    - microstructures of carbon steels and how these relate to relevant mechanical properties and industrial applications
    - current uses of plastics in a contemporary engineering context

- Topic 3 subject matter knowledge, including interpretation of specific conditions to create logic gate circuits that include clearly annotated inputs and outputs, e.g. on and off conditions for a range of familiar and unfamiliar contexts

- further development of students' abilities to fully read, interpret and understand the instructions provided in short response written and calculation questions, including understanding
  - of the cognitions in the question and how to respond appropriately to them
  - that answers to calculation questions must be provided as specified by the question, e.g. to the nearest whole unit, or to a number of decimal places with the correct unit provided
  - that written explanations must include all the relevant information as specified by the question.

Additional advice

- When performing a multi-step calculation, it is recommended that students leave rounding until the end of the calculation to reduce the risk of responses being out of acceptable tolerance ranges.
- When calculating the input power from the efficiency, it is recommended that students divide by the efficiency as a percentage of 100 in decimal form, e.g. 80% would be divide by 0.8 rather than multiplying by the total efficiency plus the efficiency lost. Interpreting 80% efficiency as 100% efficiency plus the 20% loss of efficiency, therefore multiplying the input power by 1.2 is incorrect practice.