

Course Companion

International Baccalaureate · IB Diploma · Design Tech- nology · SL

Every topic handout in one volume

exercises.lol

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Design in theory

International Baccalaureate · IB Diploma · Design Technology · SL

Scope and prerequisites

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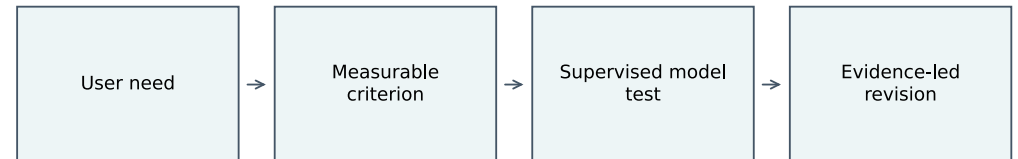
Designing for actual users

■ What would explain this observation?

- A handle that feels comfortable to its designer may exclude another user. Design evidence starts with the people and context of use.
-

■ Build the model

- Anthropometric data describe body dimensions.
- **Ergonomics** concerns the relationship between people, tasks and products.
- A design **specification** turns a user need into a measurable requirement.
- ergonomics: Designing the fit between people, tasks and products.
- specification: Measurable requirements a proposed solution should meet.



Turn a user need into a measurable criterion, test a model against it, then revise from the evidence

■ Choose evidence that can test it

- Choose data for the target population and task.
- Clearance often needs a larger-user percentile; reach may need a smaller-user percentile.
- A single mean dimension cannot satisfy every design constraint.

In the lab: Observe an approved low-risk task with consent, interview users without leading questions, and record measurable success criteria. Test an early model before committing to expensive materials. Do not collect unnecessary personal measurements.

■ Work from known quantities

- Known: a handle must withstand a 40 N use force with a design safety factor of 2.5.
- Target test load = use force $\times$ factor = $40 \times 2.5 = 100$ N.
- The factor is a design assumption to justify; it is not a substitute for a supervised safety review.

Your turn: A use force is 30 N and selected safety factor 3. Find target load.

■ Check the conclusion and its limits

- A specification is not a list of vague wishes such as nice or strong.
- User testing should evaluate measurable requirements and reveal conflicting needs.

Not true: A population mean dimension always accommodates every user. Designing for the mean fits the middle of a distribution and excludes the tails - often half the users. Ranges and percentiles, not the mean alone, decide accommodation.

Key:

- Anthropometric data describe body dimensions.
- Choose data for the target population and task.
- Watch for: A specification is not a list of vague wishes such as nice or strong.

■ Write from a target load of 80 N

- A handle must withstand a 20 N use force. The selected safety factor is 4.
- Find the target test load. The factor is a design assumption, not a safety review.

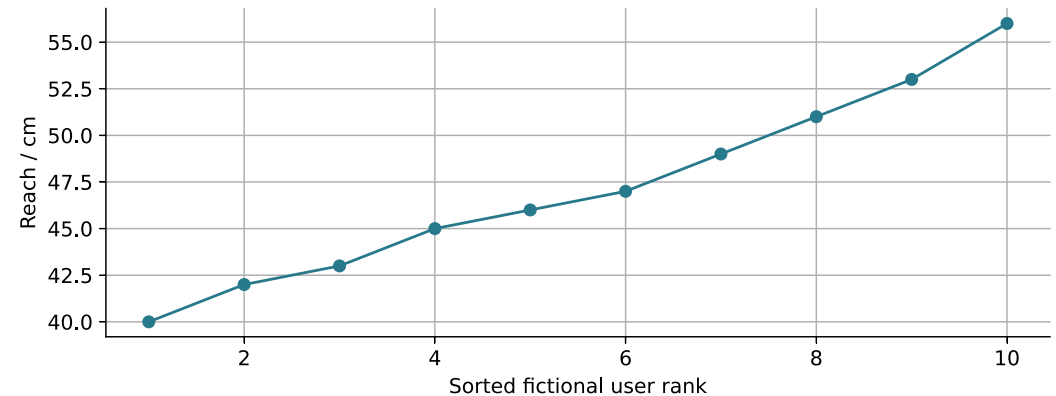
Ergonomics: fit a range of users

■ What would explain this observation?

- A handle sized for the average hand can exclude many intended users. Design decisions need a user range, task and context rather than one average.

■ Build the model

- **Anthropometry** measures body dimensions; **ergonomics** considers interactions between people, tasks and products.
- A percentile locates a value within a specified distribution.
- Choosing a lower or upper percentile depends on whether the dimension concerns reach, clearance or another function.
- Adjustable design may accommodate a broader range than a single fixed dimension.
- anthropometry: Measurement of human body dimensions for a specified population and method.
- ergonomics: Study of interactions between people, tasks and systems to inform design.



Ten sorted reaches from 40 cm to 56 cm: a reach dimension is set near the small end so short users are served

■ Choose evidence that can test it

- A clearance dimension often needs to consider larger relevant body dimensions, while reach can require smaller relevant dimensions.
- Neither principle automatically selects a universal percentile.
- The measured population, posture, clothing, capability and task determine relevance.

- Consider physical, perceptual and cognitive demands together rather than assuming body size explains every usability issue.

In the lab: Define a consenting user group and task. Use attributed data or anonymous teacher-approved measurements, record measurement posture and units, and test safe low-fidelity models before construction. Include users whose access needs differ. Set measurable acceptance criteria and retain qualitative feedback about grip, visibility and comprehension alongside dimensions.

■ Work from known quantities

- Known: sorted fictional reach measurements are 40, 42, 43, 45, 46, 47, 49, 51, 53 and 56 cm.
- Under a stated nearest-rank classroom convention, the 10th percentile uses rank $\text{ceil}(0.10 \times 10) = 1$, giving 40 cm; the 90th uses rank 9, giving 53 cm.
- A 53 cm control distance is beyond the recorded reach of eight users.
- The small fictional sample does not define a product standard.

Your turn: A stated nearest-rank method uses $\text{ceil}(p \times n)$. For $p = 0.90$ and $n = 20$, find the rank.

■ Check the conclusion and its limits

- Percentile methods differ, especially for small samples.
- A percentile is not a percentage of a body dimension.
- An average dimension and a successful test by one user do not establish accessible design.

Not true: A product dimension based on the mean automatically accommodates every intended user. Half of all users are above or below the mean, so a mean-based dimension excludes a large share by construction. Accommodation is judged across a range - often 5th to 95th percentile - not at the average.

Key:

- Anthropometry measures body dimensions; ergonomics considers interactions between people, tasks and products.
- A clearance dimension often needs to consider larger relevant body dimensions, while reach can require smaller relevant dimensions.
- Watch for: percentile methods differ, especially for small samples.

■ Write from rank 12

- A nearest-rank method uses the ceiling of percentile times sample size.
- The percentile is 0.80 and there are 15 sorted fictional measurements.

■ Write from a percentile range

- A door handle is placed for the 5th-percentile reach and sized for the 95th-percentile hand.
- The placement serves the shortest adult's reach; the size fits the largest hand – one product serving a RANGE, never the average user only.

■ Write from an inclusive check

- A control panel is tested on the design team, who are all right-handed.
- The sample proves nothing about left-handed or gloved users – inclusive design tests the full intended user range, not the designers.

Design in practice

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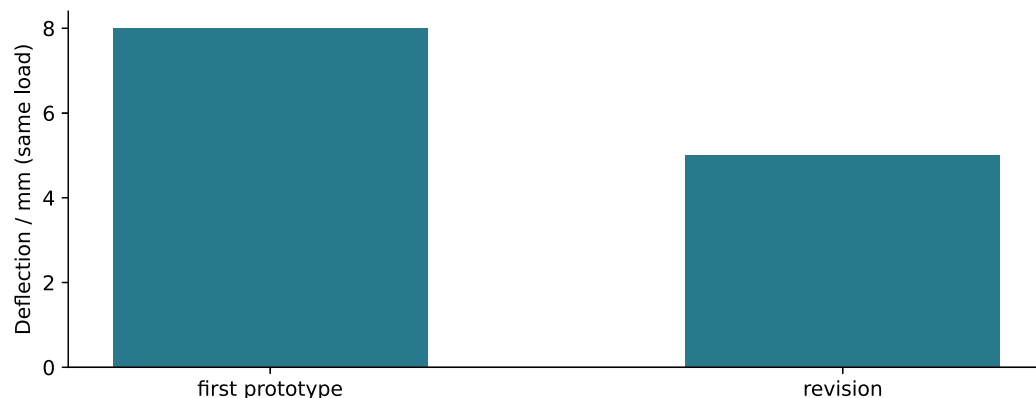
Models, materials and iterative prototyping

■ What would explain this observation?

- A cardboard **prototype** can reveal reach and arrangement without proving that the final material is strong enough. Different models answer different questions.

■ Build the model

- A model represents selected features of a design.
- A prototype supports testing before or during development.
- Material selection depends on mechanical properties, manufacture, use conditions and end-of-life choices.
- prototype: A developing version used to test a solution.
- **iteration** : Revision guided by evidence and repeated testing.



Deflection falls from 8 mm to 5 mm under the same load: a 3 mm, 37.5% reduction

■ Choose evidence that can test it

- State what each model includes and omits.
- Compare tests with the same load, geometry and conditions.
- Iteration means using evidence to revise a solution and testing the revision against the original success criteria.

In the lab: Make a low-risk model under school workshop rules. Record dimensions, material, process and test method. Use photographs, measurements and user feedback as evidence. Machines and load tests require teacher supervision and approved guards.

■ Work from known quantities

- Known: a beam prototype deflects 8 mm under a stated load; a revision deflects 5 mm under the same conditions.
- Reduction = $(8-5)/8 \times 100 = 37.5\%$.
- The result supports greater stiffness in that test, not proof of every strength or fatigue property.

Your turn: Deflection falls from 10 mm to 6 mm under equal conditions. Find percentage reduction.

■ Check the conclusion and its limits

- Stiffness is resistance to elastic deformation; strength concerns failure stress.
- A visually accurate model need not reproduce material behaviour.

Not true: An attractive model proves the final product mechanical safety. Appearance is not performance. Mechanical safety depends on material, geometry and manufacturing; a good-looking model proves only that the design looks right.

Key:

- A model represents selected features of a design.
- State what each model includes and omits.
- Watch for: stiffness is resistance to elastic deformation; strength concerns failure stress.

■ Write from a 25 percent reduction

- A beam deflects 12 mm. A revision deflects 9 mm under the same load, geometry and conditions.
- Find the percentage reduction. Cardboard can test arrangement without proving the final material.

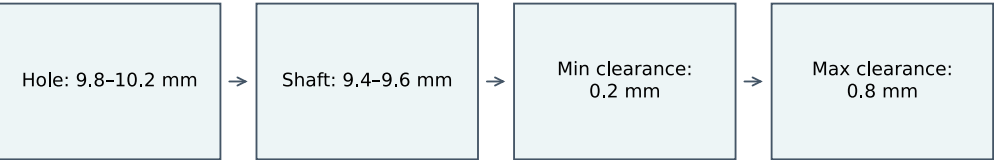
Manufacture: tolerances, variation and inspection

■ What would explain this observation?

- Two parts can each match a nominal drawing yet fail to assemble if allowed variation has not been considered. Manufacture produces a range of dimensions.

■ Build the model

- A **tolerance** specifies an allowed dimensional range around or beside a nominal value.
- Precision concerns consistency of repeated measurements or production, while accuracy concerns agreement with a reference.
- Process selection must consider material, geometry, quantity, surface finish, waste and achievable variation rather than appearance alone.
- tolerance: The allowed range of variation in a specified dimension.
- **clearance** : The dimensional space between mating parts under the stated model.



Minimum clearance = smallest hole – largest shaft = 0.2 mm; maximum = largest hole – smallest shaft = 0.8 mm

■ Choose evidence that can test it

- For a worst-case clearance model, subtract the largest shaft from the smallest hole for minimum clearance, and the smallest shaft from the largest hole for maximum clearance.
- The calculation assumes the stated dimensional limits and ideal geometry.
- Shape, alignment, temperature and measurement uncertainty can affect actual assembly.

In the lab: Use safe school-made models or a provided dimension dataset. Specify

dimension units, nominal values and limits before testing. Measure with an appropriate calibrated instrument at agreed positions, record every result and classify against the specified range. Retain rejected pieces and explain whether the problem concerns the design limits, process variation or measurement method.

■ Work from known quantities

- Known: a hole is 10.0 ± 0.2 mm, giving 9.8–10.2 mm; a shaft is 9.5 ± 0.1 mm, giving 9.4–9.6 mm.
- Minimum clearance is $9.8 - 9.6 = 0.2$ mm and maximum is $10.2 - 9.4 = 0.8$ mm.
- This model predicts positive clearance across the stated limits.
- It does not establish strength or fitness for a safety-critical application.

Your turn: A hole ranges from 12.0 to 12.4 mm and a shaft from 11.5 to 11.8 mm. Calculate minimum clearance.

■ Check the conclusion and its limits

- A tighter tolerance can increase cost, inspection time and waste, and may not improve the user outcome.
- A measuring instrument with a fine display does not automatically have the accuracy required to accept a part near its limit.

Not true: A finer instrument display guarantees sufficiently accurate dimensional inspection. Display resolution is not accuracy: an instrument can show 0.001 mm while being systematically off by far more. Inspection near a tolerance limit needs a calibrated instrument with proven accuracy.

Key:

- A tolerance specifies an allowed dimensional range around or beside a nominal value.
- For a worst-case clearance model, subtract the largest shaft from the smallest hole for minimum clearance, and the smallest shaft from the largest hole for maximum clearance.
- Watch for: A tighter tolerance can increase cost, inspection time and waste, and may not improve the user outcome.

■ Write from a minimum clearance of 0.1 mm

- A hole ranges from 20.0 mm to 20.3 mm. A shaft ranges from 19.6 mm to 19.9 mm.
- Find the minimum and maximum clearance. The limits do not prove strength.

■ Write from a Young modulus comparison

- Two beams have the same shape; one material is three times stiffer.
- Under the same load the stiff beam deflects one-third as much – stiffness is a MATERIAL choice; deflection also follows shape, so change one at a time.

■ Write from a tolerance stack

- Three parts in series each may be 0.1 mm off.
- The assembled length may be off by up to 0.3 mm – tolerances STACK along a chain, which is why assemblies specify the worst case.

Design in context

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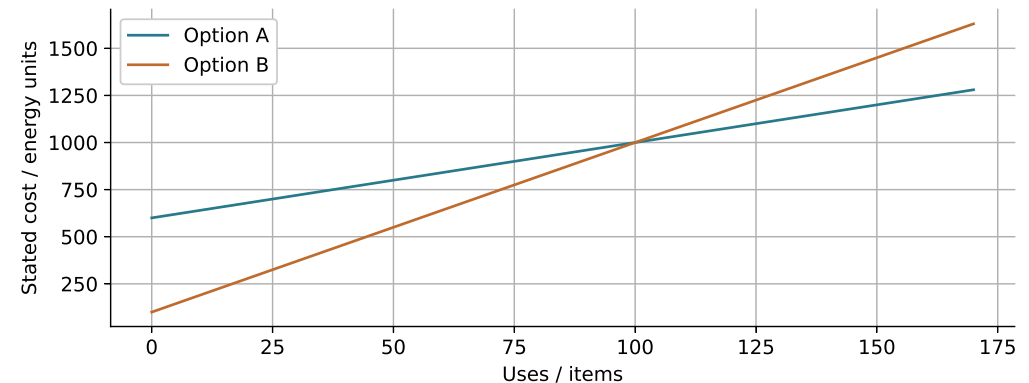
Design sustainability and production choices

■ What would explain this observation?

- A repairable product may cost more initially but stay in service longer. A design decision needs evidence across manufacture, use and disposal.

■ Build the model

- **Design for disassembly** supports separation of materials and replacement of parts.
- Manufacturing choices depend on production volume, **tolerances**, material properties and cost.
- Sustainability includes environmental and social effects.
- design for disassembly: Design supporting separation and replacement of parts.
- tolerance : An allowed dimensional variation.



Option A ($600 + 4n$) and option B ($100 + 9n$) cost the same at $n = 100$; above that A is cheaper

■ Choose evidence that can test it

- Compare a common service over a stated lifetime.
- Separate fixed tooling cost from cost per item.
- Include repair, energy, transport and realistic end-of-life pathways rather than using a recycled label as the whole judgement.

In the lab: Create a bill of materials and an annotated assembly plan. Test whether a worn part can be replaced with normal tools. For HL project development, evaluate production feasibility and commercial assumptions against the applicable cohort guide.

■ Work from known quantities

- Known: method A costs 600 fixed units plus 4 per item; method B costs 100 fixed units plus 9 per item.
- Equality: $600 + 4n = 100 + 9n$.
- Rearranging: $500 = 5n$, so $n = 100$ items.
- Other quality and sustainability criteria may change the choice.

Your turn: Fixed costs differ by 400 units and unit costs differ by 5. Find cost break-even quantity.

■ Check the conclusion and its limits

- A cheaper process is not automatically preferable.
- Cost estimates need currency, quantity and assumptions, and prototypes do not prove mass-production consistency.

Not true: A recycled-content label establishes the entire product life-cycle impact. Recycled content describes one input. The full life-cycle impact also includes manufacturing energy, transport, use phase and end-of-life; one label cannot establish all of them.

Key:

- Design for disassembly supports separation of materials and replacement of parts.
- Compare a common service over a stated lifetime.
- Watch for: A cheaper process is not automatically preferable.

■ Write from a break-even of 200 items

- Method A costs 900 fixed units plus 3 per item. Method B costs 300 fixed units plus 6 per item.
- Find the quantity where the costs are equal. Quality and disposal can still change the choice.

■ Write from a full-life comparison

- Method A is cheaper per item; method B lasts twice as long before disposal.
- Recompute the cost PER YEAR OF SERVICE: doubling service life can beat a lower unit price – sustainability arithmetic is a life-cycle choice, not a shelf choice.

■ Write from a circularity check

- A proposed product is recycled at end of life, but only 60 percent by mass.
- The other 40 percent is waste – a circular claim names the fraction, the route and the energy cost, or it is marketing.

Design project

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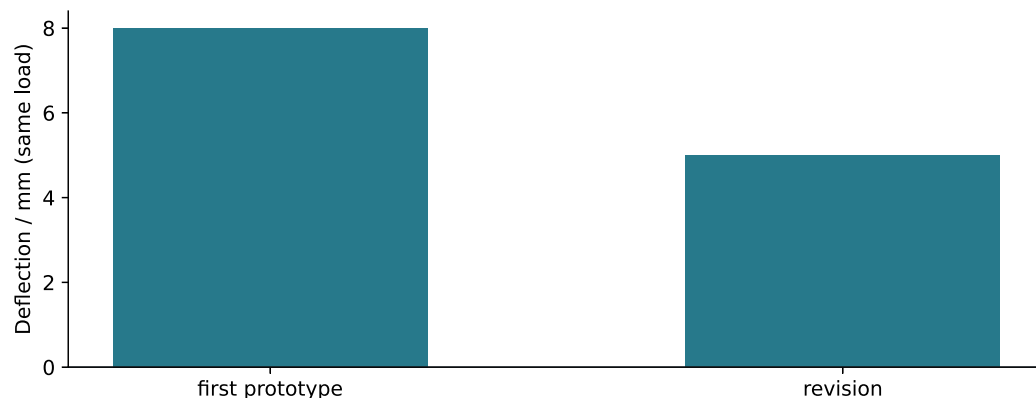
The design project: fit, models and evidence

■ What would explain this observation?

- A locker shelf built to the average student height fits nobody: the tall cannot reach past it, the short cannot see under it. Design is the fit between people, tasks and products, and an average is not a fit.

■ Build the model

- Choose anthropometric data for the target population and the task.
- Clearance often needs a larger-user **percentile** ; reach may need a smaller-user percentile.
- A single mean dimension cannot satisfy every design constraint.
- A **model** is a developing version used to test a solution.
- percentile: The value below which a stated share of the population falls.



Deflection falls from 8 mm to 5 mm under the same load: a 3 mm, 37.5% reduction

■ Choose evidence that can test it

- Observe an approved low-risk task with consent; interview users without leading questions.
- Record measurable **success criteria** before building.
- Test an early model before committing to expensive materials.
- State what each model includes and omits; compare tests under the same load, geometry and conditions.

In the lab: Make a low-risk model under school workshop rules; record dimensions, material, process and test method; photographs, measurements and user feedback are the evidence.

■ Work from known quantities

- Known: the shelf must clear the 95th-percentile bag (clearance, larger users) and stay within the 5th-percentile reach (reach, smaller users).
- Success criteria: a loaded school bag retrievable in 10 seconds, one-handed, from a seated position.
- Cardboard model 1 tests fit only (geometry right, strength out of scope, stated).
- Ply model 2 repeats the same 5-kilogram load test: the comparison is like-for-like.

Your turn: A handle must suit grip width and door thickness. Which percentiles would you ask for first?

■ Check the conclusion and its limits

- Iteration means using evidence to revise a solution and testing the revision against the original success criteria.
- A model that changes two variables at once cannot attribute the improvement.

Not true: The next prototype is better because it is more advanced. Better is a judgement against the original success criteria under the same conditions.

Key:

- Percentile by constraint: clearance large, reach small.
- Success criteria measurable before the first model.
- Watch for: two variables changed between tests.

■ Write from a percentile choice

- Seat width is a clearance dimension; a control's placement is a reach dimension.
- Clearance takes the 95th percentile (fit the large), reach takes the 5th (serve the small) – percentile by constraint.

■ **Write from a measurable criterion**

- Replace comfortable with mean rating at least 4 of 5 across 10 users.
- A criterion measurable before the first model can be failed by it – that is its job.

■ **Write from a single-variable test**

- Two seat prototypes differ in tilt AND padding; users prefer the second.
- Neither variable's effect is isolated – change one, hold the rest, or the test answers nothing.

■ **Write from an iteration decision**

- Prototype 2 rates higher, but it changed two things at once.
- The next test isolates the single variable with the larger effect – one variable per iteration is what makes a design project learn.