Physical design workshop

Student handout - Class 4 - one evolving LEGO model per group

Research question

How do diet and housing affect average daily gain in growing pigs, and does the effect of diet depend on housing?

Study structure

The facility has four rooms. Each room contains four pens, and each pen contains six pigs. Feed and enrichment are applied to whole pens. Every pig is weighed.

Factor	Levels	LEGO notation
Diet	Standard; high-fibre	Green/red 1x4 tiles
Housing	Standard; enriched	Transparent blue plate absent/present

Kit limit

Your kit contains one dark-grey 32x32 baseplate, four azure 16x16 room plates, sixteen yellow 4x4 pen plates, 96 pink 1x1 pig bricks, 16 green and 16 red 1x4 tiles, and 96 transparent 1x1 plates in each of five colours: clear, light blue, yellow, orange and green. The main activity uses eight tiles of each diet colour and eight transparent blue plates for enrichment. Reuse the same pieces at every stage. Do not build a second facility.

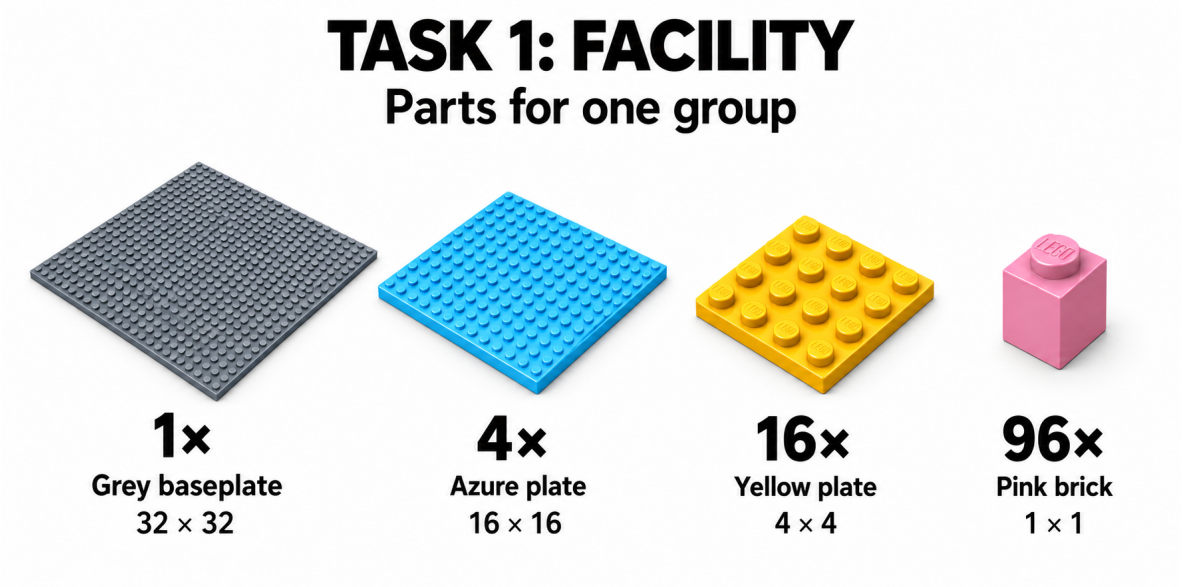
Group roles

Role	Responsibility
Builder	Moves pieces after the group agrees
Recorder	Records the realised allocation
Design lead	Explains the scientific reasoning
Skeptic	Checks confounding, replication and randomisation

Working rule

A moved treatment marker represents a real change to the experiment. Record each realised allocation before rebuilding.

Task 1: Build the facility



Place the four azure 16x16 room plates on the dark-grey 32x32 baseplate. Place four yellow 4x4 pen plates in each room, using all 16 pen plates and all 96 pink pig bricks. Put six pigs in each pen. Label rooms 1-4 and pens 1-16. Do not add treatment markers yet.

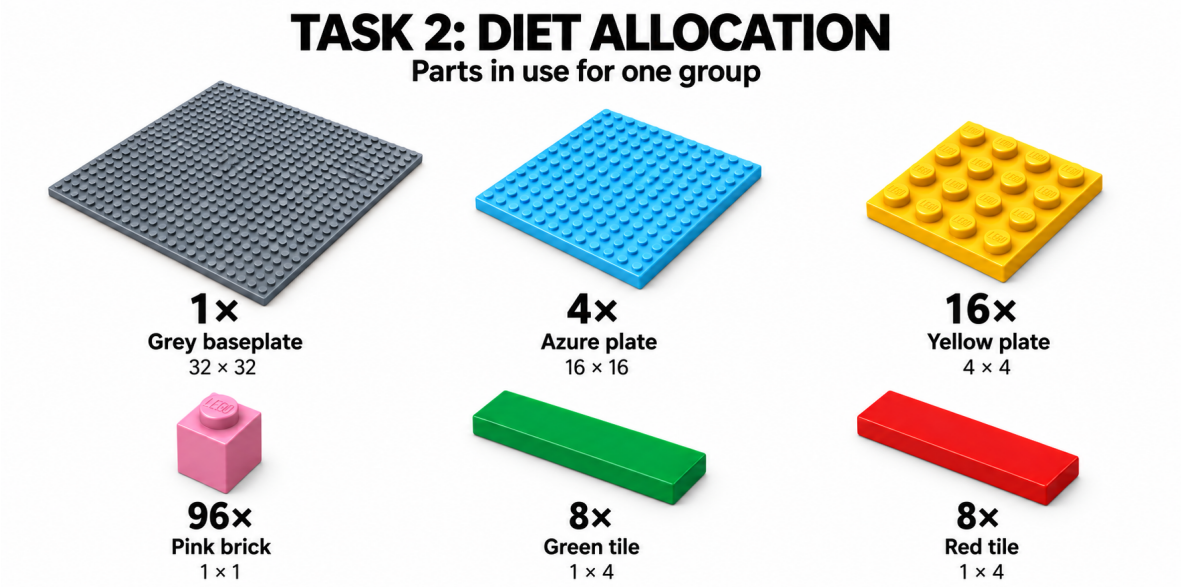
Sketch or photograph reference for your facility

Question	Group answer
What is the experimental unit?	
What is the observational unit?	
How many experimental units are available?	
How many animal observations are planned?	
What grouping could act as a block?	
Why can pigs in one pen not receive different diets?	

Checkpoint

The group must agree on the experimental unit before collecting diet markers.

Task 2: First diet allocation



Keep the facility and pigs from Task 1. Add only the eight green and eight red tiles shown. Counts are for the complete model, not additional copies.

Add 8 green standard-diet markers and 8 red high-fibre markers. Arrange them in any way your group initially considers sensible. Do not consult another group.

Record the layout before changing it

Room	Position 1	Position 2	Position 3	Position 4
Room 1				
Room 2				
Room 3				
Room 4				

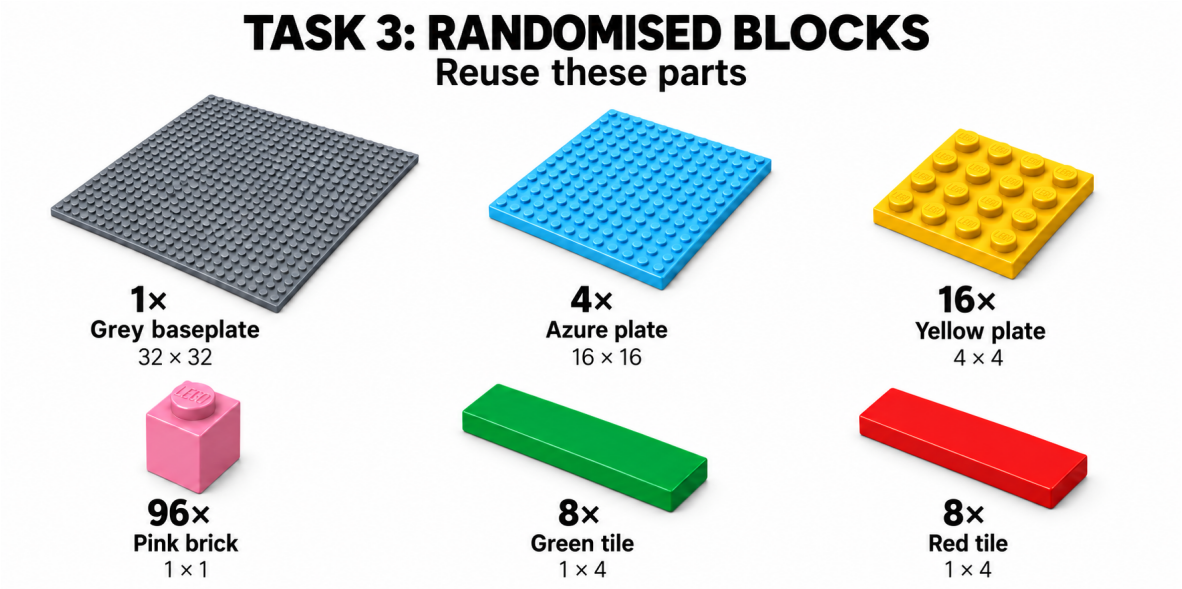
Why did your group choose this allocation?

Design diagnosis

Check	Yes / no	Evidence
Eight pens receive each diet		
Both diets occur in every room		
Chance determined pen positions		
A diet effect can be separated from room		

What could be mistaken for a diet effect?

Task 3: Randomised blocks



Reuse Task 2's pieces. No additional LEGO is required. Keep a cup or bag available for the unseen draw.

Rebuild the diet allocation. Every room must contain two green and two red markers. For each room, mix two green and two red markers unseen and draw one marker for each pen position. Repeat the draw separately in all four rooms.

Three distinct features

Balance fixes the treatment counts. Blocking places both diets in every room. Randomisation uses chance to choose the pen positions.

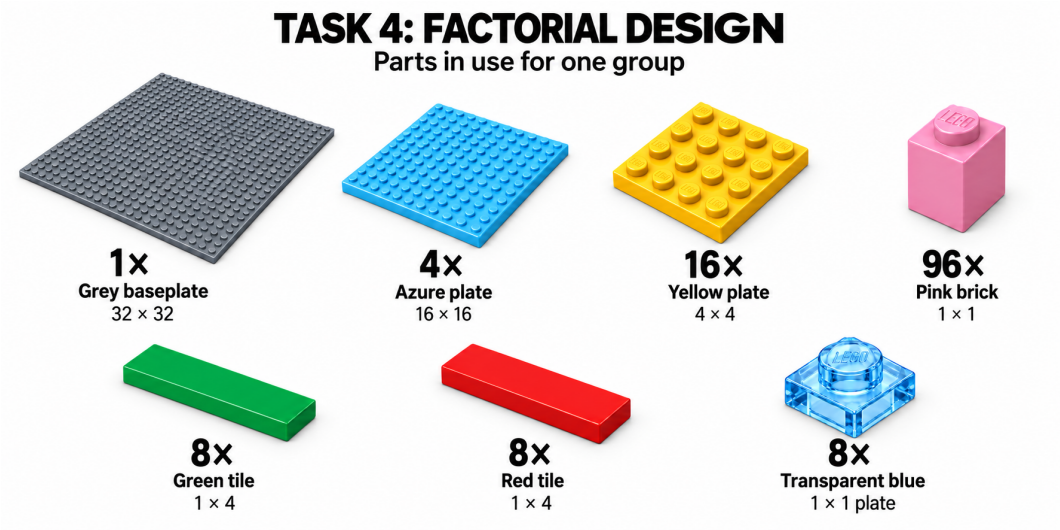
Realised allocation

Room	Position 1	Position 2	Position 3	Position 4
Room 1				
Room 2				
Room 3				
Room 4				

Audit	Required result	Observed
Diet counts overall	8 green; 8 red	
Diet counts in every room	2 green; 2 red	
Chance procedure	Separate unseen draw per room	
Allocation record	All 16 positions recorded	

Why would a fixed green-red-green-red sequence fail the randomisation check?

Task 4: Factorial design



Keep the same 16 pens, pigs and diet markers. Add exactly 8 blue enrichment markers. The four treatment combinations are:

Code	Diet marker	Housing marker
SS	Green	No blue
HS	Red	No blue
SE	Green	Blue
HE	Red	Blue

Design constraints

• Every room contains one SS, one HS, one SE and one HE pen.

• Shuffle the four printed combination cards separately within each room.

• Place diet and enrichment markers to match the card drawn for each pen.

• Record the realised order. Do not copy the same positional order into every room.

Realised factorial allocation

Room	Position 1	Position 2	Position 3	Position 4
Room 1				
Room 2				
Room 3				
Room 4				

Audit	Required result	Observed
Each combination overall	4 pens	
Each combination in every room	1 pen	
Diet totals	8 green; 8 red	
Housing totals	8 without blue; 8 with blue	

Group check

No new pieces. Keep the completed Task 4 model and all its markers in place.

Stay with your own model. Check the questions below together and show your allocation record to the instructor. Keep the model intact. After the instructor checks your reasoning, collect your stress-test card.

Audit question	Evidence from the model or record
What is the experimental unit?	
Does every room contain all four combinations?	
Are the overall factor totals balanced?	
What chance procedure produced the positions?	
Could either factor be confounded with room?	
How many independent replicates exist per combination?	
How many pigs are observed per combination?	

One strength of the design

One question for the instructor

Stress test

Use the parts inventory on your own group's stress-test sheet. Keep the completed model; add or remove only the pieces specified on that sheet.

After the instructor checks your model and allocation record, open your group's stress-test card. Change the physical model only as the card requests. Then classify exactly what changed.

Feature	Before challenge	After challenge
Experimental units available	16 pens	
Animal observations available	96 pigs	
Treatment replication	4 pens per combination	
Balance	One combination per room	
Repeated measurements	One planned growth response	
Missingness or protocol deviation	None	

What should the researcher do next, and why?

What should be documented in the experiment record?

Give the instructor a 90-second report, then complete your design table.

Design table

No new pieces. Keep the current model and use your saved allocation record.

Create one row per pen. Use your realised factorial allocation, not an idealised order.

Room	Pen	Diet	Housing	Combination	Pigs planned
1	1				6
1	2				6
1	3				6
1	4				6
2	5				6
2	6				6
2	7				6
2	8				6
3	9				6
3	10				6
3	11				6
3	12				6
4	13				6
4	14				6
4	15				6
4	16				6

Checks

- The table contains 16 rows and 16 distinct pen identifiers.
- Each treatment combination occurs four times overall.
- Every room contains all four treatment combinations.
- Diet and housing repeat for all six pigs within a pen in an observation table.

Optional build challenge

Each challenge sheet has its own parts inventory. Quantities show the pieces used by one group, including reused pieces. Put all unlisted markers aside. If a stress test removed pieces, restore the stock before selecting the next build.

After completing the stress test, report-back and design table, ask the instructor for one build-challenge card. Save the original allocation and stress-test record before rebuilding. Use only the pieces already in your kit.

Challenge routine

Build the specified layout. Diagnose its design properties. Repair it when the card asks for a repair. Be ready to justify every change.

Question	Group response
What design did the card require?	
What is balanced?	
What is blocked?	
What was randomised?	
What is confounded or otherwise limited?	
How many independent pen replicates remain?	
What repair or conclusion is justified?	

Record the realised layout or repair

Start rebuilding only after the instructor checks your design table. Keep the original allocation and stress-test records.

Four-factor allocation record



Use with Challenge 9. List every distinct combination on scrap-paper slips, shuffle them, and record the allocation to numbered pens. Record actual factor levels, including absent markers. All six pigs in a pen share its allocation.

Pen	Diet	Housing	Feeding	Lighting
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				

How many pens receive each complete combination? How many receive each factor level?

With the same 16 pens, what would you change to obtain replication within combinations?

Exit questions

Answer individually about the original two-factor, four-room experiment before the group packs away the model.

1. What is the experimental unit, and what feature of treatment application determines it?

2. What is the block, and what comparison does it support?

3. How many independent pen replicates are there per treatment combination?

4. What scientific question does the interaction address?

5. Would weekly weighing increase treatment replication? Explain.