

## Working as Design Engineers

### The K'NEX Pedestrian Bridge Project

#### INTRODUCTION

Many students believe that a design and create assignment ends when they can demonstrate that their product works. In real life, however, the process of getting a product to its target market can often be lengthy.

Professional designers and engineers operate in a world in which their designs must not only work and be aesthetically pleasing, but they must sell at the right price, in the right market, and generate a good profit for all those who have invested in the development and production. For a company to be successful it must be able to gain repeat sales, often from the same customer – their satisfaction is critical to a company's profitability.

Moving from a single prototype to full production is a complex process requiring much planning. In addition, the manufacturing process itself must be cost effective if it is to meet the financial requirements of the business that markets and sells the product.

Nowhere is this more important than in the development of a large structure such as a bridge or tunnel, especially as there is sometimes only one chance to get it right. Mistakes in the construction industry can be very expensive to rectify. For example, the cost of removing the excessive movement in London's Millennium Bridge across the River Thames – a pedestrian bridge, first opened in 2000 - was \$7.5million. Controlling manufacturing or construction costs, therefore, is one essential requirement for any successful business.

This activity is designed to give students an opportunity to experience for themselves some

of the issues faced by professional engineers. Depending on the ages, aptitudes and interests of the students, they can also make use of spreadsheet software to cost and model their plans, use computer aided design (CAD) software to produce simple working drawings, and use planning software to create flow diagrams or make use of Gantt planning charts. This activity builds upon the skills acquired by students in previous sections.

#### THE K'NEX PEDESTRIAN BRIDGE CHALLENGE

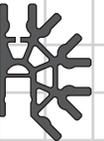
A whole class activity involving project teams, each comprised of approximately 4–6 students. Each team adopts the role of a Design Engineering company.

#### OBJECTIVES

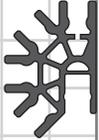
The K'NEX Pedestrian Bridge Challenge is intended to help students learn and develop a range of key skills as they work on a design and technology project in which they take a product – a bridge – from the design phase through to its final construction. Their bridge must meet cost and time parameters laid down in the product specification.

#### The key skills identified include:

- *Communication* – through the generation and exchange of ideas, with peers and teachers, concerning the design of a bridge that meets the specifications.



# Design Project



## SECTION IV

- *Numeracy* – through measurement, estimation and costing of activities and materials needed for the construction of a structure designed by the students.
- *Planning* – to take into account the relative costs of materials, labor and time when deciding how best to use available resources to successfully complete a design and create task.
- *Team building* – within a large group project, to generate and discuss their own and other people's ideas. To deal with conflicting views and to agree on the best way to work together to achieve a common goal.
- *Problem solving* – not only solving specific design and technology problems, but also to be able to deal with and resolve conflicting needs resulting from the project.
- *Information Technology* – in the reviewing of information, preparation and presentation of their work, and processes involved in completion of a bridge design task.
- *Improving on learning performance* – at the end of the project students will be encouraged to evaluate the whole process and to identify where and how they might improve their overall performance.

### TIME REQUIRED

The project can take place over the equivalent of one 35-minute and two 70-minute sessions. Part of an additional lesson may be needed to complete the review and evaluate their performance.

#### First session

35 minutes:

Understanding the design specifications and initial brainstorming session.

#### Second session

70 minutes:

Finalizing bridge design, drawing plans, costing materials and planning construction.

#### Third session

70 minutes:

Construction, testing, review and presentation of company results.

### MATERIALS

- K'NEX Real Bridge Building set(s)
- Copies of the Design Engineering Guidelines for Students
- Copies of the Suppliers Price List/Order Form for each team
- Weights or masses (10g-1000g)
- Flip chart paper or large sheets of paper

### SCENARIO

The development of new roads throughout the region has identified a need for a number of pedestrian bridges.

The company that can design and successfully construct a bridge that meets the

- customer's design specifications
- at the lowest cost
- and can complete on time,

can expect to be rewarded with additional contracts for similar projects in the future. These contracts will provide security for the company and its workforce for many years ahead.

# Design Project

## THE RULES

Each company will receive the same set of design specifications. The design teams within the company must:

- Design a structure to meet the specifications.
- Complete construction within 30 minutes.
- Prepare a presentation to market/sell their design to the customer (maximum of 3 slides for each presentation and maximum 5 minutes presentation time). No extension to the 5-minute time will be allowed.
- The presentation should also include the company's estimate for the total cost of the project to the customer. Designing time is not to be included in the construction cost estimates.
- Shareholders expect a minimum profit of 20% of the total construction costs:  
i.e. Project cost = construction cost + profit  
(20% of construction cost)

## BONUS PAYMENTS

Completion of construction ahead of schedule:  
\$100 per minute.

The total value of bonus payments will be added to the estimated company profit. If, however, the structure fails to meet the design specifications, no bonus payments will be made and penalties will apply.

## PENALTIES

- Overrun of contract: \$150 per minute.
- Structure fails to meet the design specifications: 50% of the value of the contract.

The total value of the penalties will be deducted from the company profit on the contract.

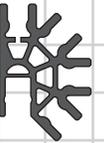
## CONTRACT AWARD

This will go to the company whose design meets their customer's specifications and requirements and makes the greatest profit margin.

## EXTENSION IDEAS

Students could be asked to build a *factor of safety* into their designs and have their bridges tested until failure occurs.

The activity can be extended to the use of other materials including balsa wood or other suitable woods that require a different set of construction skills, knowledge and understanding of materials.



## Design Project

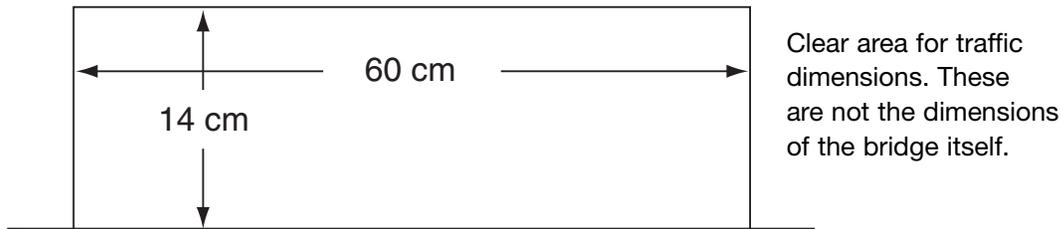
# Design Engineering Student Guidelines

## The K'NEX Pedestrian Bridge Project

### Sunrise County Public Bid # 78680

#### Job specifications for a pedestrian bridge

1. The bridge should consist of two towers connected by a pedestrian walkway.
2. A clear area for traffic to pass under the bridge will be a box 14cm. high by 60cm. wide. No part of the bridge structure may pass through this clear area.



3. The minimum width of the pedestrian walkway will be 6.5cm.
4. The completed bridge must be capable of supporting a load of 2kg placed anywhere on the pedestrian walkway. (When being tested, the bases of each tower may be supported because in the real world these would be set in concrete footings which would stop them moving outwards.)
5. The bridge must remain level when loaded.
6. Foot access to the bridge walkway need not be included in the design at this stage.

### SUNRISE COUNTY PEDESTRIAN BRIDGES PROJECT: GUIDELINES FOR COMPANIES

The development of new roads throughout the region has identified a need for a number of pedestrian bridges.

The company that can design and successfully construct a bridge that meets the

- customer's design specifications
- at the lowest cost
- and can complete on time (30-minutes construction time),

can expect to be rewarded with additional contracts for similar projects in the future.

These contracts will provide security for your company and your workforce for many years ahead.

# Design Project

## TIME SCALE

- You have three sessions (the first of 35-minutes and two of 70-minutes) to complete the design, planning and construction of a pedestrian walkway bridge.
- Your company design team can use the first two sessions to research and develop ideas, design, cost, and plan how your company can construct the footbridge within the time limitations. In the final session your company will build and test your bridge design.

## COST FACTORS

- Your company will be given a supplier's price list for the K'NEX building materials that you will need to purchase before starting construction.

## Organizing your Resources

### I: Designing and planning phase (35 minutes)

#### WHAT TO DO FIRST

1. Review the job specification for the pedestrian footbridge and the rules of the competition.
2. Make sure that all members of the company understand what has to be accomplished and the rules of the competition. If unsure ask your teacher to explain.
3. Good planning is the key to any successful project. During this phase it is up to your team to look at the resources available - human as well as material - and to plan how best they can be used to complete tasks within the time available.

## WHAT TO DO NEXT

4. As a team, decide what type of bridge will meet the job specification. Remember that the company has only 30 minutes of construction time.
5. Brainstorm ideas:
  - Use a flip chart (if available) or a large piece of paper to write down everyone's ideas before discussing them one by one.
  - Every person on the team has a valid contribution to make and every idea should be evaluated on its merits.
  - Remember to check with the job specifications to make sure your ideas keep on track.
6. Finish the session with an agreed outline bridge design to take forward to the next planning session.

### II: Designing and planning phase (70 minutes)

#### WHAT TO DO

1. Finalize the decision about the bridge type you will design.
2. Assigned tasks to company members.
3. Produce plan drawings (front, side and top elevations).
4. Decided how the bridge will be constructed.
5. Produce estimates for the K'NEX building material costs.
6. Present the bridge design and cost estimates for the project to the customer (your teacher) before the end of this session. Remember other teams also need to do this, so book an appointment with your customer at a time that best suits your company.



# Design Project

## SUGGESTIONS

- Keep your presentation short and to the point – your customer is very busy and does not have much time.
- Look at the design specifications and see what the customer is really looking for from your design.
- Although the maximum time allowed is 5 minutes; plan for 3 minutes as presentations often overrun.

## ESTIMATING THE BRIDGE'S TOTAL CONSTRUCTION COSTS

Your company must take the following into account:

1. Cost of materials.
2. Construction costs.
3. Company profit.

### 1. Estimating Cost of Materials

- K'NEX components as per **suppliers price list** (make sure you obtain this from your teacher)
- Plastic decking – sold at \$100 per piece.
- Card – sold at \$10 per cm.

An order form for K'NEX building materials must be completed and the cost estimated by the end of this session. This order form will be used to collect the K'NEX components from your supplier (your teacher) at the start of the next session.

#### **Note:**

**(i). If you need additional components to complete your bridge after submitting your order, then prices are doubled.**

**(ii). Any components left over at the end of construction must be sold back to the supplier at half the original price.**

### 2. Estimating Construction Costs

- \$300 per minute per person in the construction workforce.

**Note: the whole team need not be involved in the construction of the bridge. Construction costs are high but construction time is short (30 minutes) and the project cannot be too expensive.**

**Plan for construction. Can any parts of the bridge be sub-assembled before being put into the final bridge construction?**

- To calculate the labor costs, first estimate the construction time in minutes. Then multiply the construction time (in minutes) x labor cost per minute x number of people involved in the bridge construction.

For example:

$$20 \text{ minutes} \times \$300 \times 4 \text{ people} = \$24,000$$

### 3. Estimating Company Profit

- Shareholders in your company expect a minimum profit of 20% of the total construction costs.

i.e. Project cost = construction cost + profit (20% of construction cost)

If the total construction cost of the bridge is \$100,000

$$\begin{aligned} \text{Project cost} &= \$100,000 + \$20,000 \\ &= \$120,000 \end{aligned}$$

#### **Note: The Successful Company**

The contract for the project will be awarded to the company whose design meets its customer's specifications and requirements and makes the greatest profit.



## SECTION IV



# Design Project

## Ideas to help you work through the planning sessions

1. Make sure you all understand the design brief. Clarify with the customer - your teacher - if uncertain.
2. Brainstorm/discuss/research/test possible designs for your bridge. Remember every team member's ideas should be considered. Write all the ideas down on a large piece of paper first and then discuss them. Always keep the job specification in mind.
3. Use your K'NEX Real Bridge Building components to model and communicate ideas within the team. Can you use, or modify, the plans for bridges you have previously constructed for this project?
4. Draw up plans for your bridge design. Ask yourselves:
  - a. Can it be built in the time available?
  - b. Can components that are needed be identified?
  - c. Do the plans allow your team to prepare a cost estimate for the materials?
  - d. Can everyone in the construction team understand the plans and their own role in the project?
  - e. Will the completed structure function as intended?
  - f. Are there potential weak areas?
  - g. Does it meet the measurement specifications?
5. Look at the total time available and the tasks you need to complete in that time. List the tasks and set a time to complete each task. Can different tasks be done at the same time? Which tasks depend on another being completed first? Sequence the tasks in the order they need to be done - use a flowchart or timeline for this.
6. You may find that the total time needed to complete tasks is greater than the actual time available in class. You may therefore need to agree to allocate (delegate) specific tasks to members of the team.

For example: the whole team may be involved in designing the bridge but planning how to construct the bridge in 30 minutes and the preparation of the company presentation and calculation of project cost may need to be done at the same time. Separate teams can work on these tasks. Allow a few minutes for the whole team to be informed about each team's work.
7. Someone could be given the responsibility of making sure team tasks are completed on time or negotiating additional time from other company members if needed.
8. Where separate teams are involved in carrying out different tasks, a member of each team should be responsible for keeping the team to its allotted time.
9. Always allow time for tasks to overrun. Keep some time free at the end, just in case it is needed.
10. When planning how to construct your bridge, consider if all, or only some, team members need to be involved. *Remember you need to keep construction costs to a minimum but still need to get the job done in time – beware of penalty costs!*
11. Consider the following:
  - Who will make the plan drawings?
  - What roles need to be fulfilled and what are their responsibilities? For example: Project Manager to make sure work is completed on time and meets specifications; Logistics Manager to make sure all the supplies are in the right place at the right time; Construction workers to actually make the bridge.



# Design Project

- Do team members' skills match the job they are required to do?
- Can some team members be involved in sub-assembly work while a small number complete the construction?

## III: Construction Phase (70 minutes)

### RECOMMENDED TIME ALLOCATION

#### 15 minutes (maximum)

- Final check of design and K'NEX components list.
- Collect K'NEX components from supplier and prepare site for the start of construction.
- You are allowed to have all your K'NEX components laid out for easy and fast access to help the bridge construction.
- You are not allowed to pre-assemble any parts of the bridge before construction starts.
- Once construction has started, pre-assembly of bridge parts can take place.

#### 30 minutes (maximum)

- Bridge construction.
- No materials can be left on the building site. All unused materials must be returned to the supplier and their value worked out.

#### 25 minutes (maximum)

- Test bridges.
- Complete profit/loss calculations.
- Review and evaluate performance and lessons learned from the project.
- Present company results and conclusions to class.



## SECTION IV



## IV. Suppliers Price List

A PART IDENTIFICATION	B COLOR	C COST/ITEM	D QUANTITY ORDERED	E SUB-TOTAL COST [ column (c) x column (d) ]
	Light gray	\$10		
	Black	\$10		
	Blue	\$10		
	Black	\$10		
	Brown	\$20		
	White Speckled	\$20		
	Green	\$50		
	White	\$50		
	Blue	\$70		
	Dark gray	\$40		
	Black	\$10		
	Light gray	\$20		
	Blue	\$40		
	Dark Speckled gray	\$60		
	Green	\$80		
	Light Gray long	\$90		
	Light gray	\$5		
	Bright blue	\$5		
	Black	\$100		
	Transparent White	\$20		
	Black	\$30 per 30 cm.		
<b>Card</b>		\$10 per cm.		
NAME:			TOTAL COST	

**Note:**

- Returned items will be bought back at 50% of the original cost.
- Additional items will be charged at double the original cost.