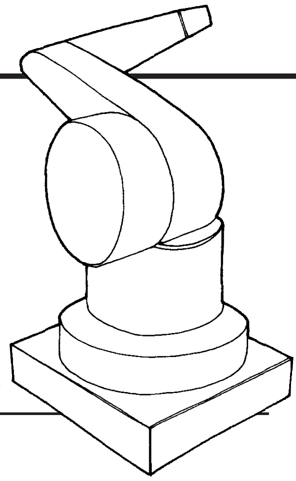
Robots are go!



The big picture

Task

To design and make a simple pick-and-place robot, paying special attention to the manipulator.

The story so far

Small robot units are often used in situations that are too dangerous for human operators – bomb disposal, handling hazardous materials, clearing blockages in pipelines, unmanned undersea and space operations. Other types of robot are used for tasks that can be carried out by humans.

The advantages of using a robot are that they can repeat complex operations precisely for long periods of time without needing to rest. It is against this background of the increasing use of robots that students are asked to develop a simple, small-scale pick-and-place prototype that could be used as a toy.

Learning

Designing

Using developments in industrial practice as a stimulus for designing.

Making

Constructing simple moving structures from wood, metal and plastic.

Building electrical and mechanical systems into a structure.

Technical matters

Linking electrical and mechanical systems. Computer control of electrical and mechanical systems.

Other matters

Developments taking place in robotic engineering. Social and economic implications of the new technologies.

Design decisions

The sort of product

This has been decided by the teacher – a toy pick-and-place robot.

The point of sale

The student can decide where the toy might be sold. This will depend to some extent on who the toy is for.

The customer

The student can decide whom the toy is for. If it is very simple it could be for a young child, if more complicated for an older child, and if sophisticated it could be an executive toy.

The performance of the product

This has been decided by the teacher – the toy robot will be able to pick up and place small objects.

The appearance of the product

The student will decide the overall style of the robot – clumsy and chunky to appeal to a young child, as opposed to slim and elegant for an executive.

The way the product works

The student will decide how the robot works. There are several different sorts of pick-and-place robots (cartesian, cylindrical, polar, jointed arm) and the complexity of the working will be governed to some extent by whom it is for. The student will have to ensure that the robot is stable during its operation.

The way the product fits together

The student can decide:

- the way that the parts of the robot fit together – which parts move, which parts are fixed;
- how to mount mechanical and electrical components on the structure of the robot;
- the placing of the power source.

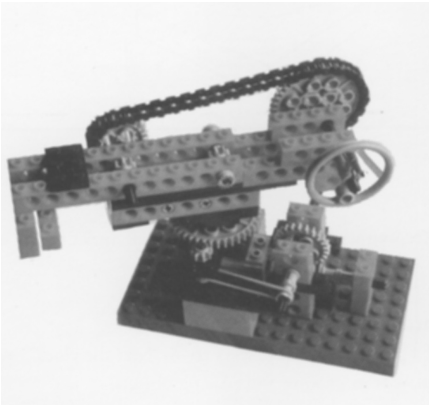
The materials, adhesives, fixings and components

The student can choose from:

- a range of construction materials: 6 mm x 6 mm softwood strip, welding wire, steel rod 3-6 mm in diameter, thin sheet material such as plywood or hardboard, thicker sheet material such as chipboard and mdf;
- a range of fixings: assorted clips for supporting motors, a selection of fixings for flexible joints, e.g. small-diameter plastic tubing for spacers, small plastic hinges, small curtain hooks and eyes, small staples, piano wire, 3 mm nuts and bolts;
- a range of components: wheels, gears, racks, pulleys, belts and chains, thin, strong cord, elastic bands;
- 6V DC electric motors (and perhaps servo motors and linear actuators), a variety of switches, electrical connecting wire, battery connectors;
- a range of adhesives: PVA glue, double-sided tape, Araldite®, resin-cored solder.

Products

The teacher provided students with plans for making a hand-operated robot arm in Lego, as shown on the left. Each pair of students made the robot arm according to the instructions and explored how it worked – the use of a belt drive and reduction gear train to swing the robot arm from side to side, and the use of a chain drive plus rack and pinion to open and close the jaws. The students practised using the Lego® model as a simple pick-and-place robot arm. The students next task was to add motors and sensors to the model and control the behaviour of the robot arm by means of a computer program. Two sample programmes are shown below.

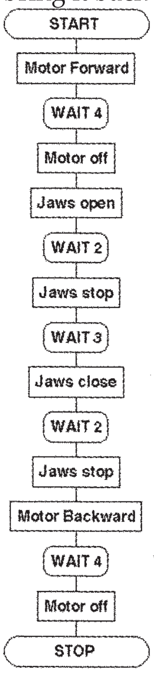


Example 1

This sequence of instructions controls the robot arm automatically. First the arm turns for four seconds, then the jaws open, stay open for three seconds (to allow an object to be placed between them), and close again to grasp the object. Finally, the arm turns in the opposite direction to bring it back to where it started.

There is no feedback built into the system, so the arm has no information about where it really is. The two-second time used to open and close the jaws was found by timing how long it actually took for the jaws to go from closed to open.

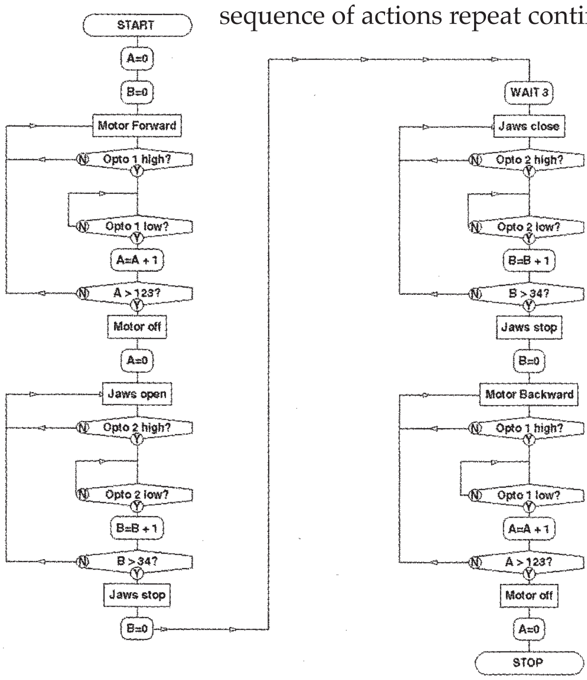
A loop could be added after the final 'Motor off' back to the 'Start' to make this sequence of actions repeat continuously.



Example 2

This sequence of instructions controls the robot arm automatically in the same sequence as is shown in Example but there is feedback built into the system. As the motor controlling the swing of the arm turns it spins a slotted disc that passing through a slotted opto-switch. Instead of the motor being on for a fixed time, it is on for the time it takes a set number of slots to pass through the opto-switch. The part of the program that detects the slots first waits for the slot to appear ('Opto high?') and then for it to pass fully through the opto-switch (Opto low?') before counting it (e.g. 'A=A+1'). Once the full number of slots has passed and the motor has been switched off, the counter is set back to zero ready for the next time it is used. The jaws are now controlled by limit switches that detect when they are fully opened and closed.

So first the arm turns for 124 slots, then the jaws open until one of the limit switches is pressed and then stays open for three seconds (to allow an object to be placed between them), and close again to grasp the object. Finally, the arm turns in the opposite direction to bring it back to where it started.



Once again a loop could be added after the final 'Motor off back to the 'Start' to make this sequence of actions repeat continuously.

Values

Technical

Students should consider the importance of accurate design and manufacturing techniques in order to produce a project which functions as intended.

Economic

Students should consider the significance of robot workers to an economy.

Environmental

Students should consider the effect of using robots in areas previously inaccessible to humans, e.g. the deep sea-bed.

Social

Students should consider the possible effects of the wide-scale use of robots on employment and lifestyle.

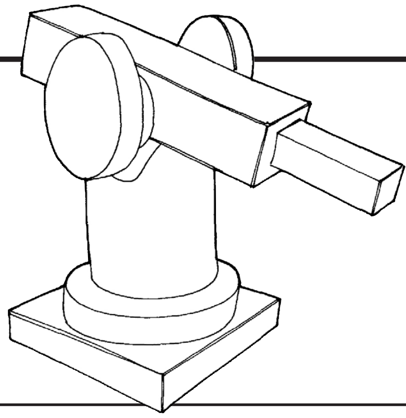
Moral

Students should consider the implications of developing artificial intelligence that is alive.

Aesthetic

Students should consider the images of robots which pervade the media and become aware of the elegance of robotic form and movement.

Robots are go!



The detail

Sample brief

Design and make a toy pick-and-place robot suitable for an identified user.

Sample specification

What the product has to do:

- pick and place a small object under the control of an operator using switches or a computer-control command program.

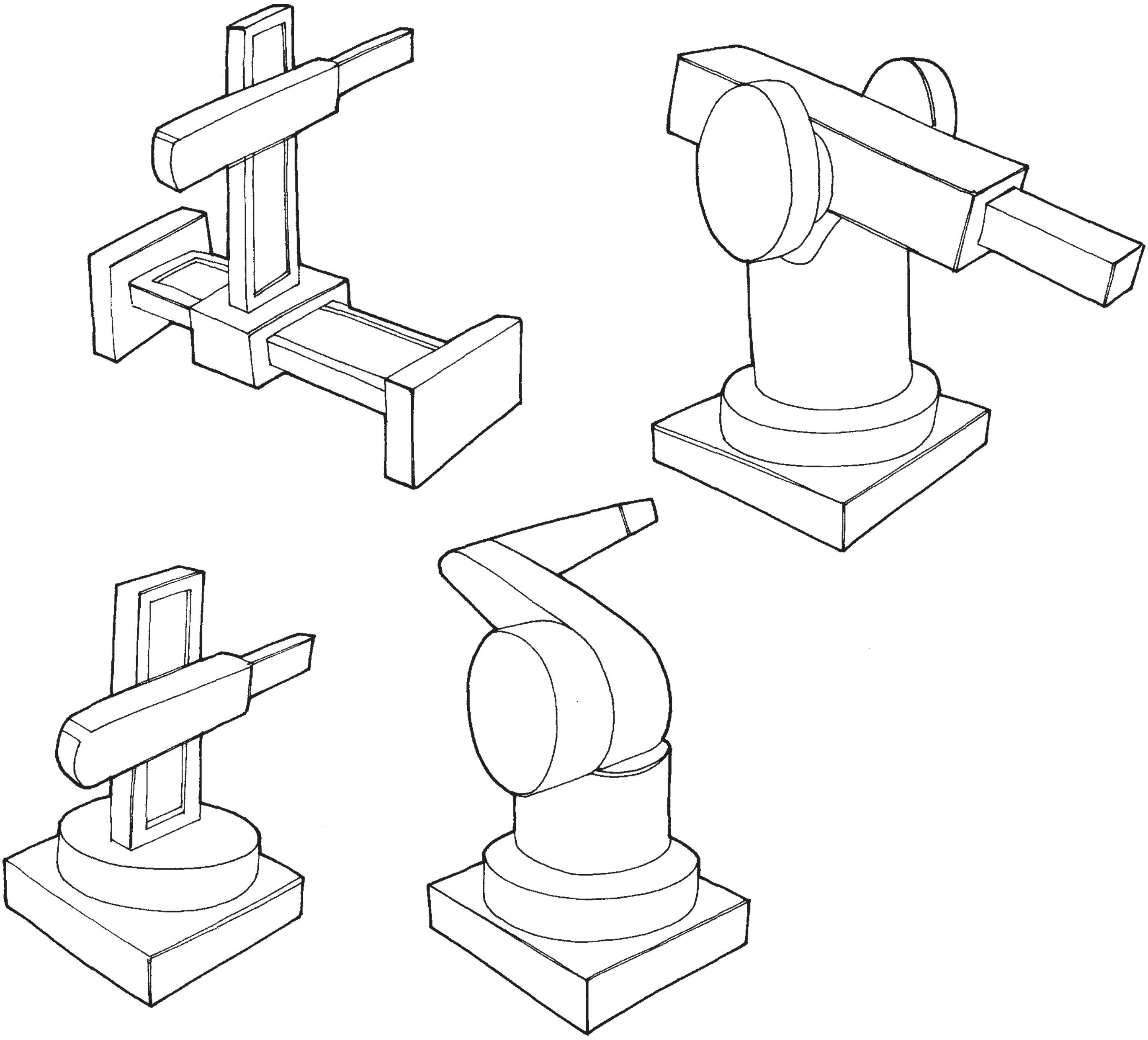
What the product should look like:

- be appealing to the intended user;
- be in keeping with the nature of the retail outlet where it will be sold.

Other features:

- part of a game in which players try to beat the clock, or other players in picking and placing objects.

Starter sketches



Nuffield teacher talk

'OK, it's a toy for a child six to eight years old. So you want to keep it simple. You like the idea of a fishing-rod robot. You've made all these tinplate fishes. You can pick them up with a magnet. How are you going to let them go once you've picked them up? Do you know what an electromagnet is? It's a piece of iron with lots of wire wound round it. When you pass an electric current through the wire, the iron becomes a magnet, when you turn the current off, it stops being a magnet. See the technician about borrowing a small one for your robot. If they're all too big, you could try winding a coil round some iron for yourself.'

'I can see that the spring holds the grippers shut, but what makes them open? The bit of string that's attached to the motor. I get it, so what's the problem? The motor doesn't turn hard enough for the string to open the grippers. Let's look at the Chooser Chart. Which bit will tell us what we want to know? That's it: to increase output force and decrease speed. So what could you use? Gears or a worm and wheel. Try the worm and wheel, as that'll give you the biggest effect with just two components.'

'OK, you two have designed the gripper and you two have designed the arm. The arm moves backwards and forwards using the rack and pinion and works OK. The grippers are made from Lego and also work OK. The gripper goes on the end of the arm but when you put the gripper on the arm, the whole thing tips over if the arm moves out more than 4 cm, and you want a 20 cm reach. So it's a balance problem, right? What are the options? Make the arm a lot lighter. Make the grippers a lot lighter. Provide some sort of counterbalance. How can you try the various options? Can you make the arm lighter? It's made from a strip of MDF and quite heavy. You could drill holes in it or substitute it with a piece of plastic tubing. Can you make the grippers lighter? Not really – you don't want to spoil the Lego. Can you provide a counterbalance? Well, the battery isn't attached anywhere at the moment so that's a possibility. And the crunch question – how do you decide which is the best option?'

'You want it to be completely hand controlled using mechanisms – no electric motors at all. Why's that? An executive toy should relieve stress, so physically doing rather than just pushing buttons or switches is important. OK. So one handle to turn the worm that causes the whole thing to rotate. Another handle to turn the pinion that works the rack that moves the arm backwards and forwards. And you're stuck on the grippers. You want to keep all the control handles fairly near one another, so you need to think about how to connect the grippers to something near the other control handles. Do you need to push or pull the grippers to get them to work? You've got designs that could work either way. Well, the thing about pulling is that it's easy to take round corners – you can use a piece of string and just wind it on a drum to get the pull. Pushing you can only do easily in a straight line, unless you use water in a tube with a syringe. You don't fancy water – the leaks and mess. OK. Well, you could mount a push stick along the length of the arm. How could you get it to push using a control handle that turns? Yes – a hand operated cam would work fine.

Resource Tasks

General design

For the first Capability Task in Year 8:

SRT 4 *Writing interview questions*

SRT 15 *Getting visual ideas from sections of pictures*

SRT 30 *Layout*

SRT 32 *Instructions*

SRT 38 *Evaluating outcomes – winners and losers*

For the second Capability Task in Year 8:

SRT 3 *Selecting recording tools*

SRT 14 *Attribute analysis*

SRT 19 *Appreciating products – feel*

For the third Capability Task in Year 8:

SRT 5 *Identifying needs and wants*

SRT 16 *Making random connections*

SRT 28 *Modelling with spreadsheets*

SRT 40 *Freehand product analysis*

Focus area design

If you use this task to teach systems then these are useful:

SRT 33 *Using system diagrams*

SRT 34 *Understanding system interfaces*

SRT 35 *Understanding feedback*

SRT 36 *Understanding flow charts*

Communication

CRT 2 *Surface shading showing textures* (unless tackled in Year 7)

CRT 3 *Surface shading – showing depth* (unless tackled in Year 7)

CRT 7 *Assembly and exploded views* Making

MCRT 8 *Assembling mechanisms*

MCRT 10 *Making your own mechanisms*

Technical

MCRT 1 *Changing types of movement* (unless done in Year 7)

MCRT 2 *Changing axis and direction of movement* (unless tackled in Year 7)

MCRT 3 *Changing force, speed and distance*

MCRT 4 *Introducing syringe systems*

MCRT 5 *Understanding levers*

ECRT 5 *Using switches to control motors* (unless done in Year 7)

CCRT 1 *Railway-crossing gates*

CCRT 2 *Home security system*

Case Studies

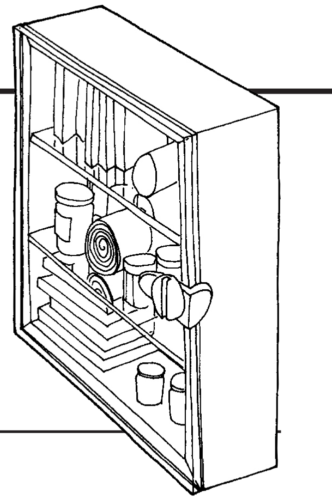
Landmines sweeper robot (photocopiable)

ICT opportunities

Use the Internet to find out about robots used for manufacturing, warehousing, exploring. Try putting 'robotics' in the search engine. Look directly at http://img.arc.nasa.gov/dante/.

Components for grippers and panel pieces that can be made from flat sheet can be designed using CAD and manufactured using CAM.

Smart-card security



The big picture

Task

To design and construct a smart-card-based security system to meet an identified need.

The story so far

Smart Security is a company that specialises in developing security systems for a wide range of customers. Its products are usually based on smart-card technology.

The students' task is to identify a situation where an electronic security system is required and then to develop a smart-card-based system that meets the security needs in that situation

Learning

Designing

Using a technical innovation (in this case smart-card technology) as a starting point for designing.

Making

Constructing shell forms.

Building electromechanical systems.

Technical matters

Linking electrical and mechanical systems.

Smart-card control of electromechanical systems.

Other matters

Developments taking place in smart-card technology. Social and economic implications of the new technologies.

Design decisions

The sort of product

This has been decided by the teacher – a smart-card based security system.

The point of sale

The student can decide where the product might be sold – Halfords, Dixon's a large department store, e.g. John Lewis, a specialist security services supplier.

The customer

The student can decide whom the product is for.

The performance of the product

Although the overall purpose of the product has been decided by the teacher (a security system) exactly what the system does is decided by the student. It could be used to protect valuables from theft, protect premises from illegal entry, protect those at risk from harm, allow privileged access to sensitive materials.

The appearance of the product

The student can choose the appearance of the product so that it has appeal for the intended user, and is appropriate for the setting in which it will be used and the retail outlet where it will be sold.

The way the product works

The student can decide the details of the electro-mechanical security system that is controlled by the smart card: sensors, limit switches, actuators, locking/unlocking mechanisms.

The way the product fits together

The student can decide:

- the way the overall system fits together – which parts move to provide locking/unlocking, which parts move to allow access, which parts are fixed to provide the basic structure;
- how to mount mechanical and electrical components into the system;
- how the electrical components are interfaced with the smart card;
- the placing of the power source.

The materials, adhesives, fixings and components

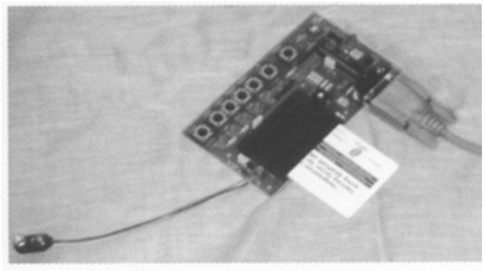
The student can choose from:

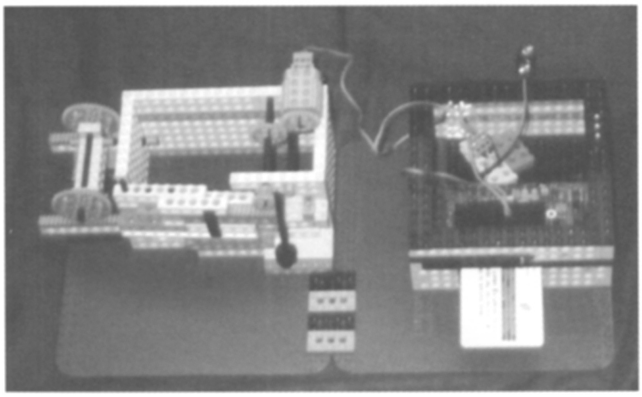
- a range of construction materials: thin sheet material – polystyrene, thick and thin card, flexible plywood, square and round section plastic tubing of various diameters, 6 mm x 6 mm softwood strip, welding wire, steel rod 3-6 mm in diameter;
- a range of fixings: assorted clips for supporting motors, small staples, 3 mm nuts and bolts;
- a range of components: 2 wheels, gears, worms, racks, pulleys, belts and chains, thin, strong cord, elastic bands, low-voltage DC electric motors, low-voltage DC solenoids, a variety of switches, electrical connecting wire, battery connectors, light sensors, heat sensors, tilt sensors;
- a range of adhesives: PVA glue, double-sided tape, Araldite®, resin-cored solder.

Products

In this school the teacher taught the students how to programme smart cards using the TEP Smart-card Controller. The students developed solutions using Lego®.

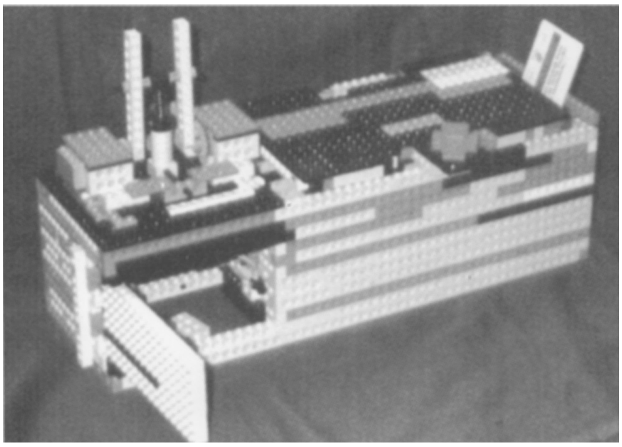
The TEP Smart-card Controller can be programmed on its own or via a computer.



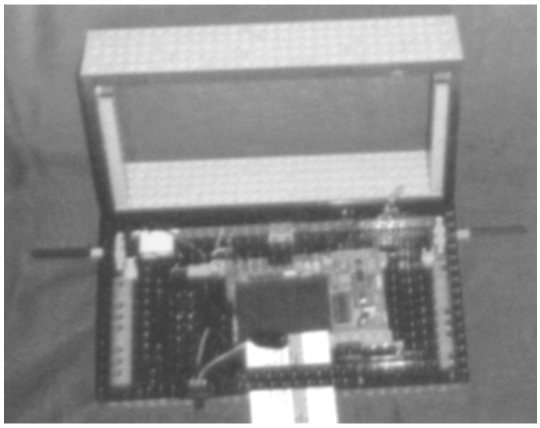


Here the student has developed a model of a security box. There is a separate control box for the smart card and the lid of the box is operated by a rack and pinion.

Here the student has developed a model of a security door. When the correct card is inserted a motor is operated, this is used to pump air into a pneumatic system which in turn opens the door. When the door is fully open, the pumping mechanism is stopped. The door is closed when a switch is pressed by releasing the air.



Here the student has developed a jewellery/security box. When the card is inserted and a button is pressed, the lid is driven to the rear on the rack and pinion system shown. Pressing the button again closes and locks the lid.



Values

Technical

Students should consider the need for reliability in a security system.

Economic

Students should consider how a mass-produced system can be adapted to be used in small markets.

Environmental

Students should consider the source of the materials used, their disposal of the device after its useful life and the effect of the manufacturing processes.

Social

Students should consider the effect of security systems on the way we live and our relationships with others.

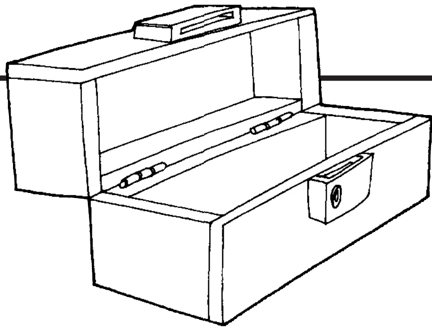
Moral

Students should consider the place of security systems in maintaining law and order.

Aesthetic

Students should consider the importance of appearance in 'functional' products.

Smart-card security



The detail

Sample brief

Design and make a security system to keep safe the jewellery belonging to an elderly lady.

Sample specification

What the product has to do:

- prevent access to the box when locked;
- signal movement of the box when locked;
- require both the smart card and a code to be given for access.
- ensure locking if the power supply is removed.

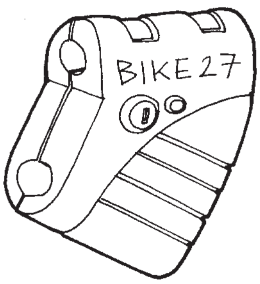
What the product should look like:

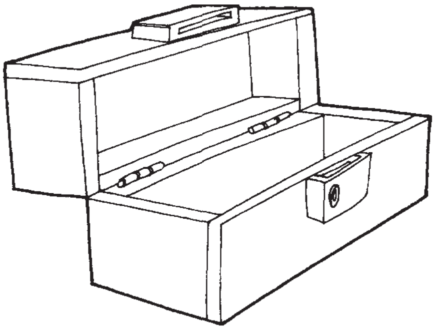
- be suitable for the intended user;
- be unobtrusive.

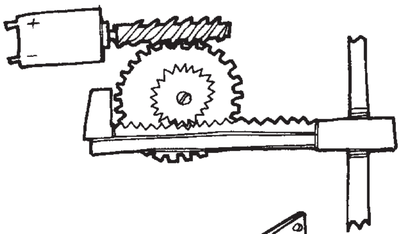
Other features:

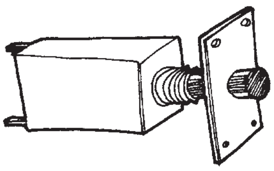
- be battery powered;
- provide access to change the battery;
- have a security mechanism that is effective;
- be easy to mount/fix in iuts target location;
- have a target price of less thatn £9.99.

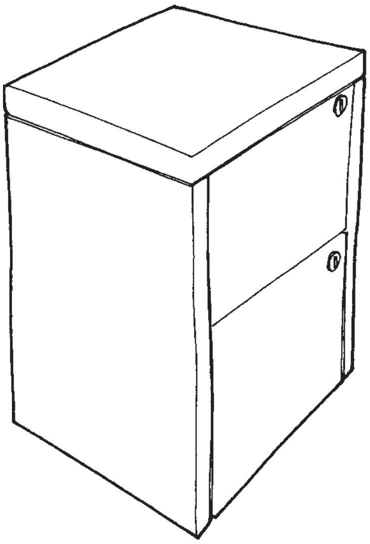
Starter sketches

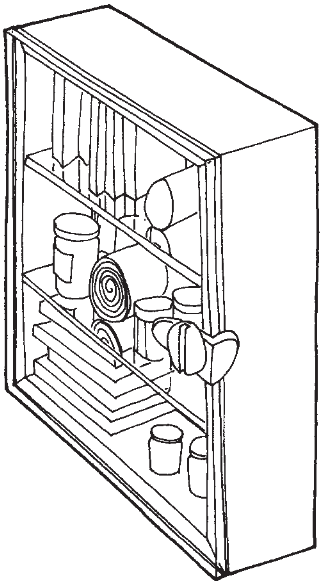


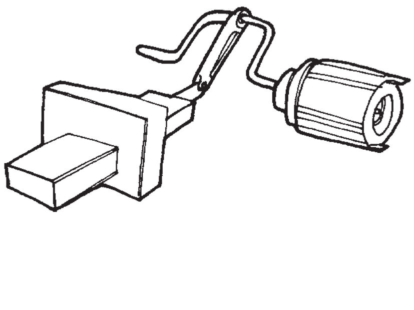












Nuffield teacher talk

'OK, it's for your gran to keep her special jewellery in. You want it to be a tube with a lid that only she can take off. And then she can lift out a set of trays on a central rod – each tray holding just one or two special items. So the key thing is the lid, right? Will it fit on in any position or do you have to get it just right to fit? Why do I want to know? Well, you want the lid to get locked into position and if it can go on in any position, I think you'll need a different sort of lock from that which only fits on one way.'

'OK, it's for your granddad's pills when he comes to stay so that your little brother and sister can't get at them. So you reckon on a small box with a hinged lid and simple solenoid lock on the front. The rod in the solenoid is 'out' when the solenoid is off, so once you set this up it'll be locked and your granddad will have to use the swipe card and the code to open it up and put in his pills. Then when he's put his pills in there, he uses the card and the code to lock it. What stops me just pushing the solenoid rod back against the spring? You're going to put the lock on the inside with a bit in the lid that sticks down and has a hole in it for the solenoid rod. You've got a good card box from Paperchase. Good. So all you've got to do is to mock up the bit that hangs down, and get it and the solenoid in the right place for it to lock. Go for it. '

'You don't want to use a solenoid and you think you've got an idea for something that'll be better. Let me see if I can tell how it works from your drawing. It's a gear in the middle, right, with a rack on either side – OK. When the gear turns, one rack moves up and the other moves down, yes? So the racks can act as bolts. So operating the lock is just a matter of switching the motor on and off, for the right time, in the right direction. Why not make it in Lego first to check that you can get it to work. Try to do that quickly because then you'll need to make it in tougher materials that fit inside your security case.'

'So if it's moved you want the alarm to sound. So you need to detect movement. How are you going to do that? It's got an LDR in the bottom and if it's lifted up the light sets it off. If I'm a smart burglar, I just slip a bit of black card under your box and I can walk off with it. Do you know what a tumbler or tilt switch is? A tumbler switch is sensitive to vibration and a tilt switch is sensitive to changes in level. We've got tilt switches in the store but it's quite fun to try to make your own tumbler switch – you can do it with a small ball bearing and a few bits of aluminium foil. Want to have a go?'

Resource Tasks

General design

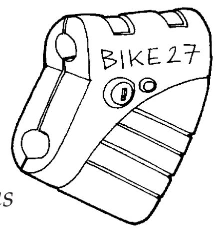
For the first Capability Task in Year 8:
SRT 4 *Writing interview questions*
SRT 15 *Getting visual ideas from sections of pictures*
SRT 30 *Layout*
SRT 32 *Instructions*
SRT 38 *Evaluating outcomes – winners and losers*
For the second Capability Task in Year 8:
SRT 3 *Selecting recording tools*
SRT 14 *Attribute analysis*
SRT 19 *Appreciating products –feel*
For the third Capability Task in Year 8:
SRT 5 *Identifying needs and wants*
SRT 16 *Making random connections*
SRT 28 *Modelling with spreadsheets*
SRT 40 *Freehand product analysis*

Focus area design

If you use this task as a vehicle for teaching systems then the following are useful:
SRT 33 *Using system diagrams*
SRT 34 *Understanding systems interfaces*
SRT 35 *Understanding feedback*
SRT 36 *Understanding flowcharts*

Communication

CRT 2 *Surface shading – showing texture* (unless tackled in Year 7)
CRT 3 *Surface shading – showing depth* (unless tackled in Year 7)
CRT 7 *Assembly and exploded views*



Making

MCRT 8 *Assembling mechanisms*
MCRT 10 *Making your own mechanisms*

Technical

MCRT 1 *Changing types of movement* (unless tackled in Year 7)
MCRT 2 *Changing axis and direction of movement* (unless tackled in Year 7)
MCRT 3 *Changing force, speed and distance*
MCRT 5 *Understanding levers*
CCRT 4 *Using smart card for control*

Case Studies

Product life cycle analysis, downloadable from the website http://www.nuffield.org/secondaryDandT

ICT opportunities

Use the Internet to find out about smart cards. Try putting '+smart +card +security in the search engine. Look directly at http://www.cardsolutions.com/.

3D shells that can be constructed from nets can be designed using CAD and manufactured using CAM. Panel pieces that can be made from flat sheet can be designed using CAD and manufactured using CAM.