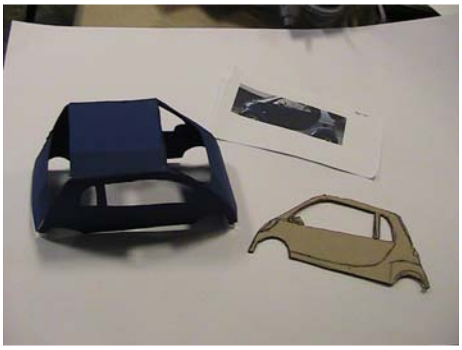
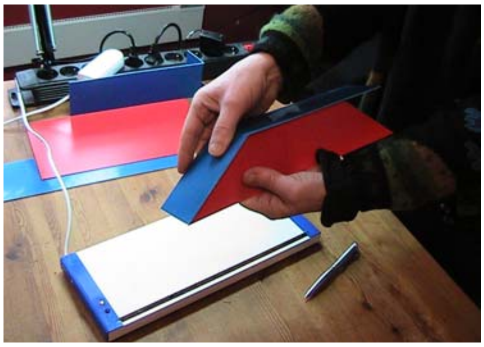
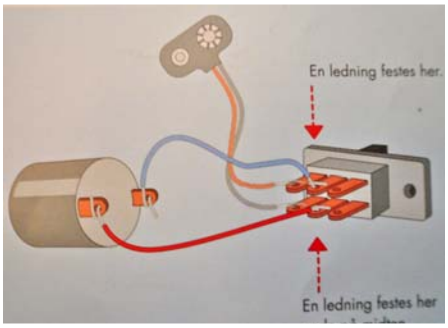




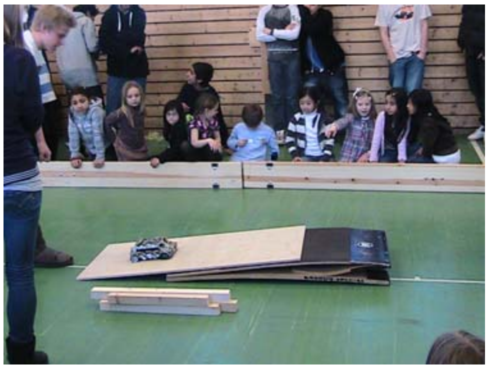


Learning by inquiry in a technological context:

Wheels on Fire!

A PRACTICAL GUIDE FOR TEACHERS





S-TEAM FIRING UP SCIENCE EDUCATION

NTNU Norwegian University of Science and Technology

Ruseløkka skole

Learning by inquiry in a technological context:

Wheels on Fire!

A PRACTICAL GUIDE FOR TEACHERS

Berit Bungum & Eva C. Jørgensen

2010

Preface

This teacher guide describes a cross-curricular project on design and technology at Ruseløkka, a school in Oslo, Norway. It aims at providing teachers, school leaders and educators with ideas and inspiration for how an extensive project like "Wheels on Fire" can be undertaken. This includes organization, pedagogy and equipment, as well as how the various school subjects can contribute and learning outcome be assessed. At the hearth of the project is pupils' learning by self-driven inquiry and problem solving in designing and making their own individual car model in plastic driven by an electric motor. This provides for highly motivating and relevant practical contexts for learning in a range of school subjects, and for familiarizing pupils with what it means to work within technology. We hope that the guide will serve as inspiration, but it is essential that the project cannot be directly copied; teachers in other schools need to develop their own projects with their own identity!

To help teachers and others further to learn from the project at Ruseløkka, the movie "Wheels on Fire" has been produced. The movie presents the content of this guide, and the atmosphere in the project, in even more visual and dynamic ways.

The production of the guide and the movie has benefited from financial support from S-TEAM, a European project within the EU 7th Frame Program. Thanks to S-TEAM, and in particular teachers, headmasters and pupils at Ruseløkka School for their co-operation, enthusiasm and creativity!

The guide and the movie are produced by Eva C. Jørgensen and Berit Bungum. Eva C. Jørgensen is educated as an engineer and works as a teacher at Ruseløkka School. She has been the innovator of "Wheels on Fire" and many other projects. She is active in curriculum development and has been co-author of textbooks (for example a resource book in design and technology for teachers, see page 25). Berit Bungum has a PhD degree on technology education and is an associate professor in science education at The Department of Physics, The Norwegian University of Science and Technology. Both have contributed extensively to in-service education for teachers.

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Contents

Wheels on Fire: A cross-curricular project

”Wheels on Fire” is a cross-curricular project developed at the Ruseløkka school in Oslo, Norway. For the pupils, it involves designing and building a car model run by an electric motor. The car model is designed according to the pupil's individual ideas and built in plastic. The project culminates in a rally where pupils compete with their car model in speed, accuracy, hill climbing and design.

Various tasks are to be solved during the project, and it therefore includes content from a range of subjects: arts and crafts, science, mathematics, first language (Norwegian) and a second language (English). Teachers from all subjects are engaged in the project, which lasts 1-2 entire school weeks for grade 9 pupils (14-15 years old).

Each pupil, boy or girl, finishes their project having experienced excitement and success in a technological field. This experience might have an impact on their choice of further or higher education, in terms of motivation, self esteem and acquired skills. It may also influence their attitude and ability to cope with technological challenges more generally, as citizens and as human beings. Though all subjects take part in the project, maths and science play an essential part. To succeed with their car model, the pupils have to acquire skills and understanding in science and mathematics, and to combine these skills with other fields of knowledge. Hence, the project is an example of how these subjects, which pupils often find difficult and irrelevant, can be enhanced through cross-curricular projects in contexts that are motivating, meaningful and creative for pupils.

The work with the car models in the project period has seven distinct phases:

- Working with ideas and moodboards
- Planning, drawing and cardboard models
- Cutting, bending and joining plastic together
- Working with motors and the electric circuit
- Mounting wheels and driving mechanism
- Testing and improving
- Organizing the Rally

This guide describes how these phases in the project are undertaken at Ruseløkka, including how the work is organized, the skills, techniques and tools involved, the pedagogy employed and how the project provides for inquiry learning in order to meet learning targets in active and creative ways.

The excitement culminates in the great Rally – will my car succeed?

Inquiry in a technological setting

Opportunities for inquiry learning

The project allows pupils to be engaged, creative and innovative in the working process, and offers motivating and authentic contexts for learning practical skills in technology, as well as content knowledge from the various school subjects involved. To achieve this, it is important that pupils have sufficient time for discussing and experimenting with different solutions, and that the product and presentation is subject to high standards of quality. Each phase of the project provides a range of opportunities for inquiry. In developing an accurate cardboard model, pupils will have to figure out how parts should be geometrically shaped to give the desired result in three dimensions. The construction of the chassis raises questions such as: 'How do I make it strong enough to survive the race?; Will my construction give room for the transmission?; How do I design and cut the parts so that I have enough materials?' The car's driving mechanism provides for inquiry into how the size of pulley wheels affects the speed and strength of the vehicle, and the pupils get physical experience of mechanical relationships in transforming forces in a technical system. In working towards the rally competition, pupils will be interested in how the friction properties of the wheels can be improved, and how motors and batteries should be placed in the interior of the car in order to optimise weight distribution. Work with the electrical circuit raises questions about circuit principles, such as: 'What are the differences between series and parallel circuits?' Pupils may also investigate how properties of light-emitting diodes can be used for controlling how lights work in combination with a two-way switch. The combination of motor and light will lead to questions such as: 'How will the inclusion of new components affect the power transmitted to the motor? Does it matter what kind of coupling I use? Do I need more batteries in order to have both lights and motor?' The practical work with circuits adds another aspect to inquiry; here pupils will need to learn about short circuits and how bad soldering makes current run through the wrong places in the circuit – or nowhere at all.

Figure 1. Pupils' products: One challenge – a diversity of solutions!

Inquiry led by pupils' questions

The essential educational point is that the questions above are posed by the pupils themselves, and motivated by their desire to build a car model that is both attractive and competitive. Motivation for the inquiry process thus becomes much stronger than when the questions are posed by a teacher. It gives room for individually adapted teaching; while some pupils acquire only basic experiences, skills and concepts about motors and electric circuits, the more able pupils will pursue complex inquiry into the combination of components in a circuit and develop higher levels of knowledge.

Experiencing technological practice

Pupils' questions and inquiry give them an experience of what characterises technology as a field of work. While some of the questions exemplified above provide for experiments and discussions that lead pupils to the standard established science knowledge in an engaging way, most of the problem solving in the project has no clear-cut textbook answers. This gives room for pupils' creativity and authentic inquiry on a need-to-know basis; pupils will have to find solutions to their own practical problems as their car model develops. This resembles how engineers work, drawing on a range of knowledge from various fields in order to solve specific problems. It gives the pupil a strong sense of ownership to the problems they identify and solve. The challenge pupils are given have a range of different solutions. This way, pupils experience how the development of a technological product is based on human desires, creativity and priorities in addition to knowledge and skills.

Assessment

Pupils' work is assessed within the subjects involved in the project. This relates partly to the product itself, and partly to additional tasks related to the project. The craft aspects of the car, such as design, use of tools and materials, joining of parts etc are assessed within Arts and Crafts. The mechanical and electrical aspects may be assessed in Science. Assessment criteria will give direction to pupils' work, and it is important that they are familiar with the criteria before the project starts. Teachers of the involved subjects must cooperate in defining tasks and assessment criteria in the planning phase of the project.

Placing the project in context

Choosing a context

Pupils will surely find the project of designing and building a model car enjoyable and motivating. However, in order to achieve the content goals of the subjects involved, it is important to place the project in a wider context. Various contexts can be chosen, for example a motor manufacturer in need of a design for a new car. The manufacturer may want to develop a new car with some key characteristics, such as efficiency, steady running, environmental friendliness and ability to climb steep hills. It is important that the chosen context provides direction for the requirements, but also that it does not narrow down design options. The project needs to be open to various styles of cars, and pupils should be allowed to define the target groups for their products themselves.

The school may choose to set up prizes for best cars. These should relate closely to the context chosen for the project. It is important that the success criteria are known to pupils when they start. At Ruseløkka, three prizes have been set up: A design prize, a prize for fastest car and a prize for the best car for steep hills. Pupils can then decide which qualities they want to focus on in their design; the possibility of winning a prize is likely to further strengthen their motivation in the project.

The winners of the prizes for speed and hill climbing are decided by a rally organized by the pupils themselves. This event provides a strong conclusion to the project, and should be undertaken seriously but with a sense of humour. Nobody should feel like a loser, and pupils should feel happy about their product even if they don't win a prize.

Possible contributors

The project can easily be connected to working life and technology in society. Representatives from corporations may visit and talk about current developments and challenges in the car industry. The local community may include other companies, organizations and institutions that might also contribute to the project. Designers may give talks about their work; engineers or engineering students may explain about motors or how cars can be made more environmentally friendly.

Likewise veteran car organizations or model car enthusiasts may like to share their enthusiasm with pupils. Companies, voluntary organizations or hobby associations may see the benefits of participation for recruitment or goodwill purposes. It is wise to involve them at an early stage and discuss how they can best contribute.

External evaluators may be used to select a car for the design prize. When not undertaken by teachers, the design prize is set apart from assessment in subjects. In addition, they can use criteria for quality in a highly professional way, enhancing the authenticity of the projects and pupils' learning outcome in terms of what good design means. At Ruseløkka, the external evaluators were graduate students from a design college, and the nomination of cars from each class was made by pupils. This reduces the number of cars the evaluator will have to consider. During their visit, the design students also speak to the pupils about what it means to become a designer in terms of education and work.

It is a good idea to involve parents at an early stage. Some of them might have occupations or education relevant to the project, and might give talks about relevant materials and techniques, for example. They might also invite pupils to visit their workplaces. Some parents might like to contribute to the project by joining in the work and helping the pupils, giving advice or supplying materials for the car models.

Tasks and assessment in the school subjects involved

A range of subjects may be involved directly and thematically in the project. It is fruitful to strengthen the focus on the project by developing supplementary tasks in the involved subjects. Priorities need to be made in order to limit the number of extra tasks to be assessed with marks, as they might otherwise kill the creativity and the joy of the project. Tasks to be assessed should be as closely as possible related to the main activity of designing and building the car. Some possibilities for assessment tasks in various subjects are:

- Working with scales in mathematics, based on the working drawing. This can be combined with drawing with perspective in Arts and Crafts
- A portfolio can be made in Arts and Crafts, focusing on the design and construction of the car.
- Calculating cost of materials. This involves a geometry task in Mathematics, as the area of each part has to be calculated. A careful working drawing is requires in order to complete this task.
- Presenting the car in a second language. The presentation could be oral or written, and involve a technical vocabulary as well as a description of the target group for the car.
- Writing a newspaper article about the project in first language.
- Analysis and description of forces and mechanical principles for transmission in Science
- Measuring and calculating velocity and acceleration of the car; a task that could involve both Science and Mathematics.
- Investigating the history of cars, their design, development and influence on society could be a task in Social Science or Technology.

Make sure pupils have enough time to work with these tasks during the project – and remind them regularly to do them! The supplementary tasks run parallel to the phases of designing and building the car, but school subjects can also benefit from focusing on related topics both before and after the project period.

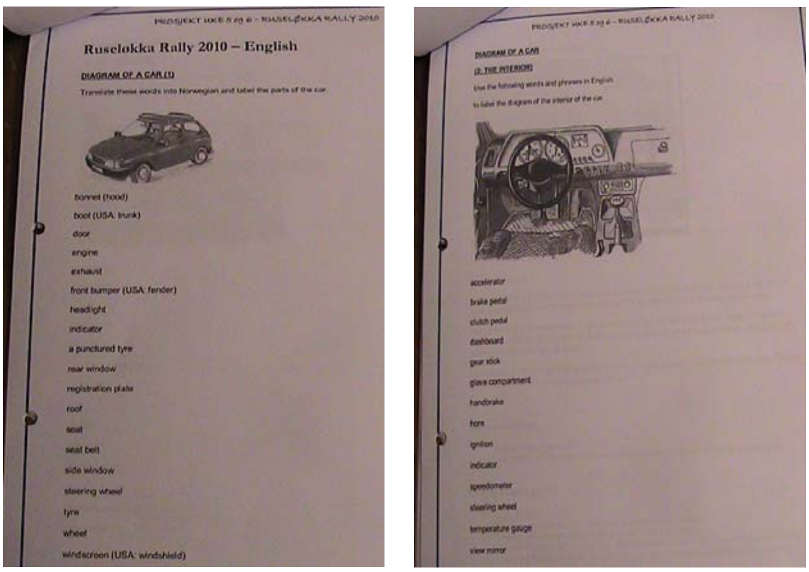

Figure 2. Examples of supplementary work in English as a foreign language, providing pupils with a technical vocabulary.

Organizing the project: requirements and opportunities

At Ruseløkka, the project is undertaken for two weeks in Grade 9 with 80-90 pupils in four classes. A team of 10 teachers is involved. The organization of the project differs from how teaching is normally organized in a school, and offers some challenges, but also opportunities. In the following we address how challenges can be met and opportunities utilised in terms of equipment, time resources, teacher cooperation, management and organization of pupils' work.

Equipment

The project's requirements for equipment may seem extensive, especially because you will need plenty of tools in order to avoid delays due to shortages. However, most of the tools and equipment can be re-used in other projects and teaching activities. In addition, pupils can be encouraged to bring simple tools from home, such as Stanley knives[1], screwdrivers and so on. This must be done in agreement with parents. If some are able to bring electric drills it will help a lot, since schools are unlikely to have many of these.

Investing time resources

The activity of building an electric model car may well be undertaken in far less time than the two weeks suggested here. If the task is limited to putting an electric motor into a wooden frame with wheels, it may take only half a day. This will, however, mean that a smaller proportion of pupils will be deeply involved, and the learning opportunities will be limited. It would then function as a traditional science experiment, with a narrower scale and lack of deep challenges.

The way the project is run at Ruseløkka means that each subject department invests time in the project. This time is a good investment, allowing pupils to go deeply into issues related to the car model, provided that all subjects and teachers are fully involved. Subject teachers will have to identify how their subject fits in, and make sure that pupils cover curriculum targets during the project.

Even before the project starts, pupils are prepared for working with the car model in the participating subjects. This builds up a motivation for the work before the project period starts. In turn, the experience of designing and making the car model motivates further interest and content in some subjects, in that some themes and questions relevant to the project are taught with a more theoretical approach in Science, Mathematics and Arts and Craft in the weeks following the end of the project. Hence, Design and Technology becomes a great meeting point for most of the traditional school subjects. However, it can be hard to fit all of them into each project, and priorities have to be made. The selected subjects need to be visible in the projects in terms of the tasks related to it, and pupils need to have enough time to prepare and undertake the work related to these tasks. Pupils need to be sure that their efforts are assessed within the subjects. This way, the time invested will pay off in terms of increased motivation and subject learning in realistic and engaging contexts.

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[1] Note: In some national contexts this may be illegal or inadvisable for health and safety reasons.

Teacher collaboration, management and preparation

A project of this size needs to be carefully planned and incorporated into the year plan for the school and each subject. Support from the school management is essential, but the team of teachers involved needs to shape and develop the project in its own style and agree on its goals. It requires teachers who are willing to take risks in order to succeed, and willing to teach in new ways. Further, the team needs to agree on issues such as the story line, assessment criteria and consistent rules for pupils. This involves deciding where pupils are allowed to be during the project, whether they are allowed to use materials other than those provided by the school, whether a standard battery should be used for competition purposes and so on.

If possible, we recommend that the teachers apply their usual time schedule, allowing for their usual work in classes not involved in the project. This means that teachers will be present with each class of pupils at their usual times during the week, although what pupils and teachers are doing in these classes is quite different. This system works well in Norwegian schools where each class has its own classroom. If this is not the case, adjustment needs to be made so pupils can stay in the same room whilst working on the project.

This organizational structure requires that each teacher must be familiar with the content and procedures of all phases of the project, since pupils will be working at different stages and face different problems. This requirement gives strength to the project as it requires each subject teacher to go into every aspect of it, and hence to explore how subject content can be fully incorporated.

The team should include (at least) one well skilled teacher with a good overview of all the practical facets and the overall aims of the project. This teacher will be a crucial resource for colleagues and pupils. The entire team will need to have frequent meetings during the project in order to discuss the need for adjustment. Some teachers might have specific responsibilities. For example, skills such as the soldering of electric circuits might be taught by a science or technology teacher one class at a time. This should be put on the schedule for the pupils during the first three days of the project. Provide each pupil with a small plastic bag for the finished circuit and motor, to take back to their classroom. One or two back-up teachers might be required across the classes, in order to assist pupils who face serious trouble with their construction, as supervision in this process is time-consuming.

School leaders should likewise be informed and invited into the project. The headmaster might be involved by giving a motivating speech to the pupils at the beginning or end of the project. It might be highly appreciated if he or she also visits the pupils during their work.

Every teacher must design and build a car!

The project is complex in all its practical phases. It is essential that all participating teachers have gone through the process of designing and building their own car model, regardless of whether they are technology teachers or teachers of English or History. This enables them to supervise pupils in a much more informed way; having experienced a range of practical problems, possible solutions and the joy of success (this guide is certainly not enough to provide the necessary experiences of possible problems and solutions!). At Ruseløkka, this is organized as an afternoon course for teachers who have not previously participated in the project. In a friendly and sharing environment with colleagues, they will develop a wider repertoire of problem solving strategies, design ideas and technical solutions.

Organising pupils' work

Each pupil – one car

We recommend that pupils design and build their own individual car, in order to strengthen their ownership of the product and to provide opportunities to pursue their individual ideas. This gives more energy to the project than groups of pupils working on the same car. Pupils are, however, encouraged to cooperate and help each other, in all phases of the project. For many practical purposes this will be a necessary part of the project.

Work in ordinary classrooms

Although most of the work is highly practical, it can be undertaken in normal classrooms rather than workshops. Pupils' desks should be placed in groups of 4-5, to encourage cooperation. Cover all desks with protective paper during the entire project. Allow constructive mess during work, but make sure everything is tidy by the end of each day.

The school needs to provide tools such as glue guns, linebenders, files, screwdrivers etc, in the rooms for each participating class. These must be counted and checked by the teacher every day. All pupils should bring a shoebox for storing their car parts and tools during the project.

Figure 3. Classroom organization: Groups of 4 desks covered with protective paper.

Give pupils responsibility

The project is a unique opportunity to give pupils responsibility for planning their work independently. Some will need help with getting organized, while others will cope better than expected when given the responsibility. It is important to make rules for work clear to pupils before the work starts. These rules may be about working hours, how and where to seek assistance and times and procedures for tidying up. Seeking advice should be pupils' responsibility; at times with high pressure on the teacher it is a good idea to make a list on the blackboard where pupils put their name successively when they are in need of assistance. This makes the work more efficient for both pupils and teacher and ensures a fair distribution of the teacher's attention. A similar queuing system might be made for tools that are in limited supply, such as linebenders for plastic.

Pupils will manage their tasks at varying speeds, and their cars will demand different amount of work due to different design choices. You will need ways of coping with pupils who finish early, as well as those in danger of not being finished in time for the final rally. Some will need a lot of assistance right up to the last minute. Pupils finishing early can be given the opportunity to make an extra car with additional facilities. Also, one should encourage pupils to help each other during the entire process.

Figure 4. Work in progress: a shoebox enables pupils to keep track of their parts.

Phases in the project

The project has seven specific phases, described in the following section. During the first two phases, pupils will usually work on the same tasks, with instructions from their teachers. In the last phases, pupils will work more at their own pace and seek advice when needed. Some will be in need of help to plan their work in order to complete the work in time.

1. Expressing ideas by moodboards

A moodboard is a presentation of aesthetic expressions of design ideas. A moodboard may contain illustrations of cars, but also objects, environments, colours and so on, that fit with how the pupil wishes to associate his or her product with certain life styles. A moodboard is both a means for communicating ideas and a means for developing the "mood" of the design. In a teaching setting, pupils may be asked to bring pictures from magazines etc that will go into their moodboard. Such materials may also be provided by the teacher. If so, it is important to provide magazines with a great breadth of styles!

Before starting their work with the moodboard, pupils are asked to express their ideas by means of three words. These words can be related to properties of the car itself, typically quick, small, safe, strong and so on. They may also be related to environments they see their car in, such as jungle, beach, summer, or to the intended users, typically teenagers, families or specific professions. As an example, the hippie-style moodboard in Figure 5 featured the three words *"Hippies, colourful, funky"*.

Figure 5. Examples of Moodboards expressing pupils' ideas.

2. Planning, drawing and cardboard models

Careful planning is essential in the project. In order to succeed with their car, pupils will need to make careful drawings, showing the geometry of the plastic parts that will form the car. The need for accurate measurements and symmetries requires a great deal of mathematics. Pupils should know how to use a pair of compasses and other techniques from mathematics in constructing correct angles and shapes in their working drawings. Correct drawings are necessary in order to calculate the cost of the car, which form part of the supplementary work during the project period. The focus on accurate drawings provides for both a quality product and mathematics content in the project. Mathematics teachers might choose to situate the geometry curriculum in relation to the project and teach the necessary skills as part of the project work. This makes mathematics lessons motivating and realistic for the pupils, as they will experience an immediate need for the knowledge and skills mathematics can offer. High standards of quality are, however, a prerequisite for mathematics to play a significant role in the project.

The cardboard model is an important visualisation in three dimensions, as it makes a link between the two-dimensional drawing and the final product. Working with the cardboard model will show pupils how their shape can be realised, and make them aware of challenges and opportunities. It is, however, important to be aware of how cardboard behaves differently from plastic when it comes to thickness, springiness and how parts can be joined.

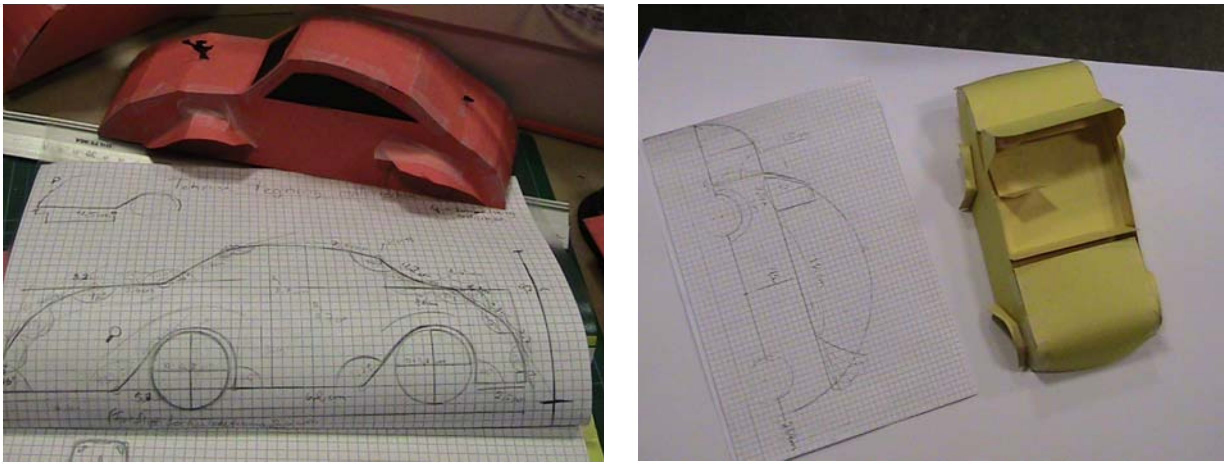


Figure 6. From workings drawings to cardboard models.

3. When ideas meet materials: Shaping the car in plastic

When the cardboard model is finished, pupils create their car chassis in plastic. At this point pupils will face challenges in transforming their ideas into a material shape; an endless number of choices has to be made in order to construct even a simple car shape. Therefore, it is important that the working drawing and the cardboard model are inspected and approved by the teacher before pupils are allowed to go on with the plastic work. This ensures quality work in the preparatory phases, and motivates pupils for doing accurate work. The teacher may, together with the pupil, spot weak parts of the technical design that can be improved before the car is built in plastic. Here, teachers should encourage pupils to be creative in reducing the number of pieces that need to be glued together. A few pieces bent in various directions to form the shape of the car will give a more robust and better-looking chassis.

Using linebenders

Plastic pieces for the car are shaped by means of a linebender. We prefer linebenders to vacuum formers, as they give more room for pupils' creativity and flexibility in the work. A linebender heats the sheet of plastic along a line, and the plastic can then bent along this line to the desired angle. Essential to the car project is the particular linebender used at Ruseløkka, shown in Figure 7. It is produced by Tisco (www.tisco.no), and can be used for plastic sheets up to A4 size. This is a neat and customized model, designed for classroom use. It is safe in use, is easily portable and costs less than a third of the price of professional models.

In a project like "Wheels on Fire", 4-5 of them should be available in every classroom. Sheets are cut in A4 size and made available to pupils in a range of different colours. The size is convenient for pupils to work with, and it sets limits to the dimensions of their cars.

Pupils should have a choice between plastic sheets of thickness 1 mm, 1.5 mm and 2 mm. Plastics with different thicknesses have different properties. The thickest is ideal for the design of a beautiful, heavy old veteran car, while the thinnest is likely to be chosen by pupils heading for a really light and fast car.

Cutting plastic parts

Plastic parts for linebending are cut by means of a ruler and a Stanley knife. Make a straight line with the knife, and break off. Do one line at a time. The straight lines are essential; other shapes are possible – but cumbersome and give a poorer result.

The order of bending various parts is important; pupils should try it out with paper shapes before they start with plastic. Encourage pupils to think and cut smart; Figure 10 shows how a car chassis can be shaped from only one piece of plastic, hence avoiding extra joining lines.

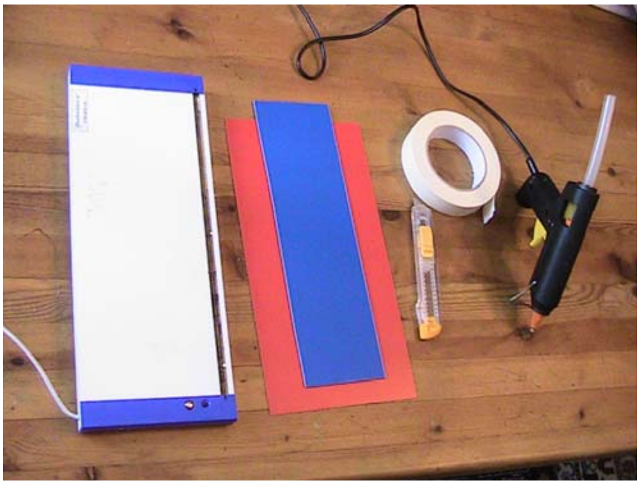


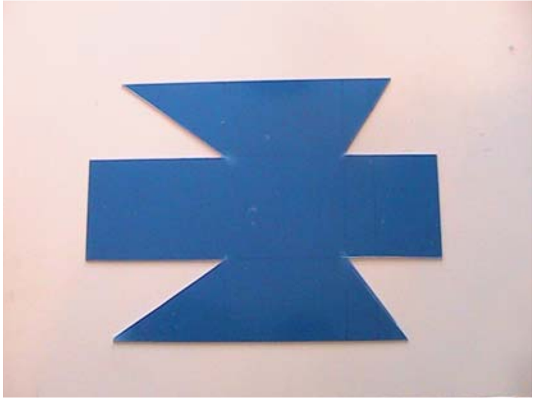
Figure 7. Equipment for shaping plastic with a linebender.

Equipment

- Linebenders
- Plastic sheets in A4 format, minimum 2 x A4 sheet per pupil. Thickness: 1mm, 1.5 mm and 2 mm.
- Stanley knife
- Glue gun
- Ruler
- Cutting mat
- Masking tape

Figure 8. Cutting plastic: Use the Stanley knife with a ruler. Make a line and break off.

Figure 9. The linebender in use.



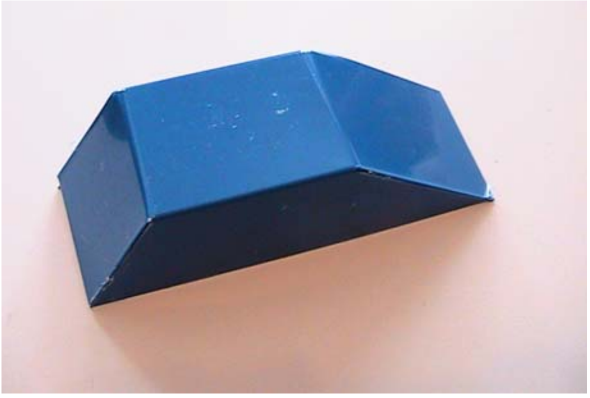


Figure 10. Well planned cutting enables you to make the car chassis in one piece.

Joining parts

Joining plastic parts is not trivial, and needs to be done with care in order to get a good result. This is a good reason for spending some time on planning in order to reduce the number of parts needing to be joined. An acceptable result can be achieved with a high temperature glue gun (shown to the right in Figure 7). These have two advantages: they are easily handled by pupils without assistance, and the glue dries quite quickly. For aesthetic reasons, always use the glue gun on the inside of the chassis. Before you glue, use masking tape on the outside in order to avoid visible unpleasant glue crumbs. Be aware of the risk of damage due to the high temperature! Ideally, pupils should use gloves when using glue guns. At least you should have cold water available.

Plastic parts joined by glue guns tend to fall apart after some time. A better result can be achieved with the kind of glue used for hobby aircrafts and train models, but this demands a lot in terms of patience and accuracy from the pupils. An alternative to the use of glue is to drill holes in the plastic parts and join them with small screws. This affects the car's weight as well as its aesthetic properties.

Gluing as well as using screws for joining plastic parts requires sufficient areas for joining on each part. This must be planned well in advance. Figure 11 shows how areas for joining may be made by means of additional bending of the plastic.

Use your creativity and keep the number of parts, and the need for joining them, to a minimum!

Figure 11.
An extra bend at the edge makes area for joining with other parts.

4. Motor and lights: Working with the electric circuit

The car is run by an electric motor connected to three 1.5 V batteries. A two-way switch is included in the circuit, in order for the motor to be switched off and for the car to go both ways. Figure 12 shows the components, and Figure 13 the wiring.

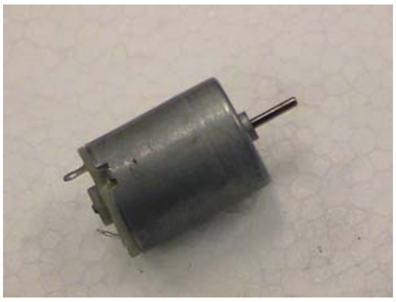
Components for each pupil

- Electric motor, suitable for 3-6 Volt
- Two-way switch
- Wires
- Batteries: 3 x 1.5 V
- Battery holder and clips

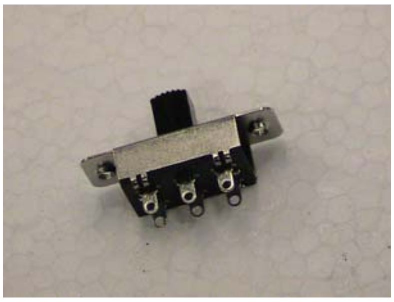
In addition for lights:

- Light-emitting diodes
- Resistors, 460 ohm

Pupils might want to have light on their car, and this provides for learning more about circuits in series and parallel. Typical questions for inquiry are: How can we make front lights go on when the car is going forwards, and back light go on when the car is going backwards? Or what if we – for security reasons – want front lights to stay bright regardless of which way the car is running? How do we then wire the LEDs?
And will the lights affect the power of the motor, since they are connected to the same battery?

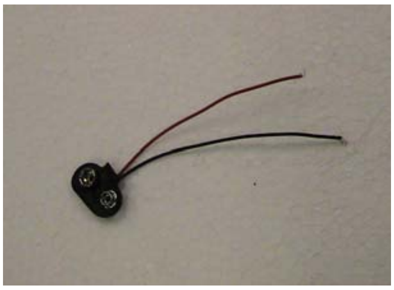


Motor



Switch

Batteries and holder



Battery clips

Figure 12. Components for the electric circuit.

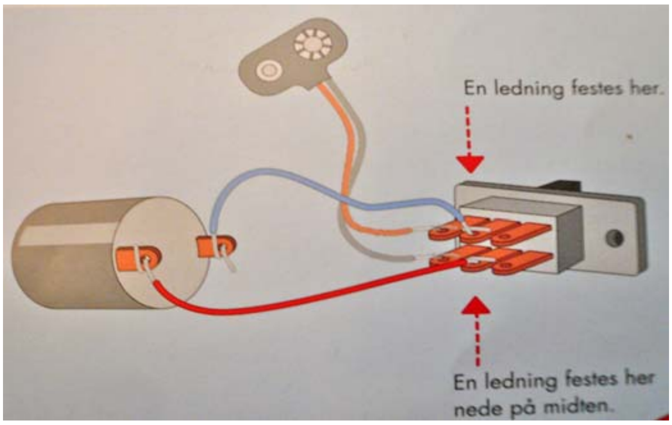


Figure 13. Wiring the circuit.

All components and wires are soldered with a soldering iron. Strip the wires in both ends with wire stripping pliers (see Figure 14) before soldering. The switch is especially small and can be cumbersome to solder. Pupils should help each other in pairs, holding the components for each other while soldering takes place.

Soldering of the circuit should be undertaken in close instruction. This can be done in classes or groups one at a time, in order to utilize equipment and skilled teachers effectively. Make sure that enough soldering irons are available for pupils, so they are not slowed down in the process. Give all pupils a small plastic bag for storing the circuit and batteries until it is time for placing them in the chassis. The soldering should take place in one room, and the room, equipment and not least the skilled teachers should be available for pupils during the remaining phases of the project, as trouble shooting and re-soldering will definitely be required.

Figure 14. Wire and wire stripping pliers.

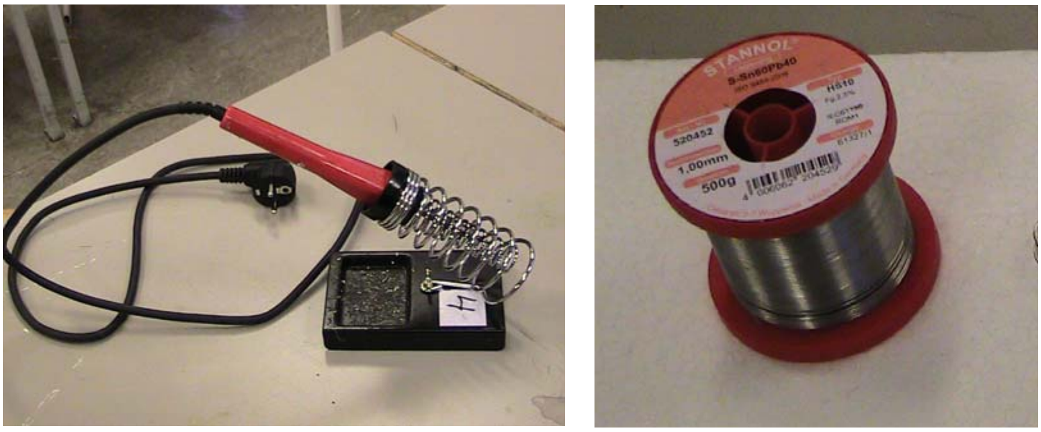


Figure 15. Soldering iron and solder.

Light-emitting diodes (LEDs) can be coupled either in series or in parallel, and in series with a resistor in order to reduce the voltage over the LEDs. Too high a voltage will destroy them. The light circuit can be connected to the motor poles, or to the switch. It may also get a battery of its own, in order to save the battery power for the motor. But note that another battery increases the weight of the car!

Note that LEDs conduct current in only one direction. Its long leg is to be connected to the positive pole on the battery.

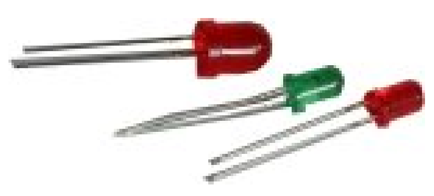


Figure 16. Light-emitting diodes (LEDs). Diameter 5 mm is suitable for the project.

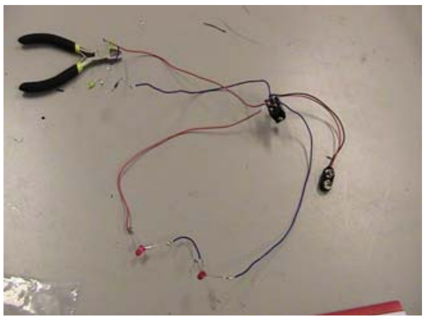


Figure 17. LEDs may be coupled in series (as here) ore in parallel, and the connected to the switch or to the motor. Remember to add a resistor!

5. Making it go: wheels and driving mechanism

There are plenty of different wheels and pulleys offered for purchase. We reccommend that pupils are only allowed to use standard, simple plastic wheels provided by the school, at least for the competition. Better wheels are often very expensive, and can take pupils' attention away from mechanisms and design issues.

Pulley wheels of various sizes should be available to the pupils. Inspire them to do systematic inquiries into how the ratio between the size of the driver and the follower affects driving properties. For a light and fast car, a small pulley wheel for the follower will be most efficient. For heavy cars attempting to win the uphill race, use pulley wheels with large diameter. Also note that crab gears can be made by cascading single pulley wheels.

Material for each pupil

- Plastic wheels, diameter 4 cm
- Pulley wheels, diameters 1, 2 and 3 cm
- Small pulley for the motor
- Steel axles, 3 mm.
- Elastic band

Plastic wheels of standard size.

Pulley wheels of different size.

Metal axles.

Small pulley for the motor.

Figure 18. Wheels, pulleys and axles.

Mounting wheels and mechanisms

Drill holes for the axles in the car chassis. Accurate measurement is necessary for placing the holes; otherwise the wheels will not run efficiently. The holes need to be in line and at the same height, allowing the axles to be parallel in the plane. However, since the car chassis are very seldom a 100 % exact construction, this is not as trivial as might sound. The process is more a question of adjusting to the best possible compromise than a strict mathematical exercise!

Cut the metal axles in appropriate lengths. File them at the end; otherwise their rough surface might destroy the wheels.

Mark positions for holes with an awl. Drill first one hole, and make the opposite hole in the equivalent position. Repeat the procedure with the other two holes, making sure the height is the same as for the first two holes. Then decide which axle should be the driving one. This affects where other components are placed. Ideally, the battery box should be placed over the driving axles. Even though low weight is an advantage, one may choose to add extra weight (for example, used batteries) in order to achieve at a balanced weight distribution. Again, a successful result is a matter of best compromise.

The pulley wheel may need to be glued onto the axle as it might otherwise spin. Remember to place the axle in the chassis before the pulley wheel is glued onto it. Be sure that its position is appropriate before you glue!

Figure 19 shows how the interior of the car may look with everything in place. It is important to place the motor in a way that allows the elastic band to run freely. It needs to run perpendicular to the motor pin and to the axles. The motor can be fastened by glue or a piece of plastic shaped in a suitable way (this can be done by a hot air gun), as shown in Figure 19. Purpose-made motor holders are also available for this purpose.

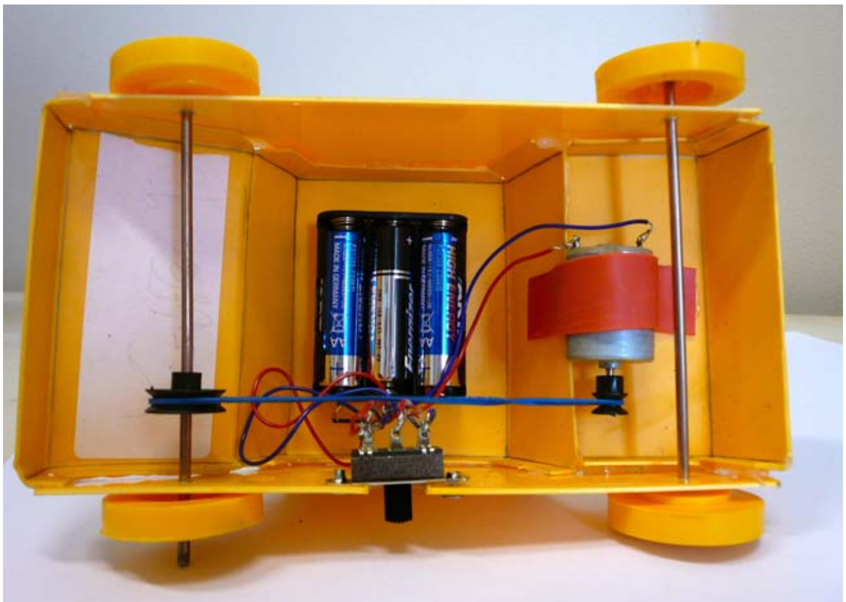


Figure 19. The interior of a car with axles, motor, pulley wheels, elastic band, batteries and switch.

Make a hole in the chassis for the switch button. Note that the main part of the switch is to be on the inside of the chassis. To tidy up, long wires may be twisted and glued to the chassis. This protects them from interfering with pulleys or the running drive belt (elastic band).

To improve the wheels' grip on the surface, rubber may be attached to wheels. Rubber can be taken from bicycle tubes. A ring cut perpendicular to the tube will make a miniature tyre perfect for our wheels. This kind of tyres can be seen on the red car in Figure 1, page 5.

When everything is ready, it is time for the trial tour. Be prepared for the fact that the car does not run properly! It is now time for careful adjustments…

6. Firing up: Testing and improving

The trial run is an important point in the process. Pupils will experience cars which seem to perform a dance, cars that tend to go everywhere but in a straight line, cars going disappointingly slowly or not at all. Make sure pupils understand that this is to be expected and take the adjustments and improvements as a positive challenge; their motivation will then offer great opportunities for learning by inquiry. Why doesn't it run steadily? Why is it spinning around? What does distribution of weight mean to the car's driving properties? What effect do small and large pulley wheels have? Can my problem be caused by a short circuit?

These cars are not industrial products. Every car will be different, with its own "personality" including lots of inaccuracies. This means that careful experimenting is required in order to make them run properly. However, here are some common issues that might be of some help in trouble-shooting:

- Axles must be parallel and at the same level in relation to the ground. Make sure both axles can rotate freely.
- The centre of mass should be over the driving wheels. Adding weight may improve driving performance by balancing the weight distribution.
- If the motor does not rotate, the problem is often that the thin wires to the battery clips are broken.
- If the motor still does not rotate, or is unstable, check all soldering points.
- If the batteries go warm, you certainly have a short circuit!
- The friction between the axles and their mounting holes should be reduced as much as possible.
- The elastic band connecting motor pin and pulley(s) must be perpendicular to the axles. This may solve the problem if the band tends to jump off.
- The elastic band must run freely and not be stopped by the battery box or switch.

Final decoration
Pupils will enjoy decorating their car with paint and details. Metal parts, for example for mudguards, can be cut from soft drink boxes, which are easy to bend into shape. Transparent plastic from waste works well for windows.

7. The rally!

The rally is an important final point of the project. It celebrates not only the winners, but also the efforts and creative results of all pupils. A group of pupils can be given the task of organizing the competition, as it gives pupil greater ownership of the event. It is a good idea to invite younger pupils as an audience; they will increase the excitement to an even higher level.

At Ruseløkka, prizes are awarded in four competitions:

1. The design prize: Design students are invited to evaluate the cars and pick a winner. It is important that they give good reasons for the choice, so all pupils can learn from the evaluation.

2. The fastest car: Cars start in groups of 5-6 cars, winners of each run go to the final run.

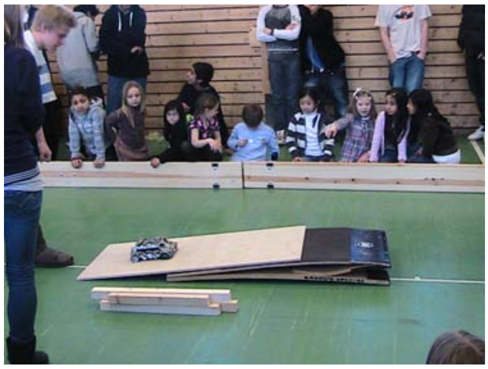
3. Steadiness: How far can the car run along a straight line? Put marks along a line with names.

4. Hill climbing: How steep a hill can the car climb?

The competitions should be taken seriously, but it should first and foremost be an enjoyable event for everybody. Make sure rules are clear, and that competitions are run in a fair way. A good and supportive atmosphere at the final rally is essential, as it will show clearly the valuable learning and joy achieved through the project.

The rally site before start.

Competing in steady driving.



Climbing hills.

A happy price winner…

… and a proud headmaster!

List of equipment

Phase 1 and 2:

Protective paper for desks
Paper
Magazines etc for pictures
Glue sticks
Pencils
Scissors
Rulers
Compasses
Cardboard
Cutting mats

Phase 3

Linebenders, 4-5 per class of 30 students
Plastic sheets: Minimum 2 A4 sheets per pupil. Thickness: 1mm, 1.5 mm and 2 mm.
Stanley knives
Rulers
Pairs of compasses
Hot glue guns
Plenty of glue sticks for glue guns
Hot air gun
Masking tape
Metal soft drink boxes, paint suitable for plastic, transparent plastic for windows etc.
Extension leads

Phase 4

Electric motors, suitable for 3-6 Volt
Two-way switches
Wire
Batteries, AA, 1.5 Volt, 3 for each pupil
Battery clips
Battery box, 3 x AA (1.5 V)
Light-emitting diodes, 5 mm
Resistors, 460 Ohm
Soldering irons and solder
Pliers
Nippers
Wire stripping pliers

Phase 5

Pulley wheels, diameters 1 cm, 2 cm and 3 cm
Small pulley for motor
Steel axles, diameter 3 mm
Metal saw
Plastic wheels, diameter 4 cm
Screws and screw drivers
Elastic bands
Electric drill
Metal files
Awl
Clamps

Resources

Tisco, for purchase of linebenders: www.tisco.no

A resource book for teachers, in Norwegian:

Eva C. Jørgensen, Rolf Ingebrigtsen & Svein Brisâ: **Teknologi & Designboka**, Cappelen Damm, 2006.

ISBN: 9788204124920 (8204124929

Some illustrations in the present guide are taken from this book.

For more resources and technology projects, see Eva's technology site: http://www.evacj.no/ (in Norwegian)