An Effective Introduction to Technology and Design in Norwegian Primary Education

Dr Pål J. Kirkeby Hansen, Professor, Faculty of Education and International Studies, Oslo University College

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Abstract

How can young pupils get *An effective introduction* to technology and design at the primary level in the Norwegian context? This question is highlighted with examples based on case studies at five classes in two schools doing their first technology and design project at grades 1 or 2 (age 6-8 years). The project was about air rockets. The discussion in this article covers five aspects of introducing technology and design at the primary level: technological literacy, design, motivation, teaching and assessment. The discussion is based on a very small sample. That is not a safe basis for drawing general conclusions about what the best introduction of technology and design education might be. There are of course many different effective ways of introducing technology and design education. Most of the pupils reached the actual curricular competence aims. The designing process and making process were interwoven and the pupils were eager to take their initial idea directly to making at the cost of reflective thinking. It seems however, that this simple but spectacular project did develop interest and enthusiasm for designing and making artefacts. The discussion identifies several characteristics of *An effective introduction*.

Key words

technology, design, primary education, teaching, learning

Introduction

The recent Norwegian national curriculum from 2006 is called *Knowledge Promotion* (KP06) (Norwegian Directorate for Education and Training (NDET), 2006a). *Technology and design* (T&D) is a new main subject area in the Natural Science subject in primary and lower secondary education (NDET, 2006b):

> The main subject area technology and design covers several subjects, including natural science, mathematics and arts and crafts. Technology and design focuses on planning, developing and making products that are useful in our day-to-day lives. The interaction between natural science and technology is a key part of this main subject area. Natural science principles constitute the basis for understanding technological activities. (NDET, 2006b:3)

T&D is not a subject on its own like for instance in England and Sweden. The subject Arts and Crafts has two main subject areas relevant for interdisciplinary work in T&D, namely Design and Architecture (NDET, 2006c:2). Mathematics has no such areas, but "shows its usefulness as a tool when we work with technology and design" (NDET, 2006d:1).

Aims

This article will discuss some crucial aspects for the introduction of T&D at grades 1 and 2 in Norway based on case studies in five classes at two schools doing the same T&D project. The class teachers have all participated in a short introductory in-service course in T&D. Different introductory T&D projects were tried out and evaluated. The teachers wanted to take one of the projects into their classrooms when doing the very first T&D project. The aim for the research is to describe and evaluate this introduction of T&D.

Literature review

During the 1980s and 1990s in several countries the technical curricula for compulsory education (woodwork, metalwork and textile craft, formerly separated for girls and boys (Rasinen, 2005)) were transformed to separate technology and craft curricula for both genders (for a deeper discussion see de Vries and Mottier, 2006). In Norway the process started 10-15 years later with a pilot period from 1997, and was accomplished by the implementation of KP06. Primary technology education varies between countries. The subject Design and Technology (D&T) in England and Wales has functioned as a model for T&D in the Norwegian curriculum (Bungum, 2003:32). In the present curriculum for D&T in England (DfES, 1999), years 1 and 2 (age 5 to 7, Key Stage 1) the knowledge, skills and understanding are centred on four major topics:

- Developing, planning and communicating ideas.
- Working with tools, equipment, materials and components to make quality products.
- Evaluating processes and products.
- Knowledge and understanding of materials and components.

For our closely related educational neighbour Sweden, the goals for the subject Technology *(Teknik)* (Skolverket, 2000) at the end of the fifth year are that pupils should:

- be able to describe some areas of technology they are familiar with, important aspects of the development and importance of technology for nature, society and the individual;

- be able to use common devices and technical aids and describe their functions;
- be able with assistance to plan and build simple constructions.

In United States (US) the International Technology Education Association (ITEA) presents 20 standards for technological literacy, years K-2 (ITEA, 2007). “Technological literacy is the ability to use, manage, assess, and understand technology” (ibid.:7, 10). The standards are a collective expert view of what should be the content of technology education when a state or local school develops their own standards (Dugger, 2006). If the standards are followed, technological education in the US is more than just ‘hands on’ activities, but involves the development of technological literacy (Engstrom, 2006).

In England designing and making products is the focus for the youngest pupils. The ITEA standards (US) emphasise starting to develop technological literacy. While in Sweden pupils should be working on both aspects of technology from the first years. In Norway both aspects are taken care of, but designing and making is prioritised at grades 1-2.

Based on the analysis of 13 case studies of primary D&T education in England from reception class to grade 6, Howe, Davies & Ritchie (2001) have written the book *Primary Design and Technology for the Future*. The present project is partly inspired by some of their conclusions, for instance that creativity is more likely to happen in interdisciplinary situations (ibid.:17). D&T is a subject that can contribute greatly to children’s creative development if the teacher motivates and encourages the children, and provides space for creativity, both physically and in time (ibid.:35). The foundation of creativity is knowledge about tools, equipment, materials and components (ibid.:25). “There is no substitute for this first-hand experience” (ibid.:58). Howe et al. have observed that D&T teaching is rarely an ordered affair in the classroom. The design process could be linear (sequential), zigzagging between hand and mind, or spiralling (circular). Making is both a ‘hands on’ and ‘minds-on’ activity. Making artefacts and products therefore becomes both a way of learning and the outcome of learning (ibid.:58).

The only Norwegian PhD-thesis (Bungum, 2003) on technology education was written during the pilot period. Bungum’s conclusion was that the pilot project was more influenced by D&T in England and Wales than *Teknik* (Technology) in Sweden. However, the educational ideas were significantly reworked when realised in the Norwegian context (ibid.:276). The teachers appreciated project work and interdisciplinary approaches, but announced difficulties in finding ways of including meaningful substance in this kind of teaching (ibid.:280). After the implementation of KP06 Bungum (2006) concludes:

> There has been a shift from new ideas [in the pilot period] towards more traditional science content during the [curriculum] process. The new science curriculum nevertheless facilitates a “partnership approach” to science and technology teaching in Norwegian schools, rather than communicating a view of technology as “applied science”.
>
> (Bungum, 2006)

Despite the differences between the Norwegian and Swedish technology curriculum, we might look to Sweden for experience of the implementation of primary technology education. When Blomdahl (2007) made her study in 2003-2004, the compulsory subject Teknik (Technology) was rather new and lacked identity and tradition. A large percentage of teachers lacked training in the subject, while at the same time issues concerning content and working methods have been left to the individual teachers to resolve. The situation in Norway after the implementation of KP06 was almost identical to the situation in Sweden described by Blomdahl. Her overall results are that the teachers try to take the pupils’ own experiences as a point of departure for their teaching in technology, and make use of the surrounding technical environment as learning material (ibid.:192). The teaching takes the form of a process in which the children’s own active learning is at the centre, instead of a process where they as teachers merely transmit content for the pupils to receive. In this process, both theory and practice are interwoven, (ibid.:192). A major conclusion is the importance of providing opportunities for reflection/evaluation (ibid.:193). The shaping of technology practice is not a linear process but consists rather of a kind of oscillation between analysis, visualisation/construction and reflection, but with different forms of guidance (ibid.:193).

‘Design’ is a part of the curriculum subject name both in Norway and England, and is inherent in the concept of the Swedish subject “teknik” (technology). According to Stables (2008) the purpose of design education for both young children and future professional designers is to nurture ‘designerly’ abilities: to ‘image’ in our minds things we have experienced and also that we haven’t; our ability to manipulate those images, both in our minds and through externalised actions such as talk or drawing; and our ability – and determination – to utilise imaging and modelling of ideas to create new future realities (ibid.:8).

In Stables's analysis of young people's approaches to their design tasks, four characteristic ways of designing were determined:

- *Balance between action and reflection* – a web of iteration between the two.
- *Reflective skew* – iteration web where the context and the issue played a dominant role.
- *Active skew* – iteration web where an initial idea was relentlessly pursued.
- *Unhinged reflective and active* – could see and articulate the issue, but the design ideas paid no attention to these – two separate iteration webs.

Hope (2009) asserts that children can begin to use drawing effectively for designing at age 6-7, but rarely are given a design assignment in which they can make real choices and make real connections with other things they know and care about (ibid.:54).

According to Piaget & Inhälder (1966, 1974) the age of 6-7 is the time when children shift from preoperational thinking where they cannot conserve or use logical thinking, to concrete operational thinking where they begin to think logically but are very concrete in their thinking. Conservation i.e. understanding that quantity, length or number of items is unrelated to the arrangement or appearance of the items, might be important for starting to think in a designerly way.

Creativity has been highlighted in the National Curriculum for England and Wales. Good & Järvinen (2007) introduced their so called Starting Point Approach (SPA) to design and technology to maximise children's creativity while making it manageable for the teacher. The pupils in this study carried out in UK and Finland, are at age 11-12, but a light version of SPA might be relevant for pupils in grades 1 and 2 in Norway as well. SPA has four phases:
Phase 1 – The basic concept of the actual technology is discussed.
Phase 2 – The pupils are shown a large copy of the device and the characteristics are discussed.
Phase 3 – The children are asked to think of where the device is used in everyday life.
Phase 4 – During the final brainstorming session, the children are encouraged to generate many new ideas for using the device.

To conclude this limited review, *An effective introduction* of technology and design education at grades 1 and 2 might have some of these characteristics:

- Project work and interdisciplinary approaches based on specific curriculum goals.
- Starting Point Approach (SPA) to take the pupils' own experiences as a point of departure.
- Teachers motivate and encourage.
- Provide space for creativity and nurture the potential for creativity.
- Use the surrounding technological environment as learning material.
- Develop knowledge about tools, equipment, materials and components.
- Theory and practice are interwoven in a 'partnership approach' involving science and technology.
- Oscillation between analysis, visualisation/construction and reflection with periods of non-focused thinking.

The very first T&D project would surely be limited in all respects and could not be expected to encompass all these characteristics. However, during the first two years of primary education, the pupils might have experienced most of them.

Methodology

Based on the experiences from the pilot period and the reviewed literature, the research question is: *What could an effective introduction to technological and design learning be at the primary level in the Norwegian context*?

The methodology used in this study has elements from *Analysing Best Practices in Technology Education* (de Vries, Custer, Dakers & Martin, 2007). Eleven experts in technology education analysed the eight cases on 11 aspects. Five of the aspects will be discussed in this article: Technological literacy, Design, Motivation, Teaching and Assessment. As in *Analysing Best Practices* the cases in the present article are presumptive good cases. The discussions are based on observations of pupils and teachers during the process, unstructured interviews with the teachers, and their reports with pictures.

Educational context and sample

The case studies were carried out in five classes at grade 1 and 2 altogether approximately120 pupils at two schools in Oslo. Project Air Rocket was chosen among several tried out at the in-service teachers' course, because the teachers found it manageable for themselves as novices, engaging and demanding – but not too demanding – for the pupils. Other arguments were that the project used a limited range of tools, equipment and materials and could be carried out in two hours. The project meets part of one competence aim for Year 2:

> ...the pupil shall be able to make artefacts that are able to be propelled by water or air and tell others about what they have made. (NDET, 2006b:4)

The pupils should design and make an air rocket which can fly as high and as far as possible when stamping on a plastic soft drinks bottle which transmits air pressure through a pipe to the rocket. The rocket should be made from office paper A4 and might be decorated by drawings. The fins should be designed and placed in the way one thinks will make the rocket fly as high and as far as possible. (Look for an English version at: http://www.sciencetoymaker.org/airRocket/index.html)

The wording and intention of the competence aims, not only in the present example but in all subjects in LK06, give much freedom to teachers in the choice of activities and teaching approaches. Project Air Rocket could also serve two competence aims in Arts and Crafts:

> ...the pupil shall be able to:
> - make simple objects and designs in paper and textiles by tearing, cutting, gluing and braiding;
> - build with simple geometrical basic forms (NDET, 2006c:3).

All parts of the rocket are geometrical forms (rectangle, triangle, circle, cylinder, parallelogram, rhombus, polygon). The pupils have to use these mathematical (geometrical) concepts when sitting in groups discussing the design and making of their rockets. The project also invites the children to measure how high and far the rockets have flown in the school yard, and make statistics for the competition. Therefore 'mathematics shows its usefulness as a tool'.

Data presentation, analysis and discussion

1. Incorporating Technological literacy into Classroom Practice

We have seen that ITEA defines technological literacy as 'the ability to use, manage, assess, and understand technology'. In Analysing Best Practices Dakers (2007:126) claims that technological literacy only can be developed as a result of the syntheses of procedural and conceptual knowledge development. The pupils have to keep not only "hands on", but also "minds on" in T&D projects and bridge the gap between the two aspects of learning (Shafer, 2008).

The question is: Could Project Air Rocket be *An effective introduction* to technological literacy given that only development of "procedural knowledge" is explicit in the actual competence aims "the pupil shall be able to make artefacts", and the first part of the overall aims is "focuses on planning, developing and making products" (NDET, 2006b:3)? The continuation of this aim however, requires more "minds on": "Natural science principles constitute the basis for understanding technological activities". This is far from a full comprehension of "understand technology" and "conceptual knowledge". We might therefore say that the aims for Project Air Rocket are pointing to no more than a limited introduction to technological literacy.

From the observations and teachers' descriptions there is no question that Project Air Rocket is a "learning space in which the predominant emphasis is upon the development of procedural knowledge" (Dakers, 2007:125). That is acceptable because this is their first T&D project. The pupils were very enthusiastic and excited when working. What Dakers (ibid.:126) goes on to say may however give some "comfort" according to technological literacy: "Where design is incorporated into technology education, we can begin to see opportunities for concept development" (ibid.). In this project design (point 2 below) is an element, but not as important as making. The two processes are interwoven.

In the report from School 1 the teachers write:
In the [pupils'] groups we talked about what a rocket is:
- What is a rocket?
- What types of rockets do we have?
- Rockets going into space.
- New Year rockets.
- The space shuttle.

Such questions turns "minds on". The first two questions could generate a discussion of "natural science principles" on an introductory level and links to what the pupils have made and done in the project (bridge to "hands on"). The last three questions widen the scope to take in Dakers' "enrich and widen the learner's knowledge about the particular technological system including the implications for humans" (ibid.). The teachers have consciously or not, tried to start the development of technological literacy.

School 2 reported that after finishing the statistics and applauding the winners, they talked about:
- What is a metre?
- What is a centimetre?
- How high could a rocket fly?
- What happened: Why do the rockets fly?
- What tilting of the pipe made the rockets fly far away?

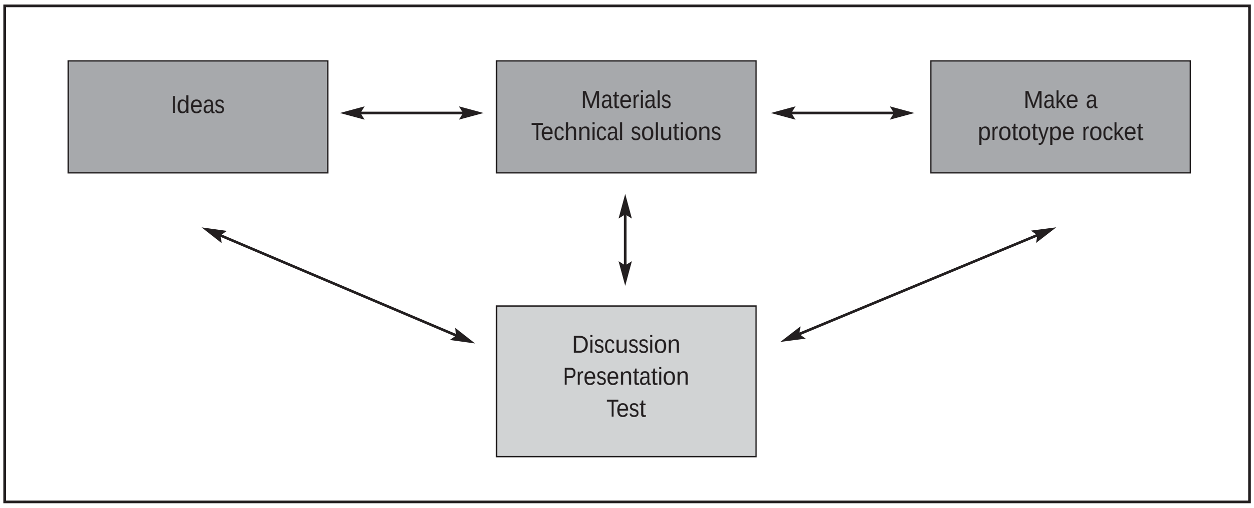
Like in the first school, the questions put "minds on" , induced discussions and could generate knowledge in a good social milieu for learning. The report does not detail the pupils' answers. The two last questions are about understanding 'natural science principles' on an introductory level i.e. a contribution to starting the development of technological literacy.

Figure 1. From ideas to completed rockets – and proud pupils in the classroom

2. Design Aspects

"Design is generally seen as perhaps the most characteristic process of technology" (de Vries, 2007:4). In *Analysing Best Practices* McCormick (2007:176) concludes: "One of the problems of technology education is that students are sometimes fed a uniform view of design, and do not have a chance to see it being treated as problem solving or as product development." During the teachers' course, we discussed how they could introduce the pupils to a design process in their first T&D project. The teachers' assertion was that their pupils would not be able to make sketches or drawings for designing, but they would be able to think logically in very concrete situations. The pupils might be able to think and talk about the arrangement and shape of parts which the rocket is made from. The result of the discussions was that in Project Air Rocket, designing should be an informal and intuitive process (Box 1) interwoven with the making from the first idea of a rocket to the launching for test and modification. The horizontal arrows indicate communication back and forth between the three phases (top). Within every phase the pupils might discuss, make a presentation or test the rocket. The design process is accomplished when the prototype reaches as high and as far as possible and the rocket is properly made and looks good. One important point in the design process is to "tell others about what they have made".

At the teachers' course we discussed how we could take the pupils' "budding" abilities in logical thinking to the design process in their first project. We called it the *installation method of design* because the parts of a product should be moved physically to be "installed" at different positions relative to each other as a response to the pupils' logical thinking – as most pupils have experienced when building with LEGO. In our method designing and making are interwoven, not two separate processes. The rocket body and the fins are the parts. The shape of the rocket body had to be given because it should fit the launcher. The only degrees of freedom in designing were the decoration and the geometrical shape and placement of the fins. From tests and retests the pupils could find the optimal technical design of their rockets i.e. the shape and position of the fins. During the work they presented and discussed their rockets with the teacher and fellow group members. The pupils have truly



Box 1. An introduction of design process

met the design process "as problem solving" and "as product development", but on an informal and intuitive level. They managed the designing and making process because the parts were few and large and hence they were easy to fit together. Mathematics was "useful as a tool" in the design process, especially during the testing when measuring height and length and making statistics.

The *installation method of design* is the pupils' first experience with a design process. According to Stables's (2007) analysis of characteristic ways of designing, Project Air Rocket for most pupils had an *active skew*. Many pupils were very eager to take their first idea directly to making. It is demanding to convince the pupils that there might be many different solutions to the specification, and perhaps some are better than the first idea.

3. Motivational Aspects

Motivation is the activation of goal-oriented behaviour. Motivation could be *intrinsic* i.e. coming from the task itself, or *extrinsic* i.e. coming from outside the pupils, like honor or good marks from the teacher.

An effective introduction in T&D must be driven by intrinsic motivation. The tasks and the activities which lead from the first idea to the completed product must be challenging, but neither too easy nor too difficult. An air rocket is relatively easy both to design and make. Before the pupils started, the teachers demonstrated their prototypes indoors so that the pupils could see that the rockets did fly. This demonstration seemed to be very motivating. The teachers gave the instruction and specification orally. During the designing and making the pupils got all the support and guidance they wanted from the teachers. The rockets were ready for testing in less than an hour. Many pupils even had enough time to decorate their rockets in personal styles which was motivating. Some were perhaps motivated by the element of competition even though there was no cup or diploma to win. The testing in the school yard showed that the

Figure 2. The rockets are tested in the school yard by proud and eager pupils: 13 metres and 40 centimetres

rockets could fly much higher and further than the pupils had guessed from the indoor presentation. The element of competition motivated for doing ‘exact’ measurements. We noted rockets going to 3rd floor (>12 metres) and more than 30 metres. Almost all rockets made a good flight on their first test. Some pupils were motivated to adjust the fins. They could see from the others that the simplest was the best, not the big fins like wings on an airplane. An important part of the whole motivation story is the teachers’ good planning, storytelling, instruction, demonstration, enthusiasm before the start and help and support during the designing, making and testing. The photos (Figure. 1, 3) show proud and happy pupils.

Project Air Rocket was accomplished almost only by stimulating the pupils’ intrinsic motivation. After having success with the rockets, the pupils were highly motivated for taking their measurements (Fig 2, 3) to the classroom and doing the statistics. The last part of the task “tell others about what they have made” and the discussion of the questions (point 1 above) also seemed to provide intrinsic motivation for many pupils.

4. Teaching approaches
The teaching methods and strategies to be used in T&D instructions are determined from the actual project and task. KP06 places emphasis on “planning, developing and making products”. The teachers in Project Air Rocket have to be less of a ‘teacher’ and more of an ‘instructor’. Perhaps more like a guide taking their pupils through different workshops with different tools, and help them to use the tools in an appropriate way.

5. Assessment
In Project Air Rocket the teachers did not use *diagnostic assessment* prior to teaching. They had decided to run the project the same way they had experienced themselves on the in-service course, and evaluate and adjust it for the future. *Formative assessment* is “assessment which is intended to enhance teaching and learning” (Bell, 2000:48), and was executed during the project. There was no need for planned formative assessment only interactive formative assessment. The main objective for the teachers was to observe and help the pupils when handling the tools and materials. There were no formal milestones, but all rockets had to be assessed as passable before the pupils could go in a body to the schoolyard and launch the rockets. All pupils had to make at least one high shot, one long shot and take part in the measuring before going back to the classroom to finish the project.

Summative assessment should prove to what degree the competence aims and other criteria are attained at the end of the project. The teachers’ *summative assessment* was informal and given orally in a few sentences to each pupil, and as a summary to the class in a plenary session.

From the assessment process in this project, other primary projects and the assessment criteria in England (DfES, 1999:7) and Sweden (Skolverket, 2000: *Bedömning i ämnet teknik*), I made a list of characteristics of the attainment of the aims in T&D at grade 2 (Table 1).

In Project Air Rocket all the criteria of Table 1 were met by some pupils. Some had ‘high attainment’ on all criteria, or

Knowledge, skills	*Low attainment*	*High attainment*
Theory, models and concepts	Can tell about the product and how it works in a simple everyday language Have some ideas about how the technology influences our everyday life	Can describe the product and how it works with use of the new concepts Can reflect upon how the technology influences our everyday life
Design and make	Can design and make with some guidance	Can design and make independently and with some creativity
Communication and social abilities	Can to some degree communicate and collaborate with others, but is not taking the lead	Can communicate and collaborate with others and is active and engaged

Table 1. Attainment of the aims in T&D at grade 2

Concentrating *Proud constructer* *Simple mathematics*

Figure 3. Launching of rockets in the school yard at winter time

'low attainment' on all criteria. Most pupils however, had 'high attainment' on some criteria and 'low attainment' on others.

In project Air Rocket most of the pupils reached the actual competence aim. They have experienced that stamping hard or jumping on the bottle makes the rocket fly higher or longer than when being more careful. Many of the children got an intuitive understanding that air pressure is driving the rocket. They have perhaps had the first tentative experience that 'natural science principles constitute the basis for understanding technological activities'. Other outcomes like the start of development of technological literacy and design and motivational abilities have been commented on the points above. The pupils have truly had 'hands on', but also 'minds on'. There have been some small signs of bridging the gap between these two aspects of learning.

Conclusions and implications

The discussions of the five aspects of introducing T&D at grades 1 or 2 are illustrated by examples from five classes at two schools doing Project Air Rocket. This very small sample from only one project is no safe basis for drawing general conclusions about what might be the best introduction to technological and design learning on primary level in the Norwegian context. There are of course many different effective introductions. Project Air Rocket has met several, but not all the characteristics discussed in the literature review:

- In spite of being a small project, there have been project work and interdisciplinary approaches based on the competence aims in science, arts and crafts and mathematics. Creativity is more likely to happen here than in a pure science classroom (Howe et al.).
- The teachers used the Starting Point Approach with all four phases (Good & Järvinen). As far as possible, the pupils' own experiences were the point of departure (Blomdahl).
- During the project the teachers motivated and encouraged the pupils individually and as groups all the time. This was important for starting children's creative development (Howe et al). The children's own active learning was at the centre all the time (Blomdahl).
- The teachers provided limited space for creativity because the degrees of freedom in designing were restricted and the making was demanding and time consuming for the pupils. Within this limited space however, the teachers tried to nurture the pupils' potential for creativity (Howe et al., Stables),
- A rocket project on this level could hardly use the surrounding technological environment as learning material (Blodahl). However, when coming to the discussion after finishing the rockets, the pupils' own experiences with different types of rockets were taken as points of departure. This could be the start of developing technological literacy (ITEA).
- The pupils had the opportunity to improve their ability to use tools and equipment, and to extend their knowledge about the materials used. This first-hand experience is the foundation of creativity (Howe et al.).
- The theory brought into the project during the practice was very limited, and could hardly demonstrate a 'partnership approach' to science and technology teaching (Bungum).

- The pupils oscillated between designing and making with reflections and periods of non-focused thinking (Blodahl). The processes were interwoven, but with an *Active skew* (Stables). The main focus was on making the artifact. There was no formal designing process. According to their teachers the pupils had no ability to make sketches or drawings for designing (as opposed to Hope).

All pupils in the present project have reached the actual parts of the competence aim. They have made rockets i.e. "artefacts that are able to be propelled by…air". Most of them could "tell others about what they have made". With some reservations Project Air Rocket has been An effective introduction. From grade 3 on the aim: "Natural science principles constitute the basis for understanding technological activities" must be taken seriously. From T&D projects at grades 8-10, we know that it is difficult to couple T&D with science in a symbiotic way, but we concluded:

> it seems like designing and making useful technological products could be a vehicle for enhancing understanding of natural science principles if the pupils get the opportunity to develop and use science in a technological context.
>
> (Hansen, 2009:51)

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PalKirkeby.Hansen@lu.hio.no

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