TO RESCUE EGGS; A DESIGN-BUILD-TEST EXPERIENCE FOR CHILDREN

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Abstract
The CDIO model involves conceiving, designing, implementing and operating a product or system as a context for engineering education. This has proved to be a successful teaching strategy for the students to gain deep, working knowledge of the fundamentals of engineering. In a societal context, this might however not be enough to fulfill the goal of producing higher quality graduated engineers, and an enough number of them to satisfy the needs of industry. In Sweden as well as in many other industrialized countries the present trend is that fewer students enroll in engineering education. One way to counteract that is to try to make younger children interested in engineering, or change their perception of what engineering is all about to start with, by introducing them to a design-build-test experience.

”The egg-fall” has since 2003 been a yearly project at Chalmers University of Technology, directed towards 11 year old primary school children in the Göteborg region. 35 schools with approximately 800 pupils took part in the November 2006 competition. The challenge is for a group of at least three children to create a device with the help of which a raw egg can withstand a fall from a height of 15 m onto a concrete floor. There are no limitations on the kinds of materials or the designs that the teams are allowed to use, unless they are obviously harmful, dangerous or unsuitable for any other apparent reason. The designs are being judged with respect to three criteria: The technically best design, the most amusing design and the best submitted presentation of a design. The basic idea behind the challenge is not new; on the contrary, the task of building an egg-saving device is sometimes used as a teambuilding exercise for adults. The intention in the project described here is however to arouse an interest in engineering problems and reasoning already in primary schools, and to let the children have an early introductory contact with a university.

The aim of the current paper is to present a well appreciated design-build experience, and to describe the impact that the project has had on the participants. Pupils and teachers were interviewed about their perception of technology and engineering, the competition, their interest in engineering as well as about their learning experiences. The pupils were also asked about their impression of the university as a possible career for them in the future, and questions to try to find out whether there are any noticeable systematic differences between girls and boys in their respective problem solving approaches.

Keywords: design-build-test, experiment, children, hands-on, contest

Introduction

One might expect that in the industrialized countries today, with their level of technical sophistication and standard of living that could not be dreamed of only a couple of decades ago, young people would be more interested than ever in engineering. That does not seem to be the case though. On the contrary, during the last years the numbers of applicants to engineering schools have in many cases gone down. Somewhat simplified and exaggerated, it seems that young people are certainly interested in what their various technical gadgets can do for them, but not necessarily in how and why they work. This should however perhaps not come as a surprise, since youngsters in these countries have never before in history had more opportunities and choices in terms of interesting jobs and things to do in their leisure time. The problem in the long run if the trend is not changed is that too few of them will embark on careers in science and engineering in order for their countries to be able to maintain and further develop their technologically advanced industry. Since a fair share of the public resources in industrialized countries comes from advanced industry production, the situation can come to pose a threat to the living standard in these countries. The CDIO model for engineering education, involving conceiving, designing, implementing and operating a product or system as a context for engineering education, has proved to be a successful teaching strategy for university students to gain deep, working knowledge of the fundamentals of engineering, but it is of little interest if we cannot get students to embark on engineering careers.

So what can be done about this worrying, but not yet alarming, situation? During the last few decades science centers have been established in many countries and cities worldwide with the purpose to explain and popularize natural sciences and engineering, especially to children. The collective conclusion of investigations into what visitors to these establishments know after they have been there, unfortunately, regrettably and maybe also surprisingly seems to indicate that the actual learning effect, in terms of for example increased understanding of physical phenomena, is limited. There is also reason to question whether hands-on experiences are necessarily superior to virtual environments when it comes to physical understanding [1], but the visitors to the science centers have certainly enjoyed themselves, and that should not be frowned at in this context. Maybe that is only what is reasonable to achieve? To give people, and especially children, a feeling that natural sciences and engineering are fun cannot be unimportant. After all, if something appears amusing and interesting to children, it is plausible to assume that the likelihood of their choosing a future career in the area increases. If their parents like it too, the kids will perhaps get another push from them.

Another way of making engineering appear fun and exciting is to organize competitions around it. Events of this kind are not uncommon in technical universities around the world, but there are also those who mainly turn to the general public rather than students. One of the authors recalls a competition of the latter kind in Boulder, Colorado where he was a student in 1983 and where the challenge was to build a human-powered vehicle that could traverse a course which was laid out both on land and water. In later years several TV shows have also been produced on the "Junkyard Blitz" theme, where the idea is for competing teams, out of what they can find in a junkyard, to build devices that are required to perform a specified task. Some of the contestants in these programs are amazingly successful, although the devices they come up with are of course of dubious quality and sometimes right out dangerous. It is however interesting to note that it is not always the trained engineers who produce the most successful designs! A previous TV show which built on the same elements of design-build was MacGyver, a popular adventure series from the 1980's about a young man who ended up in all sorts of strange situations which he managed to get out of by applying his quite impressive knowledge of science and engineering to build some ingenious gadget from whatever was available to him wherever he happened to be. There are now plans to launch a series of TV programs in which teams of high school students solve engineering challenges [2].

Technical/engineering challenges especially tailored for children are also popular and can hopefully increase the participants interest in science and engineering by putting the subjects in an amusing context [3], [4], and an element of competition may further stimulate creative thinking. The remainder of this paper describes a design-build-test competition event organized by Chalmers University of Technology for fifth grade school children in Göteborg, Sweden. The fact that the pupils actually come to the university is also something that might be positive in itself from a future student recruitment point of view. In many families no one has ever set foot at a university campus before, and the academic environment is completely unknown to them. After the competition in 2006 the children also got to attend a technical lecture especially tailored to suit them. The subjects were mathematics, nanotechnology, lasers, electronics and physical toys.

The "egg fall" contest

The "egg fall" has been a yearly November event at Chalmers during the last four years. 35 schools with approximately 800 pupils took part in the 2006 round. The Swedish name of the competition, "Rädda ägget!", is a play on words. It means "Save the egg!", which is the primary intended meaning, but also "The scared egg!" The second interpretation makes a lot of sense too, since the whole thing is about trying to prevent an egg from cracking when it is dropped from a height and allowed to land on a hard floor. This is not an original idea; on the contrary, the task of building an egg-saving device is sometimes used as a teambuilding exercise for adults. Somewhat adapted to match their skills, it is equally suitable for children though. The principle of it is so simple but yet challenging, and it allows the contestants to use their full imagination at the same time as it is easy and inexpensive for them to carry out tests at school before they come to the "race day" at Chalmers.

Image: Tommy Berglund

The basic rules and facts of the "egg fall" competition are as follows:

- Design and build a device which will protect a fresh egg from cracking when it is dropped from a height of 15 meters onto a concrete floor. Figure 1 shows two officials (undergraduate engineering students) in the 2006 competition when they have just released one of the competing designs from a sky lift.
- There is no limitations on the kinds of materials used or the specific designs, unless something is obviously harmful, right out dangerous or inappropriate for some other apparent reason.
- The mass of the device, egg included, must not exceed 5 kg.
- There is no upper limit on the size of the device, other than that it should be possible for one person to carry it.
- The device must land inside a marked 4*4 meter square on the floor.

- The team must manually release/recover the unharmed egg from the device within one minute after landing and demonstrate it to the referee.
- The competition is held in a concrete dome at Chalmers, which eliminates undesired and unpredictable gusts and side winds.
- A couple of weeks before the competition, each design must be presented in writing to the organizers, with the intended function described in a sketch or drawing.
- The competing team must consist of at least three fifth grade pupils (i.e., children 11 years old).

The competing designs are being judged with respect to three criteria:
- The technically best design
- The most amusing design
- The best submitted presentation

with prizes awarded in each of the categories.

Figure 1. Assisting undergraduate students in the sky lift have just released a competing device, its parachute unfolding. Visible to the right is a crate suspended from a crane, by which the devices are elevated from ground level to the start position.

Two main groups of design ideas can be discerned. Some teams concentrate on slowing the fall speed by either increasing the air resistance through developing parachutes (see Figure 2) or employing lighter-than-air devices such as helium-filled balloons, while those in a second category instead focus on solutions to cushion the shock when the device crash-lands on the concrete floor (see Figure 3). In the first category the speed of descent is still often too high for the egg to survive the impact at landing, so normally also these designs are equipped with some sort of padding around the egg, although not as thick as in the ones belonging to the second category.

The interviewed groups spent between 4 and 12 hours on building and testing their devices before going to Chalmers. Some teams, which were lucky enough to have a highway overpass or multiple-story building or similar close to their school managed to test their designs at almost contest-like conditions.

Figure 2. Another parachute-type design approaching the ground.

Figure 3. A - literally - cushioned design just before impact.

The speed reduction due to air resistance naturally depends on the actual shape and mass of each design, but an object which falls 15 meters with negligible drag smashes onto the ground at about 17 m/s, corresponding to over 60 km/h. A collision at that speed is of course quite a violent event, associated with a level of acceleration well beyond that required for the safety air bags in a car to inflate. The prospects for a raw egg to survive such a treatment therefore look very gloomy, but it is a fact that the majority of the teams who come to the competition manage to land their eggs unharmed. That is quite an accomplishment for a group of 11 year olds who have most often designed their devices themselves.

Figure 4. Retrieving the egg within one minute after touchdown …

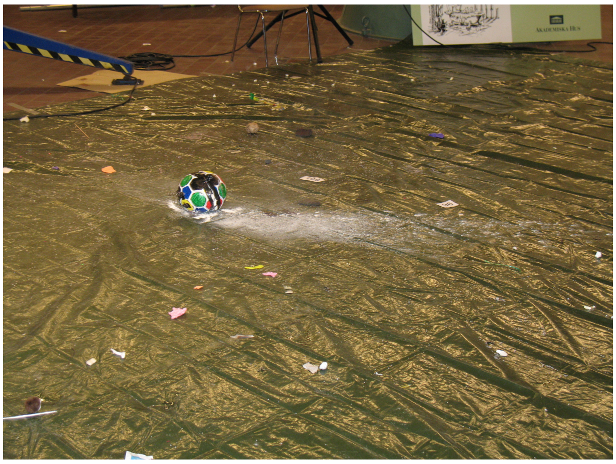

Figure 5. Hmm, reason to get "flourried"?

Figure 6. No, it worked!

Inquiry to participants

After the 2006 competition, interviews were carried out with a number of participating children and their teachers from nine different schools in order to find out, in particular, about

- Their opinions on the competition.
- What, if anything, they learned from it.
- Their perception of technology and engineering.
- Their interest in these subjects.

The children were also asked about their impression of the university (Chalmers) as well as academia, as a possible career for them in the future. Their teachers were asked if they had noticed any systematic differences between girls and boys in their respective problem solving approaches during the preceding work with their devices. Some of the children and teachers were interviewed at Chalmers immediately after the competition, while the majority was interviewed several months afterwards at their own schools.

It was our ambition to talk to one boy, one girl and one teacher at the schools where we made interviews, but we did not quite accomplish that. We met slightly more boys than girls, and in two of the schools only children but no teachers were interviewed. Seven of the schools are located in Göteborg, the other two in more rural areas outside. Some have many pupils while others are smaller. The schools also represent socially different parts of Göteborg in terms of average income and level of education.

Results from the inquiry

Some questions were common for the children and the teachers, while others were put to only one of the groups. *Common* questions, with answers (translated from Swedish), were:

What was good (↑) and what was bad (↓) about the competition?

Children: ↑ Amusing. Teamwork. Liked coming to Göteborg and ride the trams. Liked to build. Struggle. Every group gets to build its own design. You are allowed to think yourself. To compare and see possibilities for improvement. Right level of difficulty. Compete. The environment at Chalmers. Good benches (probably where they had their lunch/authors comment). We learned a lot. ↓ Everything was good except the way you were rewarded. It ought to be more difficult to win. Difficult to test beforehand from a height of 15 meters. We ought to be required by our teachers to bring more material to the projects ourselves. Some got sad.

Teachers: ↑ Everybody can cooperate and contribute something. The children get to describe in words what they have done. The lecture on nanotechnology afterwards. Arouses children’s and teachers’ interest in technology. The lecture on mathematics afterwards. The children appeared on TV. That they get to do practical work ↓ The lecture on computers afterwards.

What did the children learn?

According to them: We would have needed a larger parachute. Larger parachutes can make the device fly off. Old marshmallows tend to harden. Balloons decrease the fall speed. The parachute creates drag that slows the fall. To build robust devices according to predetermined rules. Boxes. Padding material. To build things. How to invent. Not as easy as I had expected. Design. Flour is packed around the egg at the time of impact and dampen. To have even pressure around the egg is good. My father did not succeed. Teamwork.

According to their teachers: Drag. Fly off. Weight. Cooperation. To design. To exchange ideas. Discuss. Listen to others. Test what is possible and what is not. I did not intentionally influence them during their work. Parachute slows descent. Teamwork. Different ideas. That they can accomplish something. Learned how to get something technical to work. Do practical work. Present. Solid mechanics. Buoyancy in balloon. Bicycle + helmet. Head protection. If the device is unsymmetrical, up can become down during the flight.

What is the connection between technology and this contest?
Children: We created a technical solution. Parachute + padding. We think. Falls down but doesn't crack. Think smart. Tried to get it together so that it would work. Soft things around the egg. Slow speed and soften impact. Children should learn how to build things. One can have a lid so that the egg doesn't fall out. To make inventions. I think you can use the same kind of technology when returning from space. Materials selection. To find the right size of the device. It is fun to make a construction which should be functioning and aesthetic at the same time.

Teachers: Build. Try materials. Test a design in real life. Lesson on shells. How to design. Parachutes. Design that will protect something fragile. Useful when packing to go on a trip. Soften the impact. The egg shall rest on something soft and experience an even distribution of load. Technical designs. Buoyancy in balloons. Cages made of wire netting with cotton in them. Materials selection. Design a plan and carry it through.

Did the children use something in the contest that they had learned in school?
According to them: No. About light bulbs. Electrical engineering. Bounced ideas. Materials. Not very much. Got information from my older sister who had participated an earlier year. To use the glue gun that we learned in 2nd grade. Sewing is important to make a parachute. Imagination. Teamwork.

According to their teachers: Leonardo da Vincis parachute. Mathematics. Geometry. Logical thinking. Nothing else than teamwork really, which they had practiced a lot earlier. How to present. About drag. Swedish. Read and calculate. They realize immediately that high speed results in a hard impact but do not reflect on the size of speed.

What did the children learn from their mistakes?
According to them: We had too little time available. The marshmallows must be soft. Build more durable and elegant. Continue/don't give up. One needs to think one time extra. Flour dampens the impact. The size of the box is important. It was not enough with soft padding only, you need to have a hard cover.

According to their teachers: The children became confident because their designs worked. One group had to redesign theirs though before it worked. Some materials are not so durable. More padding around the egg. It must be possible to recover the egg without having to rebuild the device after each fall. Learned through experiments. Too small parachute. Starch + water gives good jelly to put around an egg in a plastic can which is wrapped in foam rubber (this withstands anything). Too many helium balloons made the egg fly off. Egg suspended in water filled milk carton container didn't work. Yes, they thought about what they should do. Try something new. Many balloons are needed to soften the impact. A parachute can look like anything. Everything has weight. Nothing is impossible. Engineering is not that difficult. It could be made out of simple materials that could be found all around.

What does technology mean to you?
Children: Light bulb. Discover new things. Energy. Laboratory lessons. Everything possible. Ingenious things. Build. Airplane. Boat. Electricity. Mathematics. Drawing. Inventions. Thinking. A way to make work easier.

Teachers: Devices. Build. Understand. Windmills. Mechanics. Jumping jacks. Cinema. Water wheel. How everything around us works. Close and for everyday use. Technology for everyday use. Vacuum cleaner. Coffee machine. TV. Electric power. Force. To simplify man's work. The farmer made tools to cultivate the soil. Apes make tools. Practical work. Design. Enamel. Cut sheet metal. Technology in handicraft. Carpentry. Everything from the simplest tasks to very advanced things. Permeates everyday life. The kitchen for example.

Question to *the teachers* (some had accompanied classes to the same event at Chalmers in previous years, but for others it was the first time):

What did you learn?
Teachers: Competitions increase the engagement. We also learned from the lesson afterwards. Children are smarter than you think. That they can accomplish this themselves. How the children cooperate. It is necessary to dampen some and stimulate others. To teach the children through play and to introduce the physical terminology there, e.g. density and surface tension. Great event. Have learned about how children think. What is interesting and what is not. It must be allowed to take time. The road towards the goal is the important thing. The group's work. They inspire each other. Testing is a very important part of designing and building.

Did you notice any difference in boys and girls attitudes to/way of working in the project?
Teachers: The boys wanted it tough and amusing. They were also more fanciful in their ideas and needed to be more controlled. The girls did better on their own, they didn't complicate things so much and they were more flexible and ready to change. They pottered their way towards a solution. The girls are less self-confident and are more careful. The boys think that they know everything. No. The boys are more enthusiastic but do not want to document what they are doing. The girls want to understand everything, which slows their rate of progress. No, the interest is the same. The boys are more efficient and want to test though. The girls spend more time thinking before they make experiments. The boys go straight to the point and want results fast. The girls make more changes and are more patient. No, actually not, they are equally enthusiastic and meet the same difficulties. Possibly girls are more likely to see textiles as material for construction.

Questions to *the children*:

What do you think that one can learn at Chalmers?
Children: A lot of studying. Technology. A lot. Mathematics. Electronics. Swedish. English. Great freedom of choice. Natural sciences. Experiments. Writing. Research. Chemistry. Design. About machines.

Which departments/divisions do you think that Chalmers has?
Children: Physics. Biology. Chemistry (mix things). Experimental department. Culture. Environment. Natural sciences. Social sciences. Workshop (mechanical). Mechanical engineering. Mathematics. Swedish. Nanotechnology. Teacher's and staff room. History.

Technology. Handicraft. Textiles. Design. Science. Department for extreme things. Microscopy.

Who do you think study at Chalmers?
Children: Those who enjoy learning things. Those interested in science or technology. Older people (i.e. 20-30 years of age). Those who want to learn more and those who want to become teachers. Older and smart people. Those who want to continue to study. Those who have the time and want to learn more. Those who would like to work at Volvo (Göteborg is the home town of Volvo/authors comment). Those who have made it through high school and are 18-19 years old and want to become scientists. Not just anyone; you have to have high grades. Those who want to get a good education. Those who like mathematics.

Does Chalmers appear to be something for you?
Children: Yes, the design. No, I want to become a dentist. Maybe. Yes. Very good. Languages. Yes, entertaining school. Want to learn more about everything. Yes, that would be enjoyable. Yes, I want a better future and a good job. I want to protect the earth.

Analysis and discussion

It is not possible in interviews like these in words only to fully catch the responses from the interviewees. Children in particular are often physically expressive, and since the interviews were not recorded in any way - only notes were taken - we also have inexact records of what was actually said. Our impressions, and consequently analysis, discussion and conclusions, are therefore influenced also by other factors than what is summarized in the brief answers above.

Concerning the questions we set out to try to answer, it is quite clear that the children as well as their teachers are overwhelmingly positive about the egg fall event as such. It is unmistakable from the enthusiasm shown both during the competition at Chalmers and the interviews that the vast majority of the children who took part in designing, building and competing really liked doing that. And, as discussed in the beginning, this must be a positive factor if we want to make them interested in science and engineering.

By participating in the egg fall contest, the children seem through experiments and observations of what others did to have increased their understanding of the physics involved. They have acquired some insight into how one can affect the air resistance of a falling body by changing its shape, and how it is possible in various ways to reduce the harmful effect of an impact on a brittle object. They have also developed some feeling for how different materials behave when subjected to large and dynamic forces. Their teachers mention that they learned teamwork and to respect and discuss others ideas, as well as how to make something technical work. Many children were more self-confident after the competition since they had managed to land an egg that had not cracked, something which was considered a real feat. That one should continue and not give up, even if things look difficult, is also something that several mentioned as an important lesson.

The concept of technology appears to mean about the same to the children and their teachers. It stands for a collection of technical discoveries and inventions, but it also seems to carry with it an inherently positive anticipation of power to simplify man’s life and work.

Chalmers has a decidedly positive reputation among the interviewed children, and judging from their answers there does not seem to be any immediate danger that the future application rates to engineering schools will be lower than today. Considering that young students today in general appear to know less about technology than their predecessors, the children interviewed here in many cases stand out as unexpectedly well informed about what goes on in a technical university. Since it is often pointed out among engineers that our profession is for many of us less about machines and much more about working with other people than what many non-engineers think, it is particularly interesting to note here that the children have not only mentioned maths and technical subjects, but also languages and writing.

The differences, or lack of such, in boy/girl behavior are interesting to note, but not significant enough to draw any specific conclusions from. Many of the differences were qualitative and difficult to distinguish from the teacher's expectance of girlish/boyish behavior. It would be interesting though in next year's event to let a person experienced in gender research tape the children when they work and evaluate whether boys/girls have different attitudes or not towards design at such an early age. The answers from some girls reveal that they are aware of the connection between technology and mathematics in higher education, but considering that all of the answers were spread over a large number of subjects they thought were connected to a university of technology this might not be significant either.

Conclusions

We have described how to carry out a competitive design-build-test experience for 11-year old school children. Important findings are that:

- Children and teachers want the assignment to be difficult and sharp.
- The children want to compete and see how they do in relation to others.
- Testing is important in design-build activities also for younger students.
- The children are interested to see other designs than their own, and to learn from them.
- If introduced to the academic world of technology, although interested, children will only remember a small part of what they see and hear – so don't be overambitious; keep it small and let them make a study visit and meet people.
- Children are under the impression that only smart and interested people attend the university. After the contest many of them seem to think that it would be possible for the too to study there.
- The sheer size of the egg fall contest, with about 800 children present, the interest from media, pictures taken and the use of microphones etc. make the children feel that they participate in something important. A prize in this contest is told to younger children in the school as something they should go for too.

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