Concurrent Engineering : A New Way to Introduce the Engineering Profession to High School Students

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Abstract

SEEHIGHS program was developed to introduce high school students to the engineering profession. Initiated in 1993 by two engineering students from the University of Sherbrooke (Quebec), the program's main activity is a design project applying the principles of concurrent engineering. The program targets third year high school students who spend three hours per week for a full academic year working on a group project. The multifunctional approach of concurrent engineering is supported by industrial partners who introduce participating students to basic notions in marketing, product development, production and quality control. These partners also contribute to the funding of the program. In order to provide the reader with an appreciation for the scope of a typical project assigned to the students, one such project and its outcome are explained in detail. SEEHIGHS is now in its third year, and has generated much enthusiasm among students, professors and the participating industries. The program is currently offered in three schools and is projected to expand to 17 more schools by the year 2000.

Introduction

This paper describes a high school program developed to provide high school students with hands-on design and project experience and to introduce them to the engineering profession. Called SEEHIGHS (for Simultaneous Engineering Experienced by HIGH School students), the program was initiated in 1993 by two of our engineering students who submitted the concept at a Canadian engineering student competition. As their idea was well received (they won first prize), they decided to follow up by convincing one of their former high school teachers to experiment with the approach.

Our engineering students were first introduced to the concurrent engineering approach through a pilot program. Initiated in 1992 by our mechanical engineering department, the program is centered around a comprehensive 15 credit design project during which the students are required to design a product to meet identified client needs and fabricate a functional prototype.

The pilot program has proved two things: first, it is possible to use the multifunctional concurrent engineering approach for teaching design in a university environment if you have the proper facilities and tools, and if you devote enough time and energy to the process. Secondly, we firmly believe that the approach we use makes better designers out of our engineering students. This has been confirmed by employers of graduates who have completed the program.

Having defined concurrent engineering, we will briefly describe the SEEHIGHS program and its objectives. We will then look at how the program is structured and at its main participants. The type of project that high school students can tackle will be shown through an actual example. Before concluding, we will comment on the outcome of the program to date, and how we see it progressing in the years ahead.

Why Concurrent Engineering?

There are many ways of interesting high school students in technology and engineering. Initiatives can range from informal discussions between engineers and high school students, to the outright creation of a high school whose mission is to attract students to careers in engineering[2].

Why did we choose concurrent engineering? Let us start by defining what this approach involves[3-4]:

> "Concurrent engineering is a systematic and multidisciplinary approach that simultaneously integrates the different phases of product development and the management of its processes. These processes include the identification of customer needs, specification of product performance requirements, design of the product and its manufacturing processes and fabrication of the product, while considering the entire product life cycle, including distribution, support, maintenance, recycling or disposal."

Product development is the core process in concurrent engineering. It is also one of the principal attributes differentiating engineers from pure scientists. Product development is also an applied, concrete and challenging process, during which a team works from an abstract problem statement, and ultimately, fabricates a working prototype.

Objectives of the Program

The main objective of the SEEHIGHS program is to familiarize high school students with the engineering profession. Contrary to the K- 12 programs that are now part of ASEE activities in the United States, we do not have anything similar in Canada. Our students are introduced to pure science careers during their high school years through organized activities, lectures and competitions in chemistry, biology, physics and mathematics. This enables them to see if a career in these fields is appealing and if so, they can plan the following years accordingly.

Unfortunately, nothing similar exists for technology or engineering. The student who eventually ends up choosing engineering, does so as a result of hearing positive things about the profession, by reading on the subject, or simply because a friend has decided to study in this field. This may explain, at least partially, why we have been experiencing a continuous and severe drop in engineering applicants over the last four years in the Province of Quebec (Canada). This also explains why our faculty is investing time and resources in the SEEHIGHS program. Hopefully, we will see an increase in the number and in the quality of high school students entering engineering, as a direct result of the program.

The objectives of the program, from the student's point of view, are diverse and far reaching. Not only will students have a better understanding of what engineering is about, but they will also:

- learn and experience how to work in teams;
- be introduced to and use creative tools and techniques;
- deal with the uncertainty of an open-ended problem and the convergence of a final solution;
- acquire hands-on experience while fabricating a functional prototype;
- be fortunate enough to talk with engineers, visit them at their workplaces, and realize, we hope, that engineering is a challenging profession with diverse fields of application.

How is the Program Structured?

In the Province of Quebec, students must complete five years of high school and two years of junior college before being eligible for admission to university. In the fourth year of high school, a student has to choose between the humanities or the sciences, the latter orientation leading to engineering. SEEHIGHS is intended for third year high school students in the hope that the program can help them clarify their options and facilitate the choice they have to make the following year.

Concurrent engineering is fundamentally a multifunctional approach. In order to simulate such an environment, each SEEHIGHS project is linked with four local industries. The roles played by these industrial partners are to:

- introduce students to the basic notions of marketing, product development (R&D), production and quality control:
- welcome students to their facilities and familiarize them with ongoing activities;
- contribute to the funding of the program.

The students spend approximately three hours per week for a full academic year in the program. The main activity in the program is a design project leading to the fabrication of a functional prototype. The high school teacher in charge of the group plays a crucial role preparing, monitoring, encouraging and rewarding students for the length of the program. The teacher is supported by engineering professors, and the industrial partners who provide additional expertise.

Each week, students work on their project and are taught about topics related to the product realization process, or skills related to concurrent engineering. A sample of these topics includes:

- teamwork;
- the determination of the client needs;
- product specifications;
- concept divergence using creativity tools;
- an introduction to technical drawing and sketching techniques;
- the fabrication of a prototype;

Example of a SEEHIGHS Design Project

In order to provide the reader with an appreciation for the scope of a typical design project assigned to the students, we will briefly describe the first project of the program. As you will notice, the problem is open-ended and the students must try to approach a feasible, if not optimal, solution taking into account the constraints to which they are submitted.

Problem statement

Lewis Page operates a chicken farm. One day, after a severe earthquake, his farm is isolated from his consumer market by a deep fault which is at least 5 meters wide. Since his chickens are still laying eggs and he wants these to be delivered to his clients, he has to come up with a system that will transport his eggs safely across the fault.

Specifications

- The system must be capable of transporting 4 dozen eggs across the fault in less than 4 minutes.
- Only one broken egg will be tolerated for every 4 dozen transported.
- The system must be as cheap as possible, with a maximum costof$10.00.
- The available materials with which Lewis Page can have his system built are: popsicle sticks, brown paper bags, white glue, strings, elastics and a 12“X12“X1” blue Styrofoam square.
- A prototype qualifies if it meets all of the specifications stated above.

Project evolution

In this case, the farmer’s role was played by a mechanical engineering colleague. After having explained the problem, different possible solutions are brainstormed with the group of 30 students. Some are rejected by the client: “Too expensive !” he says. Others need to be analyzed further. “It would be unsafe to build a pillar close to the fault because the soil is still too unstable”. His comments force the students to stretch further, to look for alternate solutions, to grasp the full extent of the problem. “No, you can use only the available materials” says he to another group of students who are contemplating a solution that would not respect this constraint.

At the end of the first session, two interesting solutions have emerged, both using a bridge on which a device would carry the eggs across the fault. Even though the two concepts differ in more than one way, they both have one important thing in common: they meet the client’s needs. The project will now move on to the detail design phase. From this point on, any deviation from the chosen concepts will have to be agreed upon by the client.

During the following months, the students meet three hours per week to work on their project. During that time, they also have the opportunity to visit the industrial partners. This allows them to see, question, verify, and corroborate the different aspects of a multifunctional design project. While visiting a snowmobile manufacturer, students were briefed on the role of the marketing department in that company. They later had the chance to tour a research laboratory, talk with the researchers concerning the nature of their work, and look through an electronic microscope. Students were introduced to a production environment while visiting a garage door manufacturer. “How many doors can you build in one day?”. “What happens if there is a power failure?”. “What does that automated machine do?” Finally, they visited a company making rubber stripping for car doors where they were told how a quality program works and meshes in with production parameters.

Examples of design solutions

Figure 1 shows one concept that the students came up with. They built a bridge using popsicle sticks. To do so, they were introduced to the stiffening effect of trusses and were quite surprised to see that their 5.5 meter structure would hold while carrying a dozen eggs. To transport the eggs, they borrowed from the clothes line principle to pull a carriage along their structure. The eggs rested softly on foam trays, one dozen at a time (figure 2).

Another group decided to use an incline plane (figure 3). With a few trigonometric calculations, they determined the length of the different components, given a 7 degree slope, The students were always encouraged to play with more than one concept so they would come up with a better design. This is shown in figure 4 which illustrates two different ways of carrying the eggs on the inclined plane.

Where is the Program Heading Now?

We are now into the third year of the program. So far, four groups of students have graduated and we are currently managing four other groups from three different schools.

The outcome of the program has exceeded our expectations. Not only are the students enthused, but they willingly devote much energy and work to their design project. They truly seem to be having fun. The students have told us that among their diverse activities, the project is their favorite and that they are very proud to be in the program.

Have the students in the program acquired knowledge and change their attitudes towards engineering? Yes, the great majority enjoy the challenge of developing a new product and thrive on using their creativity. Teachers in other disciplines who have since had these students in their classrooms, are sometimes amazed at how efficient they are at tackling problems and assessing multiple solutions.

When the first groups of students graduated from the program in the spring of 1994, we held a special awards night at which each student was provided with a diploma attesting to his/her participation in the SEEHIGHS program. Held in a large hotel, with the media on site, the event attracted around 300 persons and was a moving experience. Each student involved invited his family and friends and it was rewarding for us to see the pride on all of these young faces.

Even though the program is fairly young, we have established a tradition of not only organizing an award's night, but also arranging for a major trip at the end of the year to cap the students' introduction to engineering. The first trip was particularly memorable as the students had the unusual opportunity to visit the Mecca of concurrent engineering: The Chrysler Technology Center in Auburn Hills (MI). Needless to say they were most impressed to see a multitude of engineers designing real cars, working in teams, with groups of them arguing about best possible solutions, and making compromises, as they themselves had done, while trying to solve Lewis Page's problem.

One unexpected outcome of SEEHIGHS, is the interest it has sparked in other secondary schools. This popularity led us to organize ourselves and expand the program. SEEHIGHS is now managed as a non profit organization. We have an active board of directors, and a full time manager whose main job is to secure adequate financing and to recruit **new** industrial partners for the new schools entering the program each year, Our strategic planning calls for 20 schools **active** in the program by year 2000.

Conclusion

The SEEHIGHS program has been very successful **to** date because **it** has adapted the concurrent engineering philosophy to its own operational approach which includes teamwork with many diverse and interesting partners. High school teachers view the program as an effective pedagogical tool and method of interesting students in technology. The industrial partners are active players who will also benefit by having a larger pool of competent engineer candidates. Our faculty has helped by providing expertise in the hope that program graduates will be more likely to enroll in engineering.

The first students to graduate from the program will be entering university in the fall of 1997. Will some of them eventually consider choosing engineering as a career? Many have said yes, and are choosing the proper courses to prepare for admission to engineering.

With the present **rate** of expansion, we anticipate that SEEHIGHS will become an established high school program in our province within the next decade. What better way of getting a young mind interested in engineering than by challenging it to find a solution to an open-ended design problem!

References

1. Proulx, D., Charron, F., "A Concurrent Engineering Pilot Project at the Undergraduate Level", 1993 ASEE Annual Conference Proceedings, pp. 932-938.
2. Panitz, B., "Strengthening the Pipeline", PRISM, January 1996, p. 13.
3. Hoover, W., Jones, J. B., *Improving Engineering Design - Designing for Competitive Advantage*, National Academy Press, Washington, D. C., 1991.
4. *Institute for Defense Analysis Report R-338, 1986.*

Biographical Information

DENIS PROULX received his B. App.S. in Mechanical Engineering from the University of Sherbrooke in 1964, and his doctoral degree from the University of Grenoble in Materials Engineering in 1973. He is currently professor and head of Mechanical Engineering at the University of Sherbrooke. His research interests are mainly in the integration of design tools in a concurrent engineering environment.

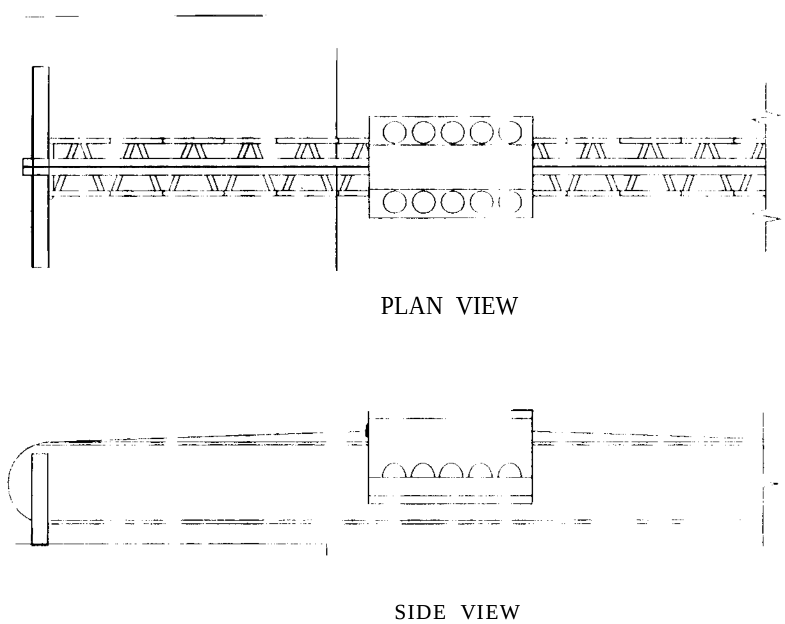

Figure 1: A bridge structure, on which a carriage is pulled to carry eggs.

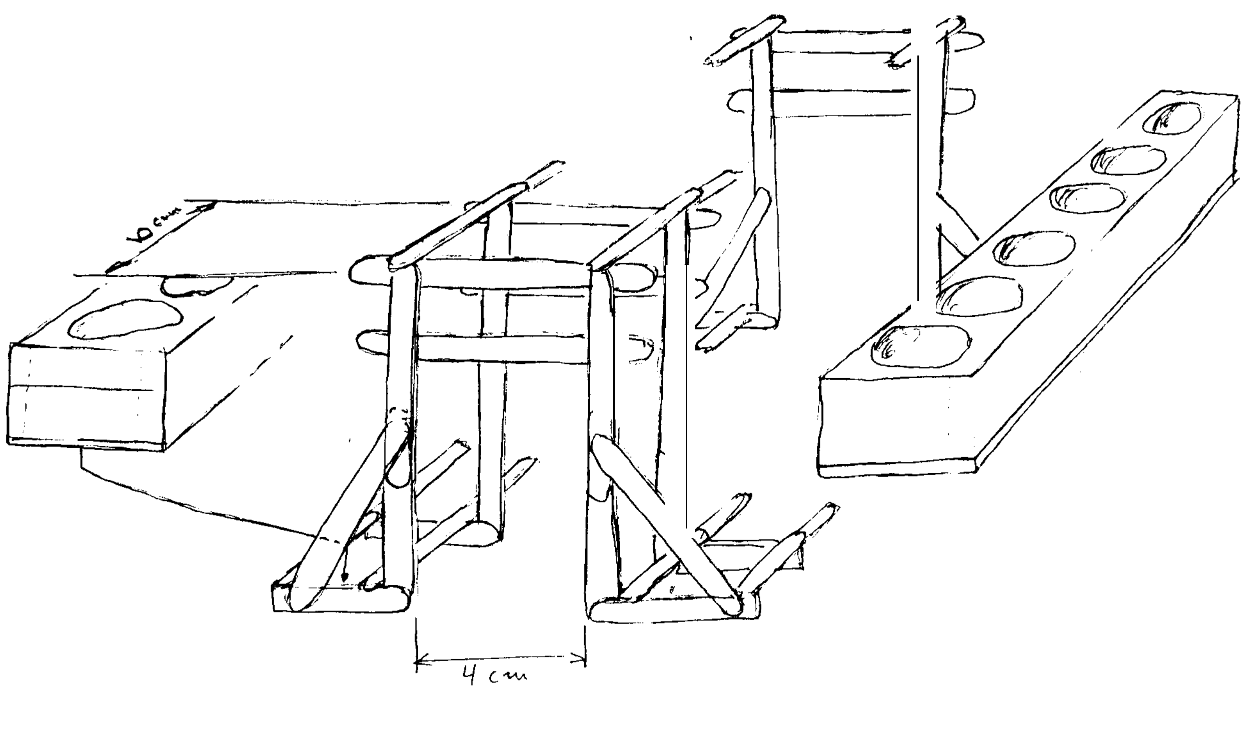

Figure 2: Sketch design of the carriage holding the eggs.

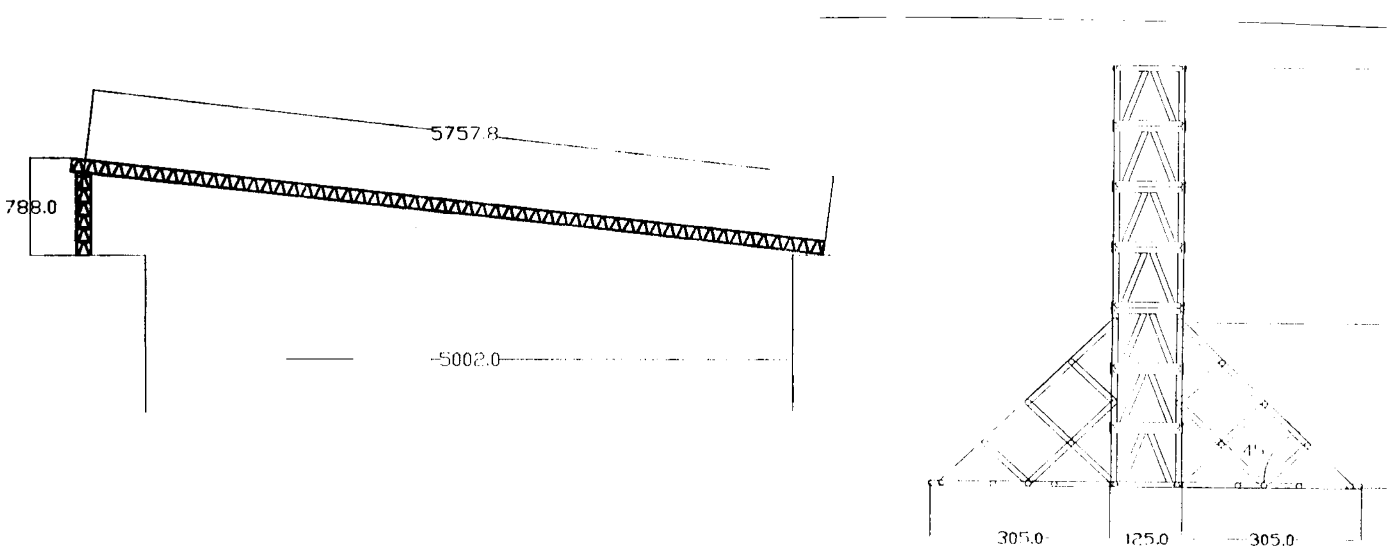

Figure 3: The inclined plane, with details of the vertical tower.

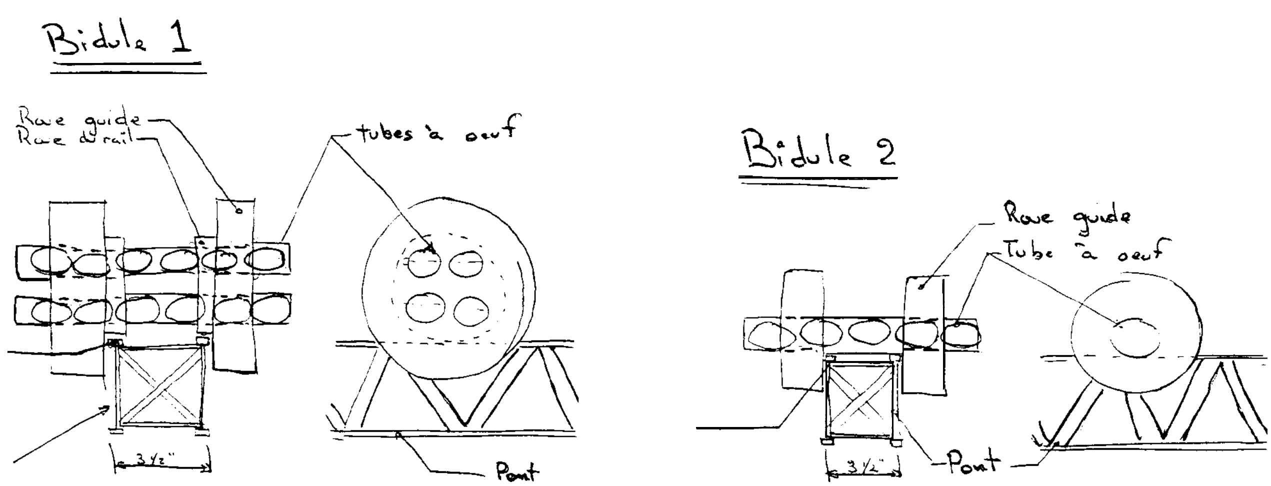

Figure 4: Sketches of two concepts for rolling eggs down an inclined plane.