



Best Practice

Product Design Engineering

Linda Hanks - Roanoke Valley Governor's School

Introduction:

The Roanoke Valley Governor's School for Science and Technology is a member of the National Consortium for Specialized Secondary Schools in Mathematics, Science, and Technology (NCSSSMST). Ours is a competitive admissions program in which students attend Governor's School for half of the school day to take accelerated and unique courses in mathematics, science, and technology. This program allows gifted students to take rigorous courses that challenge them to go beyond traditional modes of teaching and learning. This course is one of many that infuse new science and emerging technologies into the curriculum. Product Design Engineering is a technology elective. Students meet every Tuesday, beginning in the middle of the third trimester planning and preparing for the opening of the following school year. The process continues in the fall until the end of the first trimester during which students begin a research intersession allowing for full-time, focused research. The course continues until the middle of the third trimester. There are numerous handouts referenced with an * that are not included in this paper but may be accessed through the Governor's School web site.

Learning Objectives:

1. To experience the meaning of engineering as a profession, including economic, entrepreneurial opportunities, and social relationships.
 2. To integrate the processes required to design, build and test an engineering product.
 3. To integrate and reinforce mathematics, computer applications, science, technical writing, and speaking skills by solving complex hypothetical and actual problems.
 4. To apply creative thinking and problem solving techniques.
 5. To develop basic skills in the proper use of technologies, tools, machines, and related processes.
- Please see the additional attachment for course competencies and their alignment with National Standards.

Getting Started:

For approximately six weeks, students meet weekly for instruction and introductory work on their projects. Students are asked to form teams or "companies" of three and are instructed on the problem-solving process. They are taught brainstorming strategies to respond to a "Request for Proposal"* outlining the need and seeking creative solutions, then, using a decision matrix, students determine the best solution to the problem of choice. Once students have decided on a solution and thus the product, students assign themselves one or more of the following positions; Chief Engineer, Project Manager, Quality Control engineer, and Business Administrator. Each position has explicit responsibilities. The Project Manager oversees the preparation of the written proposal according to the established guidelines, all oral presentations, the preparation of the final report according to the established guidelines, the preparation of the "Weekly Plans"* and "Behind the Scenes"*, the maintenance of three copies of all computer work, and that all assignments are on time. The Chief Engineer coordinates all work required for successful construction and testing of the prototype device. The Quality Control Engineer insures that any oral presentations or proposals/reports meet established guidelines and the prototype meets established specifications, maintains the company portfolio, and oversees the creation of the project display and the company webpage. The Business Administrator assures that the prototype meets budget, all receipts are submitted, the estimated and actual cost analyses are complete, accurate, and updated on a timely basis, and the profit analysis is complete.

The Written Proposal:

At this time, students are ready to begin working on the written proposal. Each student is asked to complete a summer assignment that will be incorporated into the team's introduction to the written proposal. Once the proposal is completed, students present it orally to a panel of engineers and product designers. Students return in the fall ready to compile their summer assignments. The summer assignment that students receive is as follows:

"Your objective is to thoroughly research the area related to your anticipated problem/product and to complete a partial draft document that can be incorporated into the introduction of your company's written proposal. Your complete written proposal will be due for an early October elective class meeting in Trimester 1.

Assignment/Part I: A word-processed paper at least two pages in length (not including the bibliography, approximately 500 words) and a bibliography (make citations using the supplied examples) is to be completed.

Who: This assignment is individual. When you return for the 02-03 school year, your company will combine the individual draft documents into one very thorough, complete written proposal introduction.

Parameters:

- 1) At least 3 sources supplying information supporting a need to solve your problem and the need for your device are required. Include plenty of background information. Identify and discuss statistics (sources for these statistics are the Internet and the publication "Statistical Abstracts" published by the U. S. Census Bureau) relating to why your device should be developed.
- 2) This supporting information is critical to the successful completion of your company's prototype device. Make sure that the information included makes the best case possible for your product. Is there a market for your product? Explain it thoroughly.
- 3) Write a creative opening sentence(s) for your introduction to catch the attention of whoever reads your proposal.
- 4) Any other devices developed to solve a similar problem to yours should be identified (if possible) and discussed along with costs if appropriate (use "Consumer Reports" magazine, sources on the Internet, etc.).

Assignment Part II: A patent search for devices similar to yours must be completed. Use the Internet to find at least two patents for devices that are "similar" to the device your team has decided to develop. To find the patents at the USPTO, use the following addresses: <http://www.patents.ibm.com/ibm.html> or <http://www.uspto.gov>. The content checklist for the written proposal is provided to students when school begins. Students have approximately seven weeks to complete the written proposal. The following is an excerpt from the handout students receive for the content of the proposal:

- 1) **Cover page:** The cover page conveys the company name, logo, motto and product in an interesting and creative way. Include a focus statement describing the prototype device. Student names and jobs can also be included.
- 2) **Introduction:** Give a thorough background of the problem. Include a description of the process you went through to select your problem and your device along with as much statistical data as you can to support the fact that a problem exists. Include a detailed summary of your patent search. Be sure to indicate any outside sources you use (end notes) and put the full sources in the reference section. Where possible this information should come from your summer assignments.

- 3) **Alternative Solutions:** Include a decision matrix involving an analysis of the alternative solutions based on identified specifications. A written paragraph describing the information in your matrix is needed. Answer the question, “How did you arrive at your solution?”
- 4) **Proposed Prototype Design:** Use a CAD or other program to sketch the prototype device. Provide dimensions and descriptions that will help explain your device.
- 5) **Cost (Estimated) Analysis:** Give the estimated costs of the individual parts required for building the prototype. These estimated costs are for the parts required for one prototype device. They do not include items required for testing the device. Discuss how you arrived at these costs including \$ values. Discuss any outside resources you expect to employ such as shops or individuals.
- 6) **Product Testing Plan:** This section should be in the form of an “experimental design”, or EDD. What are the independent and dependent variables? What will be your control and experimental data? What do you intend to keep constant? What is your null hypothesis and alternative hypothesis? Include a plan to summarize how you intend to test your device. Give the objectives of your testing. Tell what data you intend to gather and the graphs you intend to plot. Be sure that the data you intend to collect will support the testing objectives.
- 7) **References:** In addition to citing various sources in the text of your report, include a list of all the references to include people you have talked to both in person and on the phone who have made substantive contributions to your work.
- 8) **Appendix:** Include copies of your patent search information collected from the Internet. Clear indication of each author’s contribution must be given at the end of the proposal.

Oral Presentations:

Students are asked to prepare an oral PowerPoint presentation of the written proposal to a team of engineers who have previously read the proposals and come prepared with questions and suggestions for improvement. The presentations are made in early October. Students receive handouts with guidelines for the oral presentations*. After the suggestions have been made, changes to the proposal that will ultimately end up in the final report are made and students begin to purchase materials needed to build the prototype. Students are given a budget of \$50 to spend on the materials needed to build the prototype. Students purchase materials from hardware stores, discount super-centers such as Wal-Mart, and electronics stores such as Radio Shack. They are reimbursed through the generous support of the Governor’s School Education Foundation. It is during this time that Governor’s School exams are given, so elective classes will meet approximately four times before Intersession begins. One of these elective classes is devoted to a guest speaker who will address the issue of engineering as a career.

Intersession

The four weeks prior to the winter break are devoted entirely to the completion of the elective course projects. Students do not attend their regular math and science classes; rather they work on their projects for approximately two and one half hours per day, every day. We refer to this period in the school year as the Intersession. It is during this time that students follow guidelines and timelines, known as Daily Operational Guidelines (DOGS), for the completion of the project in the allotted timeframe. The project is comprised of a working prototype; a final report describing methods and materials, results and conclusions, market analysis, cost analysis, profit analysis, and patent search; and a project display board. We are also fortunate enough to have two retired engineers and a shop teacher who volunteer their time to assist the students with the development and building of the prototype devices. Individuals and organizations in the community donate many of the materials students use. The “DOGS” handout follows.

Daily Operational Guidelines (DOGs):

- PDE companies work area will be 107 (classroom) and 120 (shop).
- Company members will meet in 107 each day at 10:50 or 2:50 for final daily debriefings.
- Always make at least 3 copies of your company's computer documents.
- All parts of the Final Report can be reviewed by Mrs. Hanks prior to due date. It is important that page numbers be included in the Final Report.

Week/Day

Deadlines

Week 1

Mon	•Weekly Plans for Week 1 due/Build Prototype
Tues	•Continue building prototype
Wed	•Instruction on Market Analysis portion of Final Report
Thurs	•Continue building prototype and working on Final Report draft
Fri	•Market Analysis portion of Final Report draft due •Behind-the-Scenes for Week 1 due/Portfolio updated •Project Registration Form for RVGS Forum due

Week 2

Mon	•Weekly Plans for Week 2 due •Instruction on Profit Analysis portion of Final Report • Introduction draft for Final Report due
Tues	•Methods and Materials draft for Final Report due •Cost Analysis and Profit Analysis portion of Final Report draft due
Wed	•Prototype device built
Thurs	•Prototype testing begins
Fri	•Display board at RVGS and display banner due •Prototype-testing analysis begins •Behind-the-Scenes for Week 2 & PF abstract draft due/Portfolio updated

Week 3

Mon	•Weekly Plans for Week 3 due •Test data collected and analysis complete, Results and Discussion & Conclusions portion of Final Report due
Tues	•Final Report abstract and Project Forum abstract due
Wed	•Display design plan (developed according to guidelines) due •Final Report (per Final Report guidelines) draft due
Thurs	•Project Display complete
Fri	•Final Report repairs (Final Report in final form) due •Behind-the-Scenes for Week 3 due/Portfolio updated

Week 4

Mon	•Weekly Plans for Week 4
Tues	•Final Report Oral Presentations due/Oral Presentation practice
Tue	•Intersession Ends/Final Portfolio due

The Final Report

The final research report is a critical part of the development of the product. The format* is explicitly stated for students to include the abstract, introduction, market analysis, methods and materials, results, discussion and conclusions, bibliography and acknowledgements. Students are given instruction for each of the sections of the report prior to each section's deadline. The following are excerpts from those lessons.

Market Analysis

What is a market analysis, and why should engineers be concerned with it? Students are instructed on how to determine the potential buyers or users of their products. They are directed to sources such as www.fedstats.gov or the Department of Environmental Control. They are given an exercise to get them thinking about this concept and how to write a market analysis. Part of the exercise and assignment is shown below:

How do I complete the market research?

- 1) Library: The government issues a Statistical Abstracts of the United States, which contains data relating to American society, from demographic, economic, and cultural perspectives.
- 2) Interviews with people: Go out into the field and interact with the community. Take responsibility to contact potential customers. Do a “trial run” of your survey or questionnaire to recognize overly broad or unclear questions that you will need to refine before taking the survey public.
- 3) Internet. Get on-line to find resources for potential buyers.

Exercises:

Market Segmentation: Who is the customer? Imagine an ideal customer. Describe the ideal customer very specifically. From the particular, expand to define the marketing target. What are some questions you might ask about your target customer? Examples: Age? Gender? Economic status? What kind of job? Where do they shop for clothes/groceries? What kind of magazines do they read?

1. Create the ideal customer by choosing one of each pair, then come up with your own pairs (at least 5). Finally, describe a typical Saturday in the life of your client.
female/male; old/young; educated/not educated; urban/rural; employed/unemployed; computer user/computer non-user
2. Imagine your team is inventing something for A, list potential customers that should be contacted in B, and how it would be accomplished in C.

A	B	C
Arthritis	Toys for 1 st graders	Redesigning a traffic intersection

The market analysis should be in narrative form. The following items should be included:

1. Give the product’s primary purpose.
2. Give the broad market with numbers and the basis for these numbers. (Be sure you include your resources in the bibliography.)
3. Include any assumptions you make regarding the percentages you would expect to respond to your product. This can be based on surveys to potential users or on data gotten from similar products on the market. (We will use 10%.)
4. Finally, give an assessment regarding the benefits of your product and why you would expect the potential market to respond favorably to it.

Methods and Materials:

1. Alternative Solutions: A written paragraph describing the information in your decision matrix is needed. How did you arrive at the solution to your problem?
2. Prototype Design: Provide a detailed sketch of your prototype device. Provide dimensions and descriptions, which will help explain your device.
- 4) Product Testing Procedure: This part should include testing methods, equipment and supplies used, an EDD (the number of replications, sample size, independent and dependent variables, controls, constants, null and alternative hypotheses), and the kind of significance tests used (students use Minitab software to run t-tests of their survey results).

Cost and Profit Analyses:

The students will be asked to complete a Revenue and Total Cost graph (as shown in Appendix F) for their products after being given instruction and handouts describing variable and fixed costs and the other expectations for this section of the report. They will also be asked to explain how they will market and advertise the product, list the variable and fixed costs, and state the price. Students are expected to determine the mathematical model used for both the Revenue and Total Cost lines. They must use a graphing utility to construct these lines and export them to the word processor.

Results, Discussion, and Conclusions:

Once the products have been tested, the results of the tests are documented in the results section of the paper. Summary tables/graphs containing statistical analyses are included. Discussions and conclusions are drawn stating whether or not the hypotheses have been supported, and to what extent, through such statistics as mean, median, mode, standard deviation, and t-test results. Students analyze qualitative (opinion surveys) as well as quantitative data using software available on the computers in the classroom.

The Project Forum:

Students are graded on the final report using a substantial rubric*. Once the final report is complete, displays are created for the Project Forum, a rigorous science fair in which students present their products to judges from neighboring universities and firms. The Project Forum is held on the Saturday the week students return to school from break, from 8:30 am until 3:00 pm. They must be able to speak extemporaneously about and answer pointed questions about their projects. At the conclusion, students awarded first, second, and third places in their assigned categories.

Ideally, students will have the paper and the display completed by the end of Intersession so that no work need be done over break. If students adhere to the suggested timelines, they should be ready for the Forum when they return to school. The criteria for the display board follow. The rubric may be found on my web site.

Your display should have, as a minimum, the following items.

- Color, computer-generated Banner with project title, company name, and logo.
- Statement of the problem.
- A copy of the decision matrix and key.
- Planning diagram of the prototype.
- Bullets outlining the benefits of the product.
- Bullets describing the product's market.
- Bullets describing profit analysis (include graph, mathematical models, spreadsheets).
- Testing Objectives statement, include statements of null and alternative hypotheses.
- Bullets describing the test procedure.
- Test results including summary data table(s) and/or graph(s).
- Bullets outlining the conclusions reached as a result of the testing.
- Photograph(s) of the various stages of the prototype, testing, etc.

The following should be on the table in front of the display.

- The prototype or model.
- If applicable the testing materials including a copy of the survey.
- A copy of the abstract.
- The final report with a copy of the company cover page with logo.

The Final Assignment:

Project Forum marks the end of the first trimester. The first half of the second trimester is spent on the final assignments. Students are given suggestions for improvements from the judges at the forum and are expected to make revisions and resubmit the final report to the teacher at which time it is evaluated. They are also required to create a web page to advertise the product. The web page should emphasize the purpose, benefits, design, and cost of the product. Students may use any homepage development software that is available, such as Front Page; or, in some cases, students write the Java script themselves. They are encouraged to be a team and to develop this product together. The web page should contain the company's name, logo, and motto. It may be used at some future time with the RVGS web site to inform future students of the PDE course. The current rubric may be viewed [here](#).

At the conclusion of the course, in the middle of February, students participate in a field trip to a local engineering firm. There, students form four groups with engineers in the field of their choice; civil, mechanical, or electrical; and are able to ask specific questions about engineering as a career. Students write a trip report upon their return and always give the experience favorable comments.

The third trimester begins with elective shopping day, where students visit teachers of electives to get a synopsis of those courses. It takes approximately four weeks to place students in the new elective class; therefore, the new students will start the course midway into the third trimester, where the process begins all over again!

Conclusion:

Product Design Engineering continues to be a very popular elective for the students at the Governor's School. Student requests for the course outstrip our resources to provide all comers with the experience. The products range from floating eyeglasses to a lawnmower/trimmer combination to a doormat that turns on a light in a room upon entrance and turns it off upon exit. Students are engaged, enthusiastic, and extremely proud of their designs and products. Several have been encouraged to actually pursue having their products patented. Several groups have won the National Inventive and Creative Association awards. Since the students must meet the same requirements regardless of the product, everyone feels the excitement of the engineering experience and the satisfaction of seeing the projects manifest from an idea into reality.

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Contact Information:

Linda G. Hanks
Product Design Engineering
Roanoke Valley Governor's School
Roanoke, VA
E-mail: lhanks@rvgs.k12.va.us