Engineering Design Process in Education

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Abstract

The world is evolving, and people and technology are evolving simultaneously; however, education and the integration of STEM(Science, Technology, Engineering, and Mathematics) to school curriculums is falling behind these rapid changes. In the modern world system where technology is one of the main centers of attention, it's crucial for technology to be added as a significant part of school curriculums to be taught systematically in classrooms for the greater development of future generations. Although the current system has certain flawed aspects, it's never late for refinements. For this universal problem that applies to schools all over the world, there's a simple, pragmatic and fertile suggestion: the Engineering Design Process. The EDP consists of 11 steps that allows students to develop their projects. It has a format that can, and should, be thought everywhere and be applied to all projects no matter the field. We, as two high school students interested in robotics, have seen the vigorous impact the EDP had over us. Starting high school, our knowledge in robotics was limited and we had a hard time planning and using our time and resources effectively. When we met the EDP, this rough process of planning became very simple and clear because we had a guideline. After a short notice, we started to use the EDP not only in our robot building processes but also in other aspects of our daily lives where we were in the continuous trial to overcome obstacles.

Keywords: *Technology, STEM, Engineering Design;*

Introduction:

The world is evolving, and people and technology are evolving simultaneously; however, education and the integration of STEM(Science, Technology, Engineering, and Mathematics) to school curriculums is falling behind these rapid changes. Engineering Design Process(EDP) creates a solution for this shortcoming in education.

Engineering Design Process with analysis

EDP can be defined as "a decision-making process, typically iterative, in which the basic STEM concepts are applied to develop optimal solutions to meet an objective"[5]. The EDP consists of 11 steps starting from defining the problem and ending with iteration allowing students to develop their projects.

Procedure:

Definition

First step of the EDP is defining the problem. It's mostly considered as the most important step, since students cannot find the best solution without fully understanding the problem at hand." [3][5] A complete understanding and statement of the problem is a key for the overall EDP.
VRC is a robotics competition for 6-12 grades. The concept of the competition changes every year and the participants try to fulfill the identified tasks with the robots they build. We work on robotics at our school and continue using the EDP while preparing for VRC. We defined the problems that were given to us. Since we were preparing for the VEX Turning Point Tournament, at first we looked into the tasks that our robot required to fulfill. They are: flags needed to be toggled, caps(discs) needed to be flipped and the robot should be able to climb-up platforms. Details of the problems are discussed.

Research

The problem itself, how others faced it before and details on the environment they're dealing with needs to be researched.[3][5] It's better to research not only how others have tackled this problem before but what has been done to solve similar problems to yours. Which creates the basis for a solution.

We researched the details of the problems, measurements of the obstacles and field materials to fully understand what we were trying to solve. After completely understanding the tasks and doing research about how other engineers have solved similar problems, we observed different robotics solutions and got inspired from real life systems.

Determining Solution Specifications

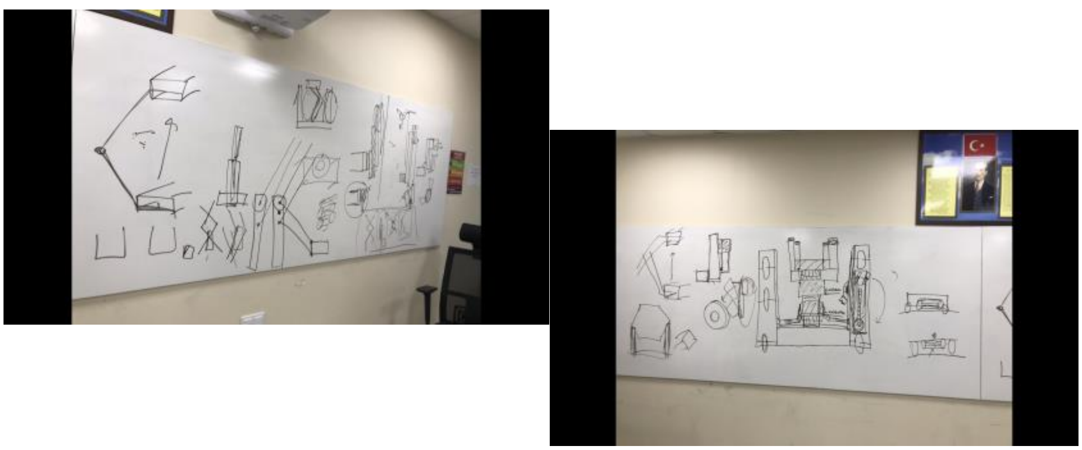
Solution at this process covers the requirements without a clarification about method. At the end, requirements are for the solution about how well the final product needs to work are specified. Moreover, making a specifications ranking is useful since aspects of the problems aren't equal and some are more important. With a demand, chart designers can ideate their solution with less loss of energy.

There are many problems that need to be solved in the VRC. As a rookie team, we decided to make not a futuristic plan. Trying to overcome all these problems at once is not a good idea so we made Wish, Prefer, Demand chart. As a result tasks in the competition is assigned from less to all through the table.

Ideating The Solution

Creativity's needed since many ways of fulfilling the specifications are thought. It's even seen that different solutions are combined to solve the problems. Brainstorming is needed to choose the most logical alternatives.[3][5] For Ideating, it's better to document the thought process and ideas. While choosing some of the best solutions, important features like the cost, time, weight, etc are considered. Decision is to build a robot that could flip the caps(discs) and climb up a platform.

Figure 1. Plans for the possible systems that can be used



With required research, different solutions become possible. Discussion is made to compare and bring the research findings together. While ideating, we weren't focused on how we can build if the design is not too much fictitious.

Making Prototypes

The concepts from the ideation are prototyped. The main aim of prototypes're to observe how solutions work in real-life. Designers don't have to build prototypes for every considered solution. How and with what materials the prototypes are going to be built, should be thought.[3][5] If prototyping a solution its' not feasible, it's a feedback to repeating previous steps.

With the three robotics teams in our school, we were lacking materials and did not have the resources to build prototypes for all the possible systems. So even it's not possible to prototype all solutions, we use different materials just to see how the solution looks like.

Choosing the best

All possible prototypes're tested since one of them needs to be chosen. Focusing on real-life performance is the best for selection. A decision matrix, the weighted objectives table(WOT), is used for selection process. The WOT is an especially effective tool since it compares alternatives based on weights assigned by the group.[3][5]

We prepared the WOT with all designs. Analysis made, revealed the most logical and reliable system. After a discussion of how the systems would work in real life, we had our solutions. It was also considered if the systems could be successfully built to not fail later on in the process and to move realistically.

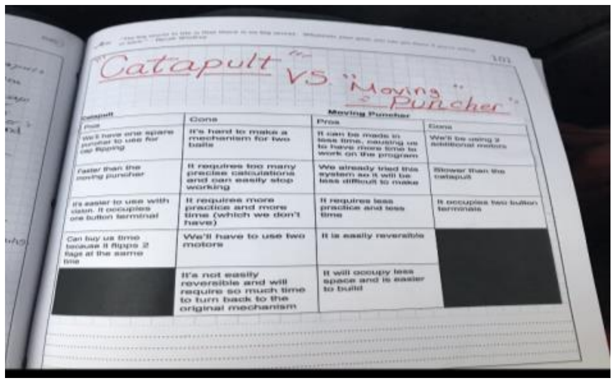


Figure 2. WOT for the selection of a system on our robot.

Refine

The chosen way of solving the problem and the prototype should be made into real. CAD Models, Assembly Drawings, Manufacturing Plans, Bill of Materials, Maintenance Guides, User Manuals, Design Presentations, Proposals are some examples to what can be generated during this process. [3][5] Starting off with an excessive plan will probably fail in the long run if the group cannot focus on all details. The chosen solution was to build an arm with a claw to flip the caps(discs). Our team designer draw the system and detailed the chosen solution. On this detailed design and team discussed "how" it will function with all details. Number of motors, lengths, operations needed to be done are discussed for the aimed system.

Alpha Test

The final design requires an approval before the implementation. A "design review" is made to see possible updates. Also, mistakes made on solution reveals during testing[3]. A cost-benefit analysis is required to see if the costs are worth the benefits of the process. Also cost isn't just money; but time, energy and resources.

We went to our mentor and physics teachers for them to review our project. For example, our mentor pointed out that the system was unbalanced and the height ratios of the sections of the arm should be changed for it to work perfectly. We made changes with respect to these feedbacks. We discussed with our mentor and other teams from our school to detect if there were any other problems with the system that hasn't appeared yet. When we were convinced that the system was ready we moved on the next step.

Implementation

With approval, the solution needs to be implemented. Different solutions also require diverse ways of marketing or presenting. Implementation of the prototype mostly shapes according to the targeted group.[3]

Since the aim is not to market the built system, we focused on presenting the system to the ones around us. Most importantly we wrote about the whole process in our Engineering Design Notebook, which is basically a notebook that includes the team’s whole work. Later on, we presented the system to both other teachers and robotics teams to share our experiences.

Field Test

Implemented solution is tested for product expectations. A review must be done to find out if any parts of the solution needs improvements or any parts doesn’t work as planned. Determination is need for required changes and/or improvements. If the design doesn't match with the requirements, going back to fix the determined problems is needed. It might even be obligatory for designers to go back some steps on the EDP or starting over by creating a new plan.[3][5]

Robot is put into competition field and tested how all the systems are working. We tried flipping caps and getting on the platforms over and over again to test its consistency. Since the systems that we built were working well, we started practicing driving for the tournament. All possible conflicts are simulated and kept on improving ourselves during the process

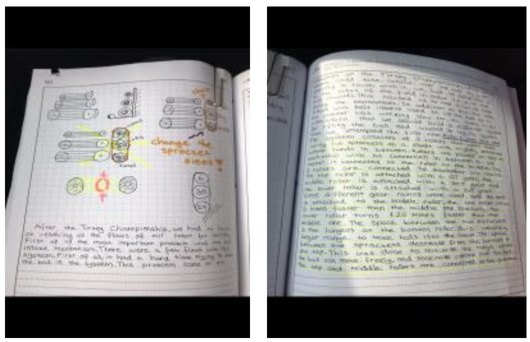


Figure 3. A problem solving process taken from the Engineering Design Notebook

Iteration

“There were several mentions during the design process of repeating certain steps multiple times until an acceptable result is achieved”. Perfection of the solution in all ways possible is required. Iteration must be done throughout the process as conflicts occur on the design, not at the end. The design process doesn't have to be too strict, it's common amongst designers to jump from step to step. There is no single way of completing the EDP, the design can always be improved.[3][5]

In our first competition which was a great experience for us, we tried all systems with alliance and opponents. we knew that our solutions could be improved and won’t be efficient for the next tournaments since our opponents were going to advance their robots too. Therefore, we went back to the beginning of the EDP and started designing almost a new and advanced robot, iterating all our mistakes.

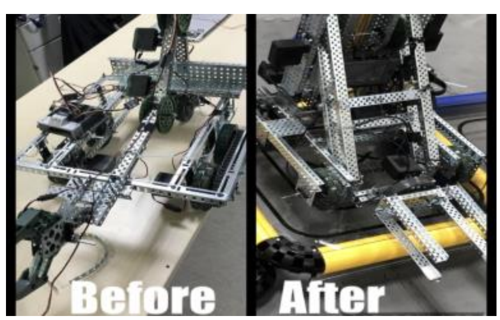


Figure 4. Improvement of robot thanks to EDP

Discussion

The EDP is not only good for problem solving in education but also it has a great impact on our lives with the skills we gain throughout the process. Working to solve problems is good but with EDP systematic and innovative thinking skills are also developed[2] In addition to giving students a new perspective at problem solving, the main goal of EDP is to help engineers, in this case students to work efficiently and find the best solutions for their problems.[3][5] The EDP was the reason that we were successful on building our robot which broughts us Turkey Championship..

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