

Teaching Pre-Engineering Education in the Global Environment using professional engineering process.

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Abstract

Although today's engineering curriculum might be too complex and too broad to be taught at the K-12 level adequately, this is possible with the engineering process: brainstorming, trade study, prototyping and testing phases can be taught to students all the way from the high school level to the elementary level given the appropriate context. Global engineering education must prepare the students of today to become the professionals of tomorrow, where they are able to solve complex problems using the resources available to them at their schools and communities. This paper will explore the use of a robotics-based curriculum to teach students the engineering process used by today's professionals in the industry.

Keywords: STEM Education, pre-engineering, engineering process

FRAMEWORK

In today's engineering environment, problems that engineers are asked to solve are very complex. There are many feasible solutions to a given problem, and alternatives need to be evaluated in a timely fashion and with consideration of the given resources available. These constraints must be addressed in global engineering education early, and a framework provided where students are able to learn and practice engineering processes and concepts in their schooling. One framework is Singapore's mathematics education. The Singapore design includes an organized framework, alignment, focus, multiple models and rich problems [5].

This same approach should be applied in the field of global engineering education where there is a shared common vision, between industry and education, scaffolding learning, level appropriate problems, multiple models with different levels of complexity and problems tackled in an educational environment. These are realistic problems, currently addressed by the industry in which will employ future practicing engineers.

A good example of an appropriate engineering problem framework is the community garden in urban settings where due to socio-economic circumstances, where there is no way to purchase health food within a reasonable distance. Students in elementary school can brainstorm ideas for different robots who can help grow fruits and vegetables. Middle School students can evaluate different robot designs and develop a trade study to help select a robot design to be further studied. High school students can prototype low-cost robots using PVC pipe. The key is to be able to involve the whole community to help solve a real problem and engage the youngest students to help get the engineering process started within the community.

SHARED VISION

It is believed that men discovered the wonders of flight in 1903 with the development of the first fixed wing aircraft. Since that time, we have not only been able to travel across oceans, but also go to space, like the first man landing on the moon in 1969. It is crucial for global engineering education include engineering history.

The same way that all students in America study American politics as part of an American History curriculum, there should be a component of American Engineering History focused on learning how we solved problems in the past and how this integrates with other disciplines like math and science, engineering problem solving and technology. Addressing engineering problem solving without constraint, within a context, is not realistic and does not help societies to address realistic problems with realistic solutions, such as going to Mars. In 2010, in the United States of America, a bill was signed allowing for a manned mission by 2030. Global Engineering education needs to start as early as possible to begin getting future engineers the system thinking concepts and shared vision on their toolbox of tomorrow, and enabling future professionals, that today might not be more than 10 year olds to be the global engineers that will be brainstorming, developing trade studies, prototyping and testing mission critical systems that will enable humankind to reach Mars.

PRE-ENGINEERING CONSTRAINTS

Time

Global engineering education is a discipline that looks into providing solutions to problems that encompasses the whole lifecycle of the solution, starting with the conceptualization (brainstorming), developing a framework to analyze the alternatives (trade study), providing a non-optimized solution (prototyping) and developing metrics to determine if a given solution is a balanced solution that satisfies the stakeholders of the given project (testing). Addressing the time constraints of a realistic engineering problem in a traditional classroom is nearly impossible, unless global engineering education is provided in a scaffolding framework.

This ensures that the process learned by a first grader is still relevant for a sixth grader and retains the consistency of concepts learned early on in learning up to when learners become productive members of the society as professional engineers.

Resources

Although the complexity of problems systems engineers are asked to solve become more and more complex, resources available to solve given problems become more scarce. Demand for limited supplies like rare earth metals increases while supply decreases, not only due to use but also political reasons. China controls more than 90% of the world's rare earth supply [9]. As engineers develop new solutions for renewable energy such, as fuel cells, it is necessary to understand that such solutions currently necessitate the use of rare materials in their construction. Global engineering education needs to include the concept of a “glocal” solution in which is global in concept and local in implementation.

BRAINSTORMING

Brainstorming usually invokes a group of individuals getting together in a circle and having a facilitator that will write out the ideas on a white board. Studies have shown that face-to-face brainstorming groups produce fewer ideas than groups of idea generators that do not interact with each other [7]. Brainstorming is a very well understood and implemented concept, not only in the engineering discipline but also in a variety of disciplines such as business, finance and marketing. An early advocate for brainstorming was Osborn, who in 1957 generated a set of ideas commonly used in “brainstorming sessions” that includes the following concepts:

- Generate ideas without discussion on the idea feasibility or merit.
- Off the Wall ideas are welcome; there is no such thing as bad ideas.
- Measure amount of ideas, the more the better.
- Piggy-back on ideas of others to generate new ideas.

According to Friedman, the world has become “flat”, where globalization has leveled the playing field, allowing ideas to become a commodity. Someone in India might have an idea that will allow mankind to reach Mars by 2030, or a sugar-cane farmer in Brazil might figure out a way to make bio-fuel economically viable for space travel. Globalization is a reality, as the world has really become much smaller, and theories, concepts and ideas change in an “internet second”. Entire industries have been reshaped, such as the encyclopedia industry. Many of the students growing up today will likely not do research using encyclopedias like professionals of earlier generations. Brainstorming no longer needs to be a face-to-face activity, since the idea of piggy backing on others’ ideas does not require necessarily a separate session where idea generators all get together. Instead, with the economical feasibility of travel and the invention of internet, someone looking for ideas to solve a problem just needs to be able to find already implemented solutions to figure out possible ideas. Educator Ron Clark believes that if we want students to be successful and leaders in their professions, they need to have a global perspective [2]. The Ron Clark Academy teaches middle school students and a strong component of their education is to take students around the world.

Global engineers need to adopt the same concept, but focusing more on the problems they face at hand and figure out a solution. An example would be the need for an engineer to develop a farming robot that can dig a square hole in the ground. From a global engineering perspective, it is necessary first to look at current solutions of two sets of problems in which include digging a hole in the ground and how to make it a square hole. The concept of the Reuleaux triangle would need to be understood to solve the problem. However from an engineering education perspective, it is necessary to provide the framework and process allowing students to find information on this topic, without giving them the key word, “Reuleaux triangle”. Global engineering education needs to be an inquiry-based curriculum, where the students ask the questions themselves and then look for the answers.

In the previous example, ideas would come up, such as antique Chinese coins, which have square holes or the fact that fence posts are squares. The solution of digging a square hole on the ground is not a new problem to American farmers today, but the solution of having a robot that can dig a square hole of different size is a problem that will require the implementation of a Reuleaux auger on a robot is a new problem. Global engineer with a good background: engineering history will be required to “find” the pieces and put the pieces together.

Curriculum for global engineering education need not only to include textbooks which show the process to be used, but also needs to include, hands-on activities where engineers are able to interact with the environment and generate ideas. An opportunity for exchange of ideas begun in 2010, providing a marketplace where ideas seekers get to meet with idea implementers. The largest state faire is State Fair of Texas, first held in 1886. In 2010, the first USA Science & Engineering Festival was held in the United States. Its mission is to engage the greatest minds in science. Engineering education curriculum needs to include visits to Engineering Festivals.

TRADE STUDIES

Trade studies are well understood in the engineering education discipline and in the business environment. It provides the information necessary for making well-informed decisions. Decision-making is also well understood and needs to be part of the context of system thinking for the K-12 community to be relevant. The current challenge is that there is currently not a standard for K-12 engineering education [1] or a consensus on how engineering education topics such as trade studies should be taught. The framework for teaching complex topics, inherent to the of domain of engineering education does not currently exist in a form that allows the existence of multiple models that are integrated.

Trade Studies is a concept that cannot be accurately described in a textbook, but it is a best described as an activity. The framework to teach global engineering needs to be not only relevant to students that will not likely pursue careers in STEM but also to students that will focus on a technical engineering discipline such as Electrical Engineering. The opportunity to give students a peek into this topic will need to be done thru experiential activities and service learning opportunities where students are able to evaluate possible alternatives to a solution and present it in a concise manner to a decision maker.

In the engineering profession, trade studies are an activity that is part of the Systems Development Life Cycle (SDLC), in which it encompasses at a minimum the tasks of analysis, design, implementation, testing and evaluation. SDLC is a generic model that is often modified to suit the organization doing the product development. Depending on the product, each phase might be shorter or longer in duration with products such as jet airplanes that were designed in the 70's and are still been redesigned and used today to transport cargo and people around the world. Schools that have a strong career development component on their curriculum will not only enable students to be better prepared to enter the workforce, but they will also have learned a key concept of engineering education, in the development of trade studies. The concept will not only allow students to be better problem solvers but also to be able to look at issues from a holistic and long-range perspective.

PROTOTYPING

Broad Engagement Spiral Demo Team Missouri (BERSDT-MO) is an all-volunteer team comprised of professionals that build robot prototypes using the same materials that student's use when participating in nationally held robotics competitions. The robots built by adults do not compete in any type of competition; instead they are prototype's, used to show students that there are opportunities for them right now to build complex systems and compete with their peers on a national level. Prototyping is usually seen as a way to produce a first article, to test a concept or process, from a holistic global engineering education perspective, prototyping is where the experience gained from activities such as brainstorming and trade studies builds upon previous experiences. Global engineering education is a continuous improvement process where it does not have a specific end state but it is continuous process which captures lessons learned from early instantiations of a given activity such as the development of prototype robots built by professionals. The key to prototyping is to develop an end product that closely reassembles the product that will serve a given purpose. The purpose of pre-engineering robotics competition is to give an opportunity for students to engage in engineering problem solving activity and be able to see a concrete outcome. As students compete, they have an opportunity to work closely with professionals as they mentor the student robotics teams.

Often we see on the news that American students are behind in mathematics and science scores compared to other industrialized countries. This is a valid issue to be considered when developing an integrated systems engineering education curriculum. Although the fundamentals are important, it is necessary to understand what skills are relevant to the industry, and how does it translate to outcomes for a systems engineering education. In today's electronic environment where applying for a job is the simple act of the click of a button, employers are inundated with resumes that show candidates with skills such as the latest programming language. In today's environment technical skills have become a commodity; the simple reality is that systems thinking has become the differentiator among candidates vying for engineering jobs. Candidates are no longer differentiated by what skills they show on their resumes or experiences similar to many other candidates applying for the same job. Instead candidates that outshine their competitions are the one that have soft-skills such as creative-thinking.

Creative thinking has become a necessity in engineering design and it is not a skill relegated to a few individuals [11]. The purpose of having an adult team building robots using the same materials that student use is two fold. The first is the reality that engineers are accustomed to solving complex systems that have the design phase measured in months and not in 6 weeks, as usually is the timeframe for many K-12 students' robotics competition. The second reality is that engineers are able to draw from a considerable stable of already known connections of subject matter expertise to design and develop a prototype. The opportunity for adults to build their own robot with their own set of goals allows them to be able to demonstrate to students in real-time how professional engineers think and what type of behaviors they use naturally while trying to develop a robot prototype.

TESTING

There is a gap between what skills are taught in K-12 curriculum and the skills are needed for students to be successful in the market places. Programs such as service learning, senior design, mentoring and shadowing are a great way for students to learn critical skills needed in the marketplace and to motivate them to pursue STEM technologies. The process of having students experience the professional environment is a key concept that needs to be replicated in reverse where professionals show how they would solve complex engineering problems given the constraints students face. BERSDT provides the opportunity for professionals to adapt their knowledge and mentoring by becoming more relevant in a pre-engineering environment. The goal of BERSDT is to bring STEM awareness to local communities by making direct investment into communities to help develop robotics demo teams in all levels. The teams will have an opportunity to test their robots at community events such as school science fair, state fairs and local county fair. The goal is to develop local teams that are able to “test” robots either build locally or by another team that is no further than 30 minutes from each other. Using a focused approach BERSDT helps develops robotics teams by providing robots either built by BERSDT members or by other teams. Those robots are loaned to a given team until they are able to build a robot on their own and develop their own “testing” strategy that is translated into an outreach demo schedule in which the team goes locally in the community testing the robot in a variety of environment and venues. Testing in a global engineering education context is about showing the features and performances of the given product that was designed to solve a given challenge. The challenge should be self contained with a well defined start and end time of performance. Testing allows students to measure how well they have done in trying to solve a given engineering problem and this phase in the process should be brought to a conclusion with an event in which recognizes the team accomplishments and set the environment for the team to pursue new challenges.

SUMMARY

The engineering process can be broken down into 4 distinctive steps: brainstorming, trade studies, prototyping and testing of a given design. Brainstorming is a process that includes the need of the end customer which will be benefiting from the engineering activity. Trade Studies needs to be done given a focus on affordability and understanding viable solutions that must be evaluated further while saving alternatives that might be risky given the current assumptions. Prototyping and Modeling needs to be done given the consideration of the lifecycle of the product and the trade-off between simulation and building low cost artifact in the process of solving an engineering problem. Lastly testing an engineering solution should not be done in a vacuum but be done leveraging the global resources and knowledge available while keeping in focus the feasibility of the solution to the given environment. In global engineering education, it is necessary to understand that those steps might have different names or that the learning process will not occur thru traditional textbook reading or even a design class project. Global engineering is about solving real problems with given schedule and resource allotment. The focus shifts from learning the process to solve a problem to the best process to solve the given problem in hand. Successful engineering programs will leverage both local resources and global programs that not only motivate students to pursue careers in STEM (Science, Technology, Engineering and Mathematics), but also give them real life experience that will prepare them to enter the workforce in their particular learning community.

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