Orientation to Engineering Education through applying "Puzzles Principles"

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Abstract

In this paper a review of engineering programs was conducted in terms of curriculum building and then application of the technique of "Puzzles Principles", developed by the author, was proposed which could be incorporated in the design of curriculums for effective engineering teaching at the onset. The concept of Puzzles Principles and its application can show how appropriately engineering education can be planned and how the requirements suggested by the Engineer of 2020 can be implemented in a "First Year Experience" type courses. An example of the application is provided to properly show the process of learning through re-engineering a product by showing the correlated possible scientific and engineering learning matters affiliated with the product design, testing , manufacturing and evaluations.

Introduction

Engineering education traditionally has been much segmented consisting of many courses being taught as independent subjects. It is typically divided into core, electives, support courses and General Education categories. In many instances a student spends the first two years taking support and general education courses and will not be introduced to an engineering course until the junior year. This is especially true when students attend Junior Colleges to prepare themselves for a four year university. Thus almost fifty percent of a new engineering student's college life is associated with diverse courses with none or little mention of any engineering application. Assuming that a student enters as a freshman to a university, they could possibly be exposed to an orientation course or an introduction course to their field. These courses are designed mostly to be a survey of the future courses that the student works through until they graduate and are referred to as an engineer. Again in most cases reasons of why those courses or the subject matters are important are not mentioned. Students assume that the faculty knows best and they help them eventually understand what is expected of an engineer. It could be said that the best possible scenario could be that an engineering student comes from a family of engineers who can inform him/her about their jobs and responsibilities.

Once their education starts, there are times that a course is selected or defined as a prerequisite for other courses without genuine relation between courses or even minimal mention of relationships to others. Worse, review of programs has shown that often courses are taught without even mentioning their interactions with specific programs. If we are shaping and developing the engineer of 2020, then we have to change from the segmented teaching, look at the curriculum more from a "Systems" point of view and clearly show the interactions of courses and interrelations of them as they are being taught. This means that while the professor is lecturing a subject, he/she has to be relating it to the next course, show why previous courses were pre-requisites, and then show how the subject is used by a professional engineer at job sites.

Additionally, to enhance the linkage of courses, and teaching engineering in general, the author believes that students should be looked at more as a whole person, capable of higher cognitive skills that we might currently expect from them. Enhancing wisdom should be considered as we improve their intelligence to prepare them to be better product and process designers. Students are not to be looked at as robots, taking notes, listening, reading books and memorizing them and then show their intelligence by answering exam questions. Enhancing wisdom should be considered as we improve their intelligence. Of course this is of special importance in a capstone course where if it is correctly designed, it should incorporate the essence of their education in engineering, and not only one or two subjects. It is the author's belief that an orientation course should also contain an element that improves the wisdom and the sense of creativity of a freshman engineering course.

Finally engineering is a profession just like those in medical or legal fields. Television and films have clearly defined what such learned people do and students of such fields understand why any topic on their curriculum helps them in becoming better professionals. Other than MacGyver there has not been any other public visual presentation of how application of engineering principles helps the everyday lives of people. An engineering student should fall in love with the filed at the orientation course by fully learning about subjects that would lead him to have the required skills. A typical general education course or even a support course such as math would not give the person the thirst and the desire to learn about engineering. Don't medical students start with dissecting cadavers to learn about the human body? Why not do the same for our freshman engineering student? How about allowing them to dissect a product or a process and then learn about engineering design and evaluation? Disconnect assembled parts that are bolted, welded or crimped to know why one could be better and where one method of joining is used.

Starting an engineering program for college freshmen is mostly filled with uncertainty. Some possibly have heard of what they are supposed to do and others have no idea, just that it sounds good to be engineers. Civil engineers build roads, Mechanicals design products,. but how does triple integrals help them with roads, products, computers, etc. Universities design curriculum for engineering programs, identify pre-requisites, co-requisites, General Education , support classes, and all to build a foundation for engineering education. To a freshman, the foundation hardly shows any correlation with the final goal of becoming a designer of products and processes. The medical school curriculum and the law school curriculum fully support their education and it is hard to question why a course in biology or chemistry is needed for a medical school student. However, where and why linear algebra is used for design of a healthcare facility could be a legitimate question for a freshman. It is time to re-engineer the engineering education to ensure that an engineering student fully realizes the importance of learning every course and know the relationship of pre-requisites and the sequential course design. Figure 1 shows an example of a typical homework in an engineering course. A freshman could fail to see the application of wisdom and creativity in such assignments. In engineering orientation courses most of the time is spent on briefly explaining what courses are ahead of the students. In most programs students however never see any engineering until the junior year. Even if they see the freshman and sophomore courses in engineering, they are at the introductory level and boring for a person who imagined that they are product designers when they have to sit in class and take triple integrals. The main reason seems to be that learned and educated engineers have designed courses for themselves rather than for young inexperienced individuals who "think" that they know what is engineering.

A machined shaft shown below is supported by two deep-groove ball bearings and transmits a torque of 100 N.m between gears X (80 teeth) and Y (60 teeth). Both gears have a pressure angle of 20° and a module of 2 and their contact to their mating gear is at 90° to each other as shown. Assume the gears are loaded midway across the face width. The shaft operates at a steady speed and is made from AISI 1095 steel which was quench & tempered at 650°C.

- Determine applied gear forces and the reactions at the bearings.
- Draw the shear, moment and torque diagrams for the shaft.
- Determine the fatigue factor of safety at location A using the ASME Elliptic criteria with a 99% reliability.

  Check 1st cycle yielding at location A.

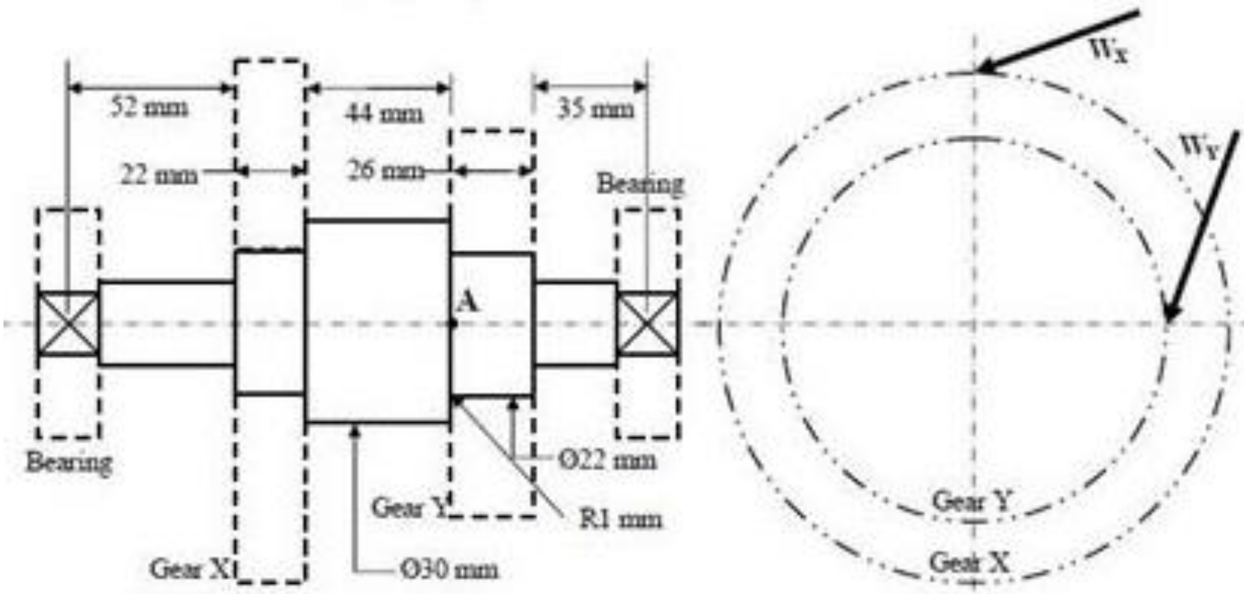

Figure 1: A typical assignment in an engineering course

Based on the author's review of many engineering curriculums the typical elements of most programs in higher education consist of:

- Flood with Information
- Combine with Technology
- Provide Diverse Subjects
- Make a Salad of Stuff

- No mention of Wisdom
- Use artificial intelligence
- No mention of Natural Intelligence
- Produce Highly Skilled Robots

The review of the National Academy of Sciences Recommendations for Engineer of 2020 shows that:

- In developing curricula, students should be introduced to the "Essence" of engineering early
- Engineering educators should introduce interdisciplinary learning in undergrad. Teaching
- As well as delivering content, engineering schools must teach how to learn
- Engineers of 2020 should know when and how to incorporate social elements at work
- Case studies approach is recommended for undergrad curricula
- Reduce the period between achieving the "Program Objective" and the "Student Learning Objective"
- Enable them to see the big picture in each and every course

Thus to prepare a better engineer from the onset, it is the belief of the author that an orientation to engineering course should be designed based on the following criteria:

a- An engineer is a creative, intelligent and wise person. Assure that the learning elements lead to improving such traits
b- The curriculum review in such classes could work better once reasons for subjects studied are understood by students
c- Dissection and re-engineering of product should be a necessary element in the curricula
d- Puzzles Principles (defined next) is applied to design the syllabi of such courses

Puzzles Principles

Based on the above arguments and more, the author has developed the Puzzles Principles. To understand the concept, the reader is asked to imagine a jigsaw puzzle (figure 2). A jigsaw puzzle consists of many pieces that make up a big picture, just like courses we put in a curriculum for an engineering program. When trying to assemble the puzzle, one looks at the main scene, visually divides the scene into sections (i.e. for a natural scene you could have trees, sky, water, etc.), groups the pieces in sub groups (i.e. borders have straight edges, pieces that look like they belong to a body of water, etc.), and although the pieces could be connected in subgroups, the relationship between the big picture, the segments and the pieces are still clear to ones mind. It seems to be essential that a freshman level student should also be able to see the big picture from day one and visualize the relationship between the courses (puzzle pieces) and any main subjects being taught (i.e. optimization) and also the big picture (i.e. any major in Engineering)? This visualization requires wisdom, creativity and intelligence, all three are the major components of the Puzzles Principles.

As the second phase of application of Puzzles Principles, the author proposes a process of redesigning an introductory course where real life puzzles are introduced (the big picture), main problems are identified (a sub-scene), and the need of the specific subject of study is clearly defined (each piece of the puzzle), and then show why the puzzle piece or the course is needed for a specific part of the curriculum (Sr., Jr, etc.)., and without this piece the engineering education is incomplete.

Furthermore, still keeping track of the concept of puzzles, engineering courses should be developed so that students use their wisdom to mainly define puzzles, and less emphasis on solving them (where they had already learned at previous stages). For real life industry problems, professionals are always faced with puzzles and not homework problems. "How" should one solve the puzzle and "What" date to gather is more relevant than discussing solving situations that computer software can actually solve problems faster and the student is merely a data entry clerk. This basically means that wisdom in decision making should be more emphasized than just the use of intelligence to solve them. Here effective approach to problem definition is emphasized (looking at the big picture), then how optimally big scenes could be divided into smaller sub-scenes, and then how to find the right pieces that belong to the sub-scenes could be emphasized. Once this activity is performed, not only solutions could be provided more efficiently, the cognitive skills used in engineering decision making is enhanced leading to better and more creative engineering designs of products and processes.

Figure 2: A Jigsaw Puzzle

The application of Puzzles Principles was developed as cases for the capstone course in Industrial and Manufacturing Engineering department at Cal Poly Pomona. In such cases scenarios were developed based on real industry situations and data (real or not) was provided without mentioning any reasons or questions. Students working in teams compete against each other to discover the main reason behind the case (the puzzle), provide problem statements, search and justify the best tools for problem solving, identify and use the right data to solve problems, and provide solution for the puzzle, the main case, and not just the sub problems. All of this is simulated through a real scenario for which the recommendations should be provided within a limited time (usually a week), and just like real life only one team is chosen by the customer (the professor) as having the right solution meeting the customer's expectation. However, unlike as in real life, the losing teams don't fail, but they receive lower scores. Although a very rigorous and time consuming course, for the last several years of applying this technique, students have praised the course as the most valuable experience in their undergraduate education. The feedback from the Course Evaluations provided at the end of each term showed learning achievement at a very high level. At the exit interview almost all students praised the course as the one that gave them the confidence they needed to enter the job market, and lastly for Program Outcome assessment alumni expressed that although they may have used some of the subjects that they learned at school in their various jobs, they have mostly benefited from the experience of tackling the puzzles of the capstone course when they were faced with the day to day puzzles that they get exposed to in the industry.

Applying the second phase of application of Puzzles Principles, the author has reviewed and redesigned the entire undergraduate industrial and manufacturing engineering curriculum as a systems analyst to ensure that the links became apparent, and in each course real life puzzles are introduced (the big picture), main problems are identified (a sub-scene), and the need of the specific subject is clearly defined (each piece of the puzzle), and then why the puzzle piece or the course is needed for a specific part of the curriculum (Sr., Jr, etc.) is shown. Figure 3 shows the procedural stages of the puzzles principles.

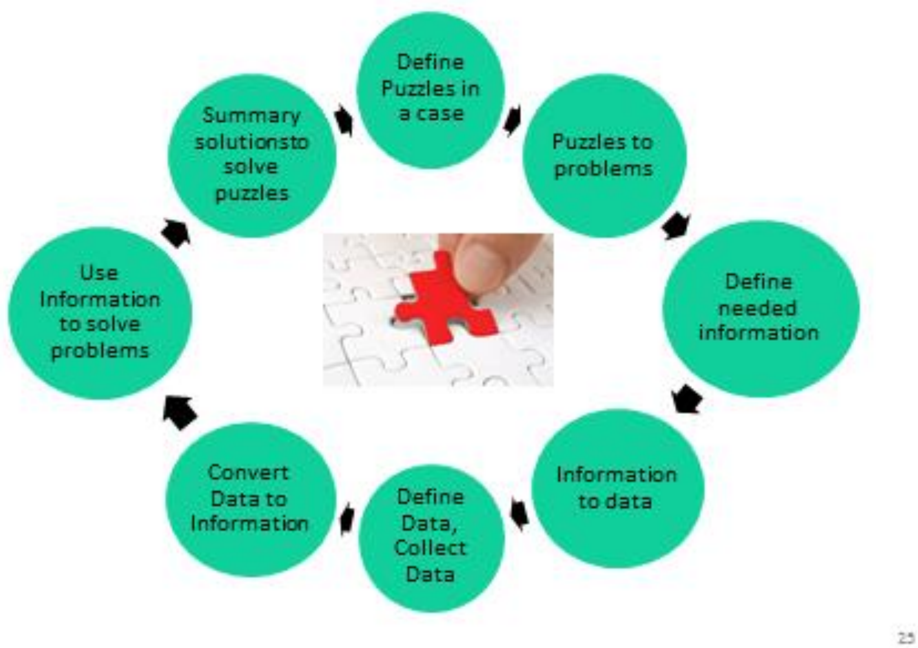

Figure 3: Puzzles Principles Procedural Stages

For the engineering orientation course the curriculum design should include the application of Puzzles Principles through stepwise systematic re-engineering of engineering design. In order to do so the author proposes the implementation of learning practices to assure the blended skillsets as described below are developed by the freshmen to the point that they realize their ability as they progress to the conclusion of the course.

The skillsets chosen for an engineer are those that are clearly identified by all stakeholders in the education of such engineers. The stakeholders include not only the students themselves, but the future employers, the professors and the university community, and the society as a whole. This is true especially for state universities that are partially supported by the public tax and industry support.

A complete set of blended skillsets are as follows:

- **Understanding Case Formats**
- Quantitative Skills
- Oral and Written Communication Skills
- Critical Thinking
- **Creativity**
- Problem Solving
- Ethical Decision Making
- Information Literacy
- **Team Working Skills**
- **Self-Direction**
- **Leadership**
- **Lifetime learning**
- **Competitiveness** to excel

The Puzzles Principles assumes the actual activities involved in its applications are done at the various stages of education of an engineering student as soon below:

- **Senior Level**: Identify Puzzles and Solve (Apply Wisdom and Intelligence): What is the Situation? Who are involved? What are the basic problems? What subjects from the curricula should be used? How should I solve them? Which techniques should I use? What are the constraints? What types of information do I need? What data do I need? What makes my recommendations better than others? How do I present it? Who do I present it to? How were the Prerequisites, GE, Core, Breath subjects incorporated?

- **Junior Level**: Solve Puzzled Problems using gathered information (Learn Wisdom, apply Intelligence): Why I am losing money? What could have improved Obama's Health Plan? Do I have enough inventory? Is 2 + 2 good? How were the Prerequisites, GE, Core, Breath classes incorporated?

- **Sophomore Level:** Learn about information, Analyze Data, Convert to Information, Solve Problems, Learn about Puzzles (Learn wisdom and Intelligence): How hot is a typical Jacuzzi, Is this a Shakespearian style of writing? What happens that you end up with a whip lash after an accident? Why lemon tastes tart? How were the Prerequisites incorporated?

- **Freshman Level:** Visualize yourself as a wise and intelligent professional after graduation, Gather Data, Analyze Basic Data, Learn basic data-Information conversion, Solve basic Puzzles, Learn about how to become wiser and more intelligent by participating in a re-engineering of a puzzle solved.

The following specific procedure is proposed to be incorporated in an orientation to engineering course:

1- Choose a puzzle from a real life situation solved and reviewed by engineering professionals that was reviewed by upper classmen. Example: The management at a luxurious hotel are unhappy seeing housekeeping carts in the hallways and they believe such items should be invisible to their guests, however the carts are needed for resupplying and changing room products

2- Choose a product that was a major contributor to the puzzle: The cart

3- Who are involved: Guests, Management, Housekeepers, Maintenance, Buyers

4- How are they affected: Housekeepers have to push carts, guests see obstacles, and maintenance personnel repair them.

5- Basic problem: Although necessary for transportation of items to, they are heavy, bulky, hard to move causing back problems, esthetically not pleasing …

6- How are they Designed and manufactured: Take a part, identify the material used for manufacture and assembly, review the design, identify the design criteria and strategy (Biomimicry, Total Design,..), identify the manufacturing and assembly processes (Design for Maintainability, Design for Manufacturing or assembly), identify other options,..; What is the cost; Where is the product purchased from? Who makes them?

7- Identify the subjects and courses in the curricula applied to the design and evaluations: Wheels go over the floor carpet for which we should know the coefficient of friction (mechanical engineering, civil engineering, materials engineering); The height of the cart should be less than the height of the housekeepers, the weight should be so that it would not cause joint problems (human engineering, anthropometry, biomechanics);…In order to biomechanically analyze the situation one needs to know Statics and Dynamics,…. To solve a statics problem one needs to apply physics, and math,…; Cost accounting and engineering economic analysis to justify costs;..; Quality and reliability of product performance affects the costs (SPC, Statistical Analysis) needing mathematical analysis;..

8- Where and how to collect data for analysis: Use Force gages, time studies, contact material producers, carpet manufacturers, wheel manufacturers, weight of linen, strength of housekeepers,…; All such data gathering are shown in engineering laboratories (Mechanical, Material, Biomechanics, anthropometric tables),..

As shown in the above steps, students get fully engaged in all aspects of a real life puzzling situation from ground zero, at the freshman level, where an engineered product is evaluated and redesigned and using their creativity and wisdom identify the importance of all the puzzle pieces involved in completing the entire picture, their course of study in engineering.