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Project Based Curriculumfor Millennial Learners @ Florida Polytechnic University

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Abstract:On the project based learning, the author of this abstract (instructor of the course) adopted “Bridge Design Competitions” based on his Statics “Engineering 3311” course. Students in a team of four or five are provided with accessories such as popsicle sticks and wood glue etc. to build their unique bridge design based on the concepts they learned in the classroom, these are namely, distribution of forces, moment couple, support reactions, trusses, zero force members etc.This project based teaching and learning approach was alos deployed in our recently funded "Renewable Energy and Sustainability Systems Course (EEL 3287)" which shed some success in terms of students' learning outcome and competencies based assessments.

Keywords: Project Based Learning, Active Learning, Engineering Design, Renewable Energy, Sustainability, Millennial Learners, Final Project Presentations, Course Assessment.

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1. Introduction

Problem- and Project Based Learning as examined and implemented by researchers from Stanford and Vanderbilt Universities in the USA [1] clearly identified four corner design principles which are vital for its success. Those are namely to define the learning processes with an appropriate goal that lead to deep understanding, start with problem- based approach involving embedded teaching and learning, develop a social structures that enables active participation, and assess the outcome of the results for enhancement of learning process among students. The National Effective Teaching Institute (NETI) training workshop was organized by the American Society of Engineering Education (ASEE) topromote and demonstratethe best practices of innovative instructionsuite for different style learners (students), especially co-operative learning involving team projects and individual accountabilities for its successfulness [2]. The 2012 technical report of PCAST (President's Council of Advisors of Science and Technology) [3] has produced its five salient recommendations based on the “Engage to Excel” principles to improve the first 2 years of STEM (Science, Technology, Engineering and Mathematics), provide all students with the tools to excel and diversify pathways to STEM degrees. Validating teaching practices (or Evidenced Based Teaching Methods) and offering discovery based research courses are the two out of five PCAST's recommendations which reinforce the need for the project- based learning. The report further elaborates

that the first two years of Introduction to Engineering and Design courses in STEM subjects make individual ownership of projects and discovery feasible in the classroom. It is indeed recognized that the discovery- or project- based learning or courses, enhances the learning process via engaging them with possibility of true discovery and exploring the unknowns.The aforementioned features were clearly missing from traditional intro lab courses since it does not capture the creativity of STEM disciplines, often involve repeating classical experiments to reproduce known results and repeating what is known to have worked in the past. Implementing and institutionalizing the successful transformative pedagogy like the project based curriculum require shared vision through activities like strategic planning and amendment of new policies and procedures from the top level administration (dean, chair) and then to course specific faculty [4]. Seven essentials of project- based learning were reported by Larmer et al, [5], such essentials for example, (i) a need to know the contents by launching a project, (ii) a driving questing which captures the heart of the project, (iii) student's voice and choice in selecting or opting the project, (iv) 21st century skills needed to address the project like collaboration, communication, critical thinking etc, (v) inquiry of innovation that triggers students' interests, (vi) feedback and revision to make project meaningful and (vii) a publicly presented product, that is their project outcome to real audience and stakeholders. Based on the aforementioned literature survey and author's personal experience, the current project on project- based learning is launched in couple of sophomore and junior level courses at Florida Polytechnic University. The course assessments based on the defined students' learning outcome (SLO), for example, understanding of the concepts, and demonstrate the skills and aptitutdes to solve problems etc. have been analyzed and assess for future implementations.

2. Materials, Methods and Methodology

Two Engineering courses have been considered for the project- based learning case study. One course is a Mechanical Engineering sophomore level on “Statics (EGN 3311) and the other course is an elective for Engineering majors with Junior or senior standing, that is “Renewable Energy and Sustainability” course (EEL 3287). For the statics course, students in a team of three or four have proposed a Bridge Design and start building their bridges based on the concepts they have learned throughout the courses. Some of the course topics which aligns and reinforce the concept of bridge design are, trusses, force vectors, torque or moment of force, zero force members and so on. Student team also instructed to go around the Innovation Science and Technology (IST) building at the Florida Polytech's campus and snapshot the joints and trusses with much importance to statics course outcome. Student teams have been provided with equal number of Popsicle sticks (200), glue sticks, tissue towels, paper clips and a maker's space. The major reason to choose the statics course is because the topics learned in this course are the basic building blocks of others courses such as dynamics, fluid mechanics, Strength of Materials CADS, junior and senior capstone design projects.

As it clearly pointed out earlier, the ownership of the projects at the early stages, will enable students' to implement such techniques directly in to their design and capstone projects or in fact to their internship experiences. For the Renewable Energy and Sustainability course, the instructors have introduced many green energy and sustainability conceptsby inviting subject experts in and around State of Florida and from other US Institutions.

Student teams were given instructions to pick their project, minimum expectations, within the limitations of the scope of the course. Once they picked the proposal project, they were requested to pitch-in their hypothesis, ideas and methodology to execute the project. Finally, students of both EGN 3311 and EEL 3287 courses were informed to present their project to their peers and other personal in an open platform set up, hence their final exam scores have been justified based on their involvements in project design and implementation in a collaborative team setup.

3. Results and Discussion

3.1) STATICS (EGN 3311) COURSE:Though the statics bridge design projects were conducted in the past three consecutive semesters, the latest fall 2016 semester's design contest is considered for our case study. However, we will time to time demonstrate the salient features and outcomes of the project- based learning and associated assessments from previous semesters. Peer evaluation to evaluate the magnitude and transparent nature of the bridge design is administered via set of queries, which are assigned with instructor's score point. Number of other project related activities such as submission of one or two pages of report on their bridge design experience,

photos of Florida Polytechnic University's - Innovation Science and Technology (IST) building's static architectural identities like pin joints, trusses and zero force members etc. have been solicited. Highlight of the bridge design course is the "Statics Day" where the student teams in professional attire have demonstrated their unique product (that is the bridge design) and additionally they have pitched in their presentations in an open platform to their peers, other students, faculty and administration. After their presentation, all the teams took their bridges and smashed under the in-house tensile tester machine and learned about the maximum load of the bridge, number of sticks used and the unique nature of Statics and equilibrium principles.

Five teams of 3 to 4 students have been asked to propose their bridge design write up during the mid of the semester. This activity is necessary so that entire class understand the bridge design is an integral part of their grading and replaces the final exam traditional close book examination. By the mid semester examinations, the students' get the full concepts of force vectors, equilibrium, rigid body dynamics and moment of force with problem solving strategies. In the following week, the instructor will distribute necessary supply materials such as Popsicle sticks, glue, paint, paper clips, tissue towel etc to each team representative. It is recommended that students to log-in and log-out their hours in their record books so to evaluate the time spend by each member of the team on the project development. After couple of weeks on the project life cycle, the student groups are then required to present their status of the bridge- design project to other peers and the instructor. It is noteworthy to mention that the student groups enjoyed in such bridge design and presentation activities, which enhanced their critical thinking skills. Number of parameters to compromise for a joint and collaborative project are, for example, time management, listen to team member's comments and suggestions, delegation of works and workflows, example writing, typing, literature search and mathematical or computation calculations. It is even noticed that some student teams went above and beyond to use state-of-the-art software, CAD, Solid Works etc for their bridge design project. Salient features and uniqueness of the bridge design of the student teams are given in the following paragraphs and images which exemplifies the course content and concept building.

Team Truss Fall build their bridge design based on the concept that with the Truss bridge, where the trusses are be strong enough to hold the weight of 100 to 200 pounds under the tensile tester machine. Therefore, the team created extra support of the top portion of the bridge using 3D CAD model (see Figure 1) and replicated by the existing bridge model "Pratt Truss". The team claimed this building the bridge experience as follows; "for the bridge the experience of childhood projects was mixed with college level thinking to create what our team believes is a well design and well-built Popsicle stick bridge."

Fig. 1 Team Truss Fall Bridge design based on 3D CAD modelling.

Team Truss Nobody mimics the "Lockport Railroad Bridge (upside down bridge)" which was built in 1902 by the King Bridge Company. The team created this unique bridge in several sections, for example the faces of the bridge contained 36 degree trusses which form the outer edges of the bridge, where two 45 degree trusses which form the X shaped design in the center. The team claims that the use of triangles in these structures helped them to greatly improve the strength in the structure (See Figure 2).

Fig. 2. Team Truss Nobdody (Name of the Team) – Lockport Railroad Bridge Replica.

The third team is "Team – Equilibrium" and after many iterations, the team choose to build an upside-down truss bridge. The concept sketch of a CAD design was drawn before the actual model bridge shown in Figure 3.

The compression and tension among force members have been calculated from the simple triangular geometry configuration and linear relations for sum of all forces.

At the end of the bridge building experience, the team commended the following; "overall this bridge building experience required strong teamwork, patience, and problem solving as well as the need to refer back to Statics laws and lessons to determine best way of building and gluing supports".

Another team named Bridge has a unique design strategy where the team concentrated on a top layer which can withstand the maximum load, once the top layer is finalized, the team moved to the bottom supports and triangular trusses. The team demonstrated that by using their unique design, they could able to avoid the presence of zero force members, and hence the team used only 160 Popsicle sticks even though the instructor gave 200 counts (see Figure 4).

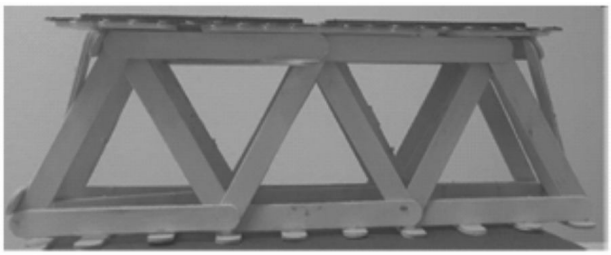


Fig. 4 Team Bridge –Final Design of with top surface reinforcement

The team, Awesome Sauce build their bridge based on the Warren Truss Bridge, which is usually used as a water or crossing bridge. The design involves equilateral triangles with a beam in the middle of each in order to ensure each truss and beam take on the forces equally. Moreover, the compression and tension to act on the bridge is ideal in terms of support reactions. The team complains about the non-uniformity of Popsicle sticks, for example dimension, and hardness, and the bridge designed is less structurally sound with low symmetry (see Figure 5).

Fig. 5 Team Awesome Sauce – Warren Truss Type Bridge Design

The last team, Pop-It have come up with an idea totally unconventional. This project even the student teams commented the following; "We are excited to see how our bridge performs with the stress test, perhaps it will be a disaster, or maybe it will be great". The team started designing their bridges based using Solidworks and stencils were 3D printed to ensure cutting the Popsicle sticks at the correct angle. The finished version of the bridge is given in Figure 6. The team was not sure how this unconventional bridge perform in terms of load testing, however, the team is ready to accept either their victory or failure and will further optimize for the Statics model.

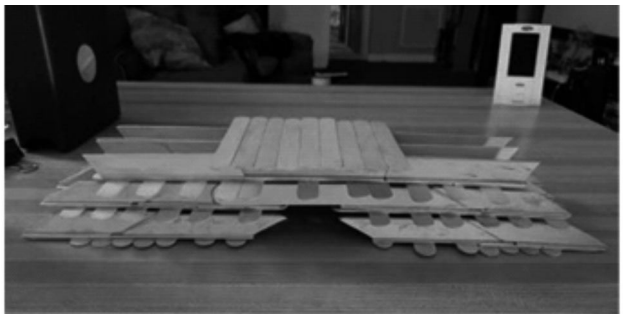


Fig. 6 Team Pop-It – Finished unconventional bridge.

Tensile Tester: This project- based learning course used our State-of-the-art equipment, tensile tester for load level testing which is the real time to test the performance of the bridges build by student teams. After all the presentations and demonstrations completed on the static day, the student teams took their bridges to the machine shop of Florida Polytech University (see Figure 7).

Fig. 7Instron Tensile Tester used for Bridge – top load testing.

After careful adjustment of height and other parameters, each bridge have been tested in front of the student team and load testing values have been tabulated below. Before load testing, each bridge will get weighed in terms of pound (lb) and noted in the table (see table 1).

TEAM NAME	Weight of Bridge (lb)	MAXIMUM LOAD BEFORE BREAK (lb)	Load/weight of Bridge ratio
Truss Fall	0.73	321	**440**
Truss Nobody	0.68	657	**967**
Bridge	1.08	393	**364**
Equilibrium	0.96	207	**216**
Awesome Sauce	1.12	1000	**893**
Pop-It	1.13	486	**430**

Based on the table and the loading results, student teams have understood that concepts of Statics equilibrium, forces, compression, tension, zero force members, trusses, moment of force, torque etc.

Bridge Design Course Level Assessment: Some of the open ended comments surveyed by the office institutional Effectiveness (both Spring'16 and Fall'16 semesters) is given below with perspective to bridge design experience and presentation to replace the traditional close book final exams.

- I learned about the applications of Physics to real world problems
- The final project was a lot of fun and very interesting
- Bridge project was very fun and exciting
- Everything, I found the materials to be interesting and love the end of term group project
- Multiple examples, bridge designing and access to lecture material
- I believe it is a very important class for a mechanical engineering
- I liked the end of the semester project
- Building a bridge at the end of the semester was fun and a good team building exercise
- Hands on bridge making
- It was fun to build the bridge
- Bridge building was fun
- The bridge project was very interesting and helped being concepts of the class together
- Very hands on class it was very fun to construct a bridge
- I liked building the bridge
- Very interactive

Annexure: In addition to bridge design, the student teams also requested to go around our Innovation Science and Technology (IST) building and snapshot the images relevant to Statics course, for example the pin supports, trusses, zero force members and other equilibrium phenomena which are an integral part of the building structure. Few images captured by the student teams are given as flavours to understand mechanistic approach (see Figure 8-10) and reinforcing the concepts of Statics.

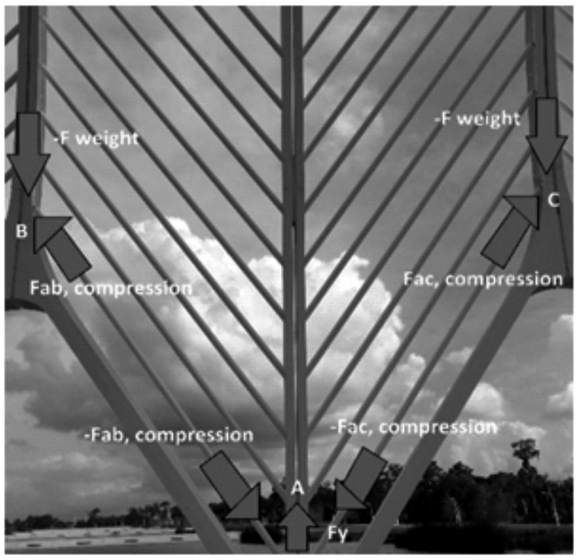


Fig. 8. One of IST building pergolas with different forces.

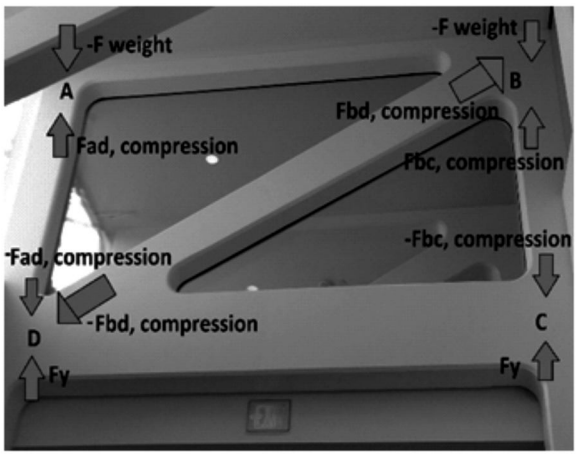


Fig. 9IST building trusses and different forces

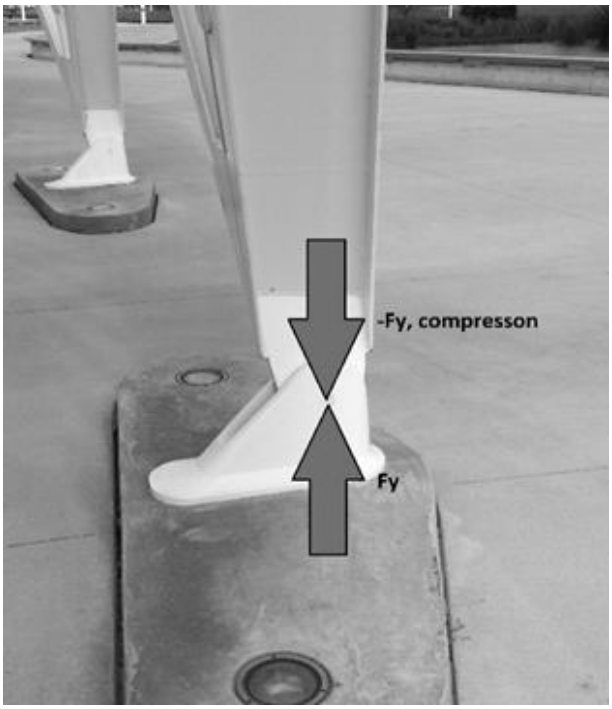


Fig. 10 IST building pergolas with pin support

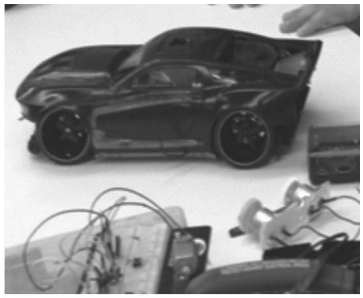
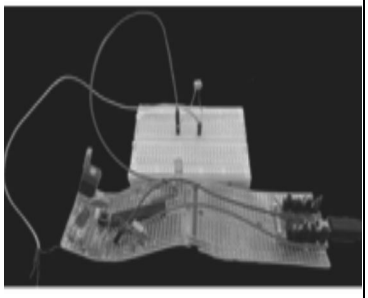
3.2) RENEWABLE ENERGY SYSTEMS AND SUSTAINABILITY COURSE (EEL 3287):

The new, project- based learning and anelective course on renewable energy and sustainability was first time offered to all the engineering majors in Fall 2016 semester. This course was team taught by three faculty of different expertise and 11 sophomore and junior standing students enrolled to gain knowledge and hands on in the fields of renewable energy and sustainable infrastructure. Another uniqueness of this course is that many invited guest speakers and subject experts from industries, academia and government were delivered their lectures and demonstrated real-time setups on various topics, so the students able to engage themselves to understand the various concepts and applications of renewable energy systems and sustainability for scientific, techno-economic developments and community outreach.The course instructors have organized a google hangout session well before the semester begin and created interest among students about the course works, topics and other necessary outcomes. A survey was conducted before the beginning of the course to understand students' motivation and interest on the subject. Here are the survey results;

- I would like to learn more about negative of Renewable Energy
- I have strong interests on environmental sustainability
- To gain better understanding of the Renewable Energy – why are not they implemented
- I would like to learn how to incorporate Renewable Energy Project Design
- I take this course because of I value Renewable Energy Systems and Sustainability
- I am taking this course to complete my elective.

The project based learning is introduced early in the semester and student teams are requested to submit the team project or proposal for evaluation and supplemented with suggestions. Since the project- is an integral component of this elective course, the grade point is distributed in the ratio, for example 10%

Table 2. EEL 3287 Course Project Team and Topics

TEAM NAME	PROJECT SCOPE
Full Control – In this project, the student team intended to develop a device that will better detect and control the quality of air based on different aspects of the environment including temperature, humidity and carbon dioxide levels in the room.	
Cars of the Future – will efficiently consume solar power and overcome past limitations through proper storage of this solar energy with a control system, which also adapts to weather and geographical quantification in the p pursuit to attain sustainability.	
Green (Sustainable) Electronics – This projectfocusseson exploring more sustainable methods of manufacturing electronics via semi-additive processes. The Arduino components will be used for this flexible electronics circuits.	

grading is for project proposal and team building, 10% is for draft project report submission, 15% project presentation by team members during mid semester evaluations, 20% grading is devoted to final project report submission and another 20% is for Final Exam project presentation. Among 11 enrolled students, three teams have been formed with 3 to 4 per team and proposed three different topics to explore. The team name and their project scope are given in the table 2.

Student's team have been very well engaged on their project and they have presented their project and the developed product to the peer members, faculty and other university administration in a formal workshop or conference set up. Industrial experts were reviewed the products and provided couple of suggestions to improve them for energy efficiency, and sustainable infrastructure. The exit survey was again conducted to evaluate the project- based learning experience. Below are the responses from the post-survey;

- Open ended project was good fun to do, but more class time to work on it with the group when we are all together would be more ideal

- I liked having the opportunity to engage with people from industry
- The topics and speakers we learned about and from were very interesting
- I enjoyed that my project I selected (all of the projects for that matter) could be feasibly completed in the time frame given.
- Good intentions, could have been executed better
- The course provided a very interdisciplinary view on the topic of sustainability.
- The open-ended nature of the project inspired the students to think critically about some very specific fields of sustainability.

4. Conclusions

In summary, the author has executed successfully the project- based learning methodologies in his two Engineering courses (Fall 2016), for example Statics – EGN 3311 and Renewable Energy Systems and Sustainability – EEL 3287. Both these courses are the springboards to evaluate the effectiveness of the project- based approach and its successfulness on the students' learning outcomes, for example whether the PBS, re-inforce the concepts, and hence is their any improvement in the performance of students for problem solving. Analysis of the results (see Figure 11), demanded the project- based learning approach, since students who can practically do hands-on either building a bridge or renewable energy related projects for which they will learn the concepts in the classroom set up.

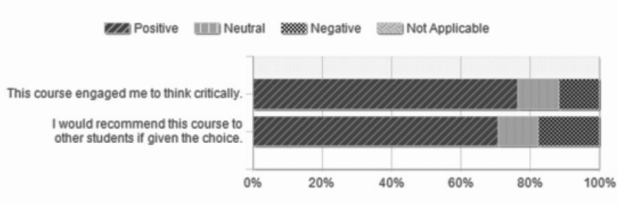


Figure 11: Aggregate Frequency Analysis regarding critical thinking enhancement among students taking this PBL based course

Though more uniformity or regularization is obviously needed for the project- based approach, students love to experiment the engineering concepts and protocols in a real-time with their peer team. We will continue adopt project- based learning approach in addition with active learning skills to enhance the classroom experience for the millenial engineers, innovators and entrepreneurs. This paper brought in some qualitative students' assessments, however, we will strive to derive more quantified results in our forthcoming journal paper. A stringent protocol will be followed in implementing project-based learning. For example, to define stipulate due dates for different project completion phases like planning, executing, monitoring, controlling and closing. Moreover the project teams will be requested to cary out, the detailed case study involving project management, scoping, scheduling, analyzing the risks and finally the cost before embarcing with the project based approach.

Though, the project based learning approach was adopted to replace the traditional paper based exam, our students did not receive prior formal or informal training in project management concepts and hence not very sure how to plan the projects and execute in professional manner.Therefore, in future, the instructor of the courses will spend couple of weeks to train the students on project management priciples, team building and engineering ethics etc, that will enable the students to handle the projects in systematic way.

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References

[1] Barronm B.J.S., Schwartz, D.L., Vye, N.J., Moore, A., Petrosino, A., Zech, L., and Bransford J.D. (2012) Doing With Understanding Lessons From Research on Problem- and Project- Based Learning, Journal of the Learning Sciences, 7:3-4, 271-311, doi: 10.1080/10508406.1998.9672056.

[2] Felder R.M., Brent, R. (2010) The National Effective Teaching Institute: Assessment of Impact and Implications for Faculty Development, Journal of Engineering Education, 121-134.

[3] PCAST (President's Council of Advisors on Science and Technology), February (2012) Report to the President: Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering and Mathematics, 103 pages, www.whitehouse.gov/ostp/pcast.

[4] Baterfield-Sacre, M., Cox, M.F., Borrego, M., Beddoes K., and Zhu, J. (2014) Changing Engineering Education: View of U.S. Faculty, Chairs, and Deans, Journal of Engineering Education, 103, 2, doi: 10.1002/jee.20043, 193-219.

[5] J. Larmer, J.R. Mergendoller, (September 2010) Seven Essentials for Project Based Learning, Educational Leadership, Giving Students Meaningful Work, 68, 1, 34-37.