FIELD EXPERIENTIAL LEARNING PEDAGOGY IN ENGINEERING MECHANICS A MEANS OF IMPROVING STUDENT ENGAGEMENT AND PERFORMANCE

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Morgan State University has remained focus in broadening the participation of underrepresented students through experiential learning, in-order to gain the necessary knowledge in STEM as well as link theory with practice. This initiative has been via internships, field trips, and meetings with consultants. As it has been noted that students become more engaged when learning experientially-hands-on, inquiry-based and project-oriented. Experiential learning connects contents to real-world applications and integrates technology and 21st Century Skills (Partnership for a Skilled Workforce: http://www.pswinc.org/technology/pipelinechallenge.htm).

The paper demonstrates that field experiential learning pedagogy adopted in an Engineering Mechanics course fosters direct experience on hands on experience in which students are able to apply Science, Technology, Engineering skills to real life situations. Engineering Mechanics is a course that is been taken by all the students in Electrical Engineering, Industrial Engineering and Civil Engineering at Morgan State University. In the past many students find it difficult to pass partly because of negative attitude and perception of the course, most especially the non-civil engineering as they perceive that the course is not relevant to their field of study. The writer has taught the course twenty times (20) at Morgan and each time he taught the class students were taken to construction site where they were able to visualize and experience the application of principles of statics and dynamics in the safe operation and maintenance of all the equipment as well as visualize the structural members of the infrastructure. This practice was proven to improve their positive attitude and perception of learning Engineering Mechanics and they were able to connect the course to their field of learning. The students were well able to visualize the concepts in absolute clarity. The real life application of concepts of statics and dynamics experienced on the construction site facilitated the acquisition and integration of engineering mechanics knowledge. The students were required to write site report which served as an instrument to assess the student achievement from the real-life application pedagogy.

The paper finally recommends that this type of experiential learning pedagogy can be adopted in institutions, where Engineering Mechanics classes are taught to non-civil and mechanical Engineering Students, in-order to help improve their positive attitude and perception of learning Engineering Mechanics and consequently enhancing their performance. This concept is easily scalable as construction sites are ubiquitous on campuses.
1. Introduction

Engineering Mechanics (Statics and Dynamics) is a course that is been taken by all the students in Electrical Engineering, Industrial Engineering and Civil Engineering at Morgan State University. In the past many students find it difficult to pass partly because of negative attitude and perception of the course, most especially the non-civil engineering as they perceive that the course is not relevant to their field of study. Promising pedagogies that utilize all the five elements of Dimensions of Learning (DOL) had been implemented. DOL is a comprehensive model that uses what researchers and theorists know about learning to define the learning process. Its premise is that five types of thinking, or the five "dimensions of learning," are essential to successful learning. The framework ensures that instruction takes into account all five of the critical components of learning which include 1) Positive Attitudes and Perceptions about Learning; 2) Thinking Involved in Acquiring and Integrating Knowledge, 3) Thinking Involved in Extending and Refining Knowledge; 4) Thinking Involved in Using Knowledge Meaningfully; and 5) Productive Habits of the Mind. The author has taught the course twenty times (20) at Morgan and each time he taught the class students were taken to construction site where they were able to visualize and experience the application of principles of statics and dynamics in the safe operation and maintenance of all the equipment as well as visualize the structural members of the infrastructure. This practice was proven to improve their positive attitude and perception of learning Engineering Mechanics and they were able to connect the course to their field of learning. The students were well able to visualize the concepts in absolute clarity. The real life application of concepts of statics and dynamics experienced on the construction site facilitated the acquisition and integration of engineering mechanics knowledge. The students were required to write site report which served as an instrument to assess the student achievement from the real-life application pedagogy.

This paper demonstrates that field experiential learning pedagogy has been adopted in an Engineering Mechanics course fosters direct experience on hands on experience in which students are able to apply Science, Technology, Engineering skills to real life situations. The paper also shows that this type of experiential learning pedagogy can be adopted in institutions, where Engineering Mechanics classes are taught to non-civil and mechanical Engineering Students, in-order to help improve their positive attitude and perception of learning Engineering Mechanics and consequently enhancing their performance. This concept is easily scalable as construction sites are ubiquitous on campuses.

2. Experiential learning

Experiential learning is any learning that supports students in applying their knowledge and conceptual understanding to real-world problems or situations where the instructor directs and facilitates learning [1]. According to Wurdinger and Carlson, 2010, [1] the classroom, laboratory, or studio can serve as a setting for experiential learning through embedded activities such as case and problem-based studies, guided inquiry, simulations, experiments, or art projects.
According to University of Texas at Huston, Learning Sciences [2] when students are given opportunities to learn in authentic situations on campus or in the community like those provided in internships, field placements, clinical experiences, research and service-learning projects, the learning becomes significantly more powerful. By engaging in formal, guided, authentic, real-world experiences, individuals:

- deepen their knowledge through repeatedly acting and then reflecting on this action,
- develop skills through practice and reflection,
- support the construction of new understandings when placed in novel situations, and
- extend their learning as they bring their learning back to the classroom.

Also according to Kolb, 1984 [3] the experiential learning process includes the integration of:

- knowledge—the concepts, facts, and information acquired through formal learning and past experience;
- activity—the application of knowledge to a “real world” setting; and
- reflection—the analysis and synthesis of knowledge and activity to create new knowledge” (Indiana University, 2006 [4])

Elements of experiential learning

The Association for Experiential Learning, 2007-2014 [5] has defined that experiential learning has the following elements:

- Experiences are carefully chosen for their learning potential (i.e. whether they provide opportunities for students to practice and deepen emergent skills, encounter novel and unpredictable situations that support new learning, or learn from natural consequences, mistakes, and successes).
- Throughout the experiential learning process, the learner is actively engaged in posing questions, investigating, experimenting, being curious, solving problems, assuming responsibility, being creative, and constructing meaning, and is challenged to take initiative, make decisions and be accountable for results.
- Reflection on learning during and after one’s experiences is an integral component of the learning process. This reflection leads to analysis, critical thinking, and synthesis (Schon, 1983; Boud, Cohen, & Walker, 1993).
- Learners are engaged intellectually, emotionally, socially, and/or physically, which produces a perception that the learning task is authentic.
- Relationships are developed and nurtured: learner to self, learner to others, and learner to the world at large.

During experiential learning, the facilitator’s role is to [5]:

- Select suitable experiences that meet the criteria above.
- Pose problems, set boundaries, support learners, provide suitable resource, ensure physical and emotional safety, and facilitate the learning process.
• Recognize and encourage spontaneous opportunities for learning, engagement with challenging situations, experimentation (that does not jeopardize the wellbeing of others) and discovery of solutions.
• Help the learner notice the connections between one context and another, between theory and the experience and encouraging this examination repeatedly.

3. Field Experiential Learning

Field experiential learning is part of experiential learning in which learning is done outside the classroom and students are forced to engage with application of concepts in a real world situation. According to Claiborne et al 2015[6], along with the engagement with concepts that is required by these experiences, the student bonding that occurs on the field trips enhances the learning experience and creates a learning community as students continue in a discipline. Teaching in the field also gives instructors the opportunity to get to know their students in greater depth in terms of how students see the world differently than the instructor [6]. This insight into student world-views can help the instructor to better communicate the concepts of the course.

Claiborne et al 2015 [6], recommended the following tips and techniques for field trip as provided by a Vanderbilt University faculty experienced in taking students on field trips:

• Set up the field trip as a research project that includes data collection.
• Conduct a theoretical examination of the issue in class long before going into the field. Students should have a sense of what the field trip is going to be about before they go.
• At least two weeks before heading into the field, develop the rudiments of basic hypotheses. At this point the instructor gives details about the field site so that students know what to expect.
• In the field, focus on the things that you’ve agreed to focus on and let the other stuff be icing on the cake.
• Take a backpack full of extra warm/dry clothes and snickers to pass out to students as the need arises.
• If for a large class, prepare TAs well to manage smaller groups of the class.
• Prepare students for practicalities including appropriate attire, expectations for physical exertion, anticipated rest stops, supplies and materials they should bring.

They [6] also proposed that the following issues must be taking into consideration

• Transportation
• Creating a sampling method suitable for students with minimal previous experience
• Weather
• Coordination with external personnel
• Effective use of TAs as team leaders (management of group dynamics)
• Student allergies and fears;

In conducting the field trip to the construction site the following strategies in line with Claiborne et al 2015 [6] are usually adopted

Search for any ongoing construction site on campus or very close to campus where students can clearly learn about the application principles of statics and dynamics in the safe operation of the equipment as well as learn from the visualizing during construction the structural members of the structures, like beams, columns, foundation, shear walls, roof trusses.

A month ahead of the visit, a letter is usually sent to the Design and Construction department requesting for permission to visit the site and also requesting for a project manager that will be able to take the students round the site and elucidate the applications of principles of static and dynamics in the safe operation and maintenance of the construction equipment as well as critically reveal the structural members of the building infrastructure. The purposes of the visit is clearly elucidated in the letter and the grading rubrics by which the student field work report will be assessed is even attached with the letter so that the project manager can help in disseminating the appropriate concepts to the students.

About two weeks before the site visit the rudiments of the basic hypotheses is given to the student. Various examples on statics problems on machines and equipment similar to the ones they will see on the field are given to the students. Also equilibrium problems on trusses and structural analysis of structural members are given. Students are also provided with the architectural and structural drawings of the infrastructure before the visit.

Students are instructed to wear appropriate attire during the visit: thick sole shoes (boots with treads), pants, shirts with sleeves. No tennis shoes, open toe shoes or heels.

Students are briefed on safety issues before entering the construction site and they are provided with reflective vest, goggles and hard hats as safety measures. Figure 1 shows the students in their safety measures attire.

The project manager then accompanies the students to the site office (Fig. 2), where he describes the entire building project and briefs the student about the architectural and structural components of the building. The briefing usually takes about an hour and the instructor interjects intermittently to ensure that the necessary concepts are passed across to the students.
Figure 1. The Engineering Mechanics Students on Field tour of one of the Construction Site on Campus.

Figure 2. The project manager describing the design, plan and execution of the project.

After the briefing the students are then taking round the site where they are shown how the concepts they are learning in class are applied to the design and construction of the structural elements of the building like: beams, column, shear walls, retaining walls, roof trusses etc. (Fig.

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3). In addition during the tour the students are able to witness the application of the principles of Statistics and Dynamics in the safe operation and maintenance of construction equipment and machines (Fig. 3).

Figure 3a: The instructor explaining the concept of an I section steal  
Figure 3b: Roof trusses  
Figure 3c: A typical construction equipment on the site.

Figure 3. Concepts of Statics and Dynamics Elucidated on Construction site

4. Impact of Field Experiential Learning

The instruments that are used to assess the impact of the real-life application pedagogy on student performance were the students’ field report and the relationship of the field project grade with the overall course grade.

Subsequently, in order to demonstrate that the real life application of concepts of statics and dynamics experienced on the construction site, actually facilitated the acquisition and integration of engineering mechanics knowledge, the essential components of four field reports submitted the students are presented below:

Student A (An Online Student Resident at Boston Massachusetts)

Construction Site Overview:

Dr. Owolabi had asked each student taking CEGR 304 course to visit a construction site and write detailed reports about the description of the site. On Tuesday, the 24th of June 2014, I had visited the Millennium Tower Development (1 Franklin St.) in Boston, Massachusetts. I had spoken to some of the site engineers/managers if they can give me an abstract description of the
ongoing construction and if they could answer some of my questions. Seeing that I was well dressed with a tie and suit on, even though the temperature that day was about 85 degrees, the construction manager asked me what the purpose of the visit was. I told him it was for school, and he agreed to show me around the site and also answer my questions. According to the site engineer I spoke to, the construction is a landmark that will gulp a whopping sum of $495 million redevelopment of the former Filene’s into a 625-foot, 450-unit mixed-use residential tower with 95,000 square-feet of retail, 450 luxury condos, all of which will range from one- to four-bedrooms. And the estimation completion time will be in late 2016. Knowing that the building is going to be about 56 towers, a lot of design principles from engineering mechanics are being applied on a daily basis. Before being allowed inside the construction site, I was being given a yellow jacket which has a reflective light so I can be visible to others around me as it was a bit dark inside the construction building, a nose mask to protect me from dust, and a hard hat for protection against nails, bricks or any other heavy site materials that might fall on me.

Figure 4: Filene’s Construction Site Boston (MA)
The Fig. 4 above is a picture of the ongoing construction. It shows an I-section where I-beams are used to transfer the load of one floor to a lower floor. These high beams are high strength structural steel member of the entire building. Again one cannot over-emphasized I-beams are stronger because it two flanges and it thicker cross-web can hold more load. They are also used because they have a better strength/mass ratio, in architecture mass is critical as the more mass you use the more support you need. And that is also why gantries are made from I-beams only.

Student B

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Because it is still in its early phase, as the Project Manager took us through the building, it was easy to see the “internal” parts of the building. It looked like a skeletal structure of the building. The structural members of the building: Columns, beams, trusses and reinforcements that provide support as well as give the building its structure are still exposed. As the Project Manager took us through the building, he pointed out different aspects of the construction that were important to note (Fig. 5). The Fig. 5 is a picture taken at the site. It shows an I-section where I-beams are used to transfer the load of one floor to a lower floor. These high beams are high strength structural steel members of the building.

![Figure 5: I-Beam Section](image)

As seen from Fig. 6, there are white marks on some parts of the concrete floors. As explained by Mr. Schalla, the white marks are used to mark the concrete where reinforcements are used. Reinforcements help prevent the structure from tearing due to high sheering force. In the article, Why reinforcement is needed in concrete slabs, Roy Reiterman explains the essence of adding steel reinforcements to concrete slabs. According to Reiterman,

> It is true that we are getting much higher quality and strength in concrete mix designs today. It is also true that all concrete will crack. … If the steel reinforcement is left out and the subgrade settles there is nothing to prevent the cracks from widening or the slab from settling or displacing.\(^\text{ii}\)

The major application of steel reinforcement is to provide strength and support to the concrete even when it undergoes cracks. Therefore, white lines are used to mark parts of the concrete where the reinforcement is applied to prevent drilling through the reinforcement material in the future as it can cause imbalance in the structure.

Also, many of the equipment used on the site operate on principles from Mechanics. For example, the pick bucket crane shown in Fig. 7 has a maximum load it can carry based on the length of its crane. This is based on the principles of moment-equilibrium of a body.
Furthermore, as stated by an intern at the site, there is a maximum wind gusts beyond which the equipment should not be operated. This is because wind contributes to the force system of the equipment and operating outside the specification of the equipment design, the wind can disrupt the balance of the system leading to instability.

Figure 6. White Marks on Concrete Floor
Machineries used for a safe constructing environment

The materials and machinery used to build the school creates an environment that is dangerous to others. Construction is one most dangerous land-based work sector. Falling from height, motor vehicle crashes, excavation accidents, electrocution, machines, and being struck by falling objects are the leading safety incidents. In this report, I will explain how the safety of construction sites will be improved by using safe operation of machinery e.g.: dump truck (Fig. 8), bulldozer, crane and safe construction design in relation to how forces interact with machinery and structures at the site.

Dump Truck

Construction of a building begins with the transport of materials to the building site. Traditionally, bricks and tiles were produced in rural areas and were linked closely to the local community. A dump truck is a truck used for transporting loose material such as sand, gravel, or dirt for construction. A typical dump
truck is equipped with a hydraulically operated open-box bed hinged at the rear, the front of which can be lifted to allow the contents to be deposited on the ground behind the truck at the site of delivery.

*Figure 8: Dump Trucks*

When using a dump truck, the balance of the dump truck is very important or else the dump truck could easily tip and fall into the hole as seen in Fig. 8 above. Because the dump truck is used for dumping, it makes the process a risky state. Accidents while using dump trucks can be prevented when there is an underlying knowledge of basic mechanic principle. While dumping, the forces present are at equilibrium on the truck and there is a frictional force because one object is sliding over another, and there is relative motion between two surfaces. The gravel from the truck will begin to slide off the bed when the static coefficient of the friction between the steel bed and the gravel is exceeded by the angle of the bed. As with the static frictional force, the kinetic frictional force acts to oppose the relative motion of the surfaces in contact. One important difference between the two is that the kinetic friction equation has an equals sign: the kinetic force of friction is always equal to the kinetic coefficient of friction times the normal force. The normal force is one component of the contact force between two objects, acting perpendicular to their interface. The frictional force is the other component; it is in a direction parallel to the plane of the interface between objects. Friction always acts to oppose any relative motion between surfaces. Coefficient of friction (static or kinetic) as in Fig. 9 is a measure of how difficult it is to slide a material of one kind over another; the coefficient of friction applies to a pair of materials and not simply to one object by itself.

*Figure 9: Coefficient of Friction*
An understanding of how these forces apply to the truck prevents the operator from causing the truck to tip. Another safety consideration is the leveling of the truck before unloading. If the truck is not parked on relatively horizontal ground, the sudden change of weight and balance due to lifting of the skip and dumping of the material can cause the truck to slide, or even in some light dump trucks to turn over.

Bulldozer

The bulldozer is driving up a vertical slope while pushing gravel as in Fig. 11 below. The operator of this machinery must realize that bulldozer maintain its position on the incline by creating force against the gravel. The force acting against the ground is known as the normal force as in Fig. 10. The normal force points away from the surface, no matter how the surface is inclined.

![Figure 10: Normal Force](image1.png)

![Figure 11: A Bulldozer](image2.png)

The Crane

Cranes are traditionally used in the construction industry or where there is a need to move heavy items. Cranes use a pulley system to reduce the strain and increase the weight that can be moved. Some cranes have magnets rather than hooks to grab items and move them. A model crane can be built using simple craft items and supplies from around the home. This model can be built with either a magnet or hook. When a crane lifts an object, the weight of the object being lifted causes a force to push down on the furthermost end of the crane, which causes an opposite upward force to occur at the other end near the vertical truss.

Foundation of a building is a very important step in construction as in Fig. 12. In this stage, the soil conditions, ground integrity, government requirements, wind patterns and home size are analyzed to ensure that a quality structural system is built. The use of post-tension engineering to help ensure the stability and integrity of each foundation, Before construction begins, the foundation, post-tension and or steel reinforcement engineering are checked for proper squareness and size.
Application of Statics and Dynamics

There are various applications of the theory of Statics and Dynamics in the construction of the new School of Business and Hospitality Management building. A few are explained below.

Structural Members

In summary, the work of the structural members begin at the roof. The roof has a roof plan where the roof weight is considered and dead weight such as concrete, is transferred to the beams, and then to the beams to the column. And all the floor loads are also carried by the beams and transferred to the columns (Fig. 13), then finally to the foundation. In Statics and dynamics, the transfer of loads is very prominent in order to reduce the loads, both vertical and horizontal loads are being transferred to the foundation. In this case, the caissons to the rock refusal and hard rock. After that is driven into the bedrock, then reinforced concrete is applied to the grade beams for more adequate support. So, to conclude, the loads have been transferred through the beams from the rooftop of the building all the way down to the caissons on the building.

Shear Walls

Shear walls used in the construction of this building are designed to serve the purpose of resisting the wind speed. Depending on the geographical features of the site location, it is designed to withstand the worst-case scenario of the wind.

Trusses

Trusses are also used in the construction of this building. Truss is a structure composed of slender members.
joined together at their end points. The members commonly used in construction consist of metal bars. In roof trusses, the roof load is transmitted to the truss at the joints by means of a series of purlins.

Equipment and safety

The safety and equipment used in construction is very critical in order to work efficiently and prevent injuries or causalities at the construction site. Workers and Visitors are required to wear a safety bib and a hard hat for protection. Visitors were also encouraged to indicate their presence around working machinery for safety purposes. In general the various equipment used were critical in the development of the building. Such machinery include but are not limited to Mobile and immobile cranes (Fig. 13). Cranes are machines that use levers and/or pulleys to lift significant weights. The platform of a mobile crane can either have traditional wheels, wheels designed for railroad tracks, or a caterpillar track, which is useful for navigating unpaved and uneven surfaces. This equipment can be used for demolition or earthmoving by replacing the hook with an appropriate tool, such as a wrecking ball or bucket. Telescopic cranes, with a series of hydraulic tubes fit together to form the boom, can also be mobile.

Truck mounted and rough terrain cranes are both essentially mobile as well. The truck-mounted version generally has outriggers to increase its stability. Rough terrain ones tend to have a base that resembles the bottom of a 4-wheel drive vehicle, and outriggers also stabilize them. They tend to be used in rough terrain, as the name suggests, and are frequently used to pick up and transport materials. The use of cranes with their accurate capabilities allows not only for safe and efficient operation, but also helps prevent accidents on the site. The major cause of crane accidents today (as shown in Fig. 14) are due to overweight balances. All cranes have weight limited to ensure the crane doesn’t tip over. To counterbalance the weight, cranes use counterweight and out-rigging systems. If the maximum weight on the crane is exceeded, or the crane has insufficient metal supports to stabilize the load, the unbalanced load will move and cause the crane to either collapse or tip over.

Figure 13: Crane in Operation
The students reports A to D demonstrate a mastery of the concepts of statics and dynamics by the students. Student A demonstrates a mastery of the concept of moment of inertia, while student B shows an in-depth understanding of the structural members of buildings and equilibrium of rigid bodies. Through Student C report it is clearly seen that the student thoroughly understands the concept of friction, while student D comprehensively reported the application of the principles of statics and dynamics in the safe operation of the construction equipment.

Students Grades:

Figure 15 and Table 4 show the results of the field report of 40 students compared to their final Semester grade. From Table 4 and Figure 15 it is clearly demonstrated that students’ grades in the field project has a strong influence on their final semester grade. This is a strong justification that the field experiential pedagogy adopted greatly enhanced the students’ performance in the class.

5. Conclusion

The Engineering Students taking Engineering Mechanics course at Morgan State University, usually embark on field trip to construction sites within the campus and around their vicinity. The purpose of the visit is to familiarize the students with the application of the principles of Statistics and Dynamics in the safe operation and maintenance of construction equipment and machines. The students are also able to witness firsthand the design and construction of the structural members of the building. The author has taught the course twenty
times (20) at Morgan and each time he taught the class students were taken to a construction site, with a view of bridging the gap between theory and practice. The outcome has been very encouraging as students have been able to link theory with practice. The field tour is part of the experiential learning initiative of STEM field. As it has been noted that students become more engaged when learning experientially- hands-on, inquiry-based and project-oriented. Experiential learning connects content to real-world application and integrates technology and 21st Century skills. Experiential learning of this kind will broaden the participation of underrepresented students in STEM field.

![The Impact of Field Project on Final Semester Grade](image)

**Figure 15: The impact of Field Project on Final Semester grades**

The students are usually accompanied by the the project manager as well as their instructor. In a report one of the online students made the following comments: “Overall, the trip to the construction site was a very interesting and rewarding experience. The tour helped expand knowledge of statics and dynamics that are being taught online by providing a tangible example. This trip helped inform me of the expansive team including every type of specialty that it takes to complete a project of this size, and showed me other uses of Industrial Engineering in addition to the obvious, Civil Engineering. I learned how very important it is to be precise in calculations with construction and safe operation of equipment because any mistake can have a tragic impact in this industry. In conclusion, having the field trip during this class was very helpful in my understanding of statics and dynamics”.

This paper demonstrates that field experiential learning pedagogy has been adopted in an Engineering Mechanics course fosters direct experience on hands on experience in which students are able to apply Science, Technology, Engineering skills to real life situations. The paper also shows that this type of experiential learning pedagogy can be adopted in institutions, where Engineering Mechanics classes are taught to non-civil and mechanical Engineering Students, as this will help to improve their positive attitude and perception of learning Engineering Mechanics as well as enhance their performance. This concept is easily scalable as construction sites are ubiquitous on campuses. Finally it is the author’s opinion that as engineering educators continues to engage in the field tours; this will foster experiential learning amongst our
students, and subsequently will improve STEM education and better enhance and strengthen our nation and raise the standards of solving engineering problems.

Table 5: The Impact of Field Project on Students Performance

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References


