Using Experiential and Constructivist Teaching Pedagogies in Undergraduate Teaching

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Abstract

This paper shows how problem-based-learning (PBL) and learning-through-service (LTS) can provide a strong framework for fostering students' adaptive expertise, flexibility, creativity, innovation, and passion in the classroom. Mississippi State University (MSU) represented by its Civil and Environmental Engineering Department (CEE) is currently in the design-development stage for the construction of a new Civil and Environmental Engineering Complex (CEEC). CEE is garnering a new focus on sustainability with special emphasis on environmentally responsible design, construction, and operation of constructed facilities. The authors have mentored a group of 22 undergraduate junior students under the High Performance Sustainable Construction class to provide a comprehensive Leadership in Energy and Environmental Design (LEED) analysis for the new CEEC using the 2009 Reference Guide for Green Building Design and Construction, The student work shows that CEEC can possibly earn up to 74 points to acquire a Gold LEED Certification. This study shows that PBL and LTS can significantly enhance students' abilities of understanding and solving complex real world civil infrastructure problems and challenges. Also, this student-driven teaching approach instills creative learning environment, understanding of the surrounding world, and a sense of social responsibility.

Keywords: *LEED, Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor and Environmental Quality, Problem-Based-Learning, and Learning-Through-Service.*

Introduction

Engineering education in the United States at the higher education level has traditionally adhered to a deductive instructor-centered approach that uses methods the profession has long left behind. However, with the current non-stopping technological advancements, professionals should also adapt to a continuously evolving environment and solve the complex real world problems. Traditional classroom environments have been criticized for not providing essential contextual features that enable students to understand and apply information [1]. Students frequently are not active agents in the learning process but are instead passive receptors of knowledge provided by an imposed educational structure [2]. Under this traditional setting, problems are designed to be well-structured with known correct solutions, which are often acquired from preferred solution methods [3, 4]. This linear process of problem solving emphasizes getting answers over making meaning [5]. Deductive teaching methods continue to have widespread application because they are easy and cheaper to implement [6]. The authors believe that passive learning environments are one of the least productive ways to foster learning and knowledge dissemination because Students learn best when they are interested in or believe they have a need to know the information. As a result, a number of national reports consider current education inadequate to prepare future leaders and illustrate the need for more dynamic learning techniques in the undergraduate and graduate levels [7, 8, 9, 10, 11].

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Authentic learning emerged as a prominent educational tool that involves understanding complex systems based on simpler real-world problems and simulations [12, 13]. It emphasizes: (1) iterative process of discovery where students gain problem-solving skills and confidence in their own learning abilities, and (2) discourse where students learn to construct hypotheses and test them against what they believe to be true, which eventually help them to view knowledge and information from multiple perspectives [2]. Thus, the role of the teacher and/or educator changes from information provider and test-creator to a more holistic framework where he/she is a learning guide, problem presenter, and research collaborator. One application of an authentic learning environment is the use of problem-based learning (PBL) techniques. Some of the benefits of PBL include: (1) improving students' problem solving and critical thinking skills, (2) promoting high motivation for students, (3) increasing the ability to integrate and apply engineering skills with fundamentals of math and science, (4) enhancing the acquisition and retention of knowledge, and (5) facilitating collaborative learning [14].

On the other hand, learning-through-service (LTS) is a combination of numerous pedagogical methods including service learning, situated learning, and PBL. LTS creates an experiential education environment where students engage in activities that address community needs with opportunities designed to promote student learning. LTS begins with concrete societal and community service experiences that generate interest, present problems that awaken new curiosities, create a demand for information, and cover a considerable time span capable of fostering development over time. Moreover, LTS situational experiences involving expert guidance and peer collaboration allow a learner to observe and model behaviors, attitudes, and emotional reactions, which encourage internalization of social and cognitive processes leading to the development of higher-order functions for later individual use. Thus, students inherently link personal and social development with academic development. LTS: (1) is an effective and desired pedagogical strategy for engineering students; (2) helps students develop more sophisticated beliefs about engineering that they may not be able to develop through their traditional coursework; (3) appears to be a desired source of learning for students who are extraverted, agreeable, and open, which flies in the face of engineering stereotypes; and (4) appear to draw students that would otherwise not choose or persist in engineering

The Department of Civil and Environmental Engineering (CEE) at Mississippi State University (MSU) has been working hard on the development of a new home, the Civil and Environmental Engineering Complex (CEEC) on the main Starkville campus. The present proposed location of CEEC is at the intersection of Hardy Street and Morrill Road on the southeast corner. This land currently stands as a gravel parking lot surrounded by campus streets on two sides, woods to the west, and another campus building to the south. The plans illustrate a 93,000 square feet building consisting of both Assembly and Business Occupancies full-time. The building has a large "C" footprint with a central courtyard facing west, towards the center of campus. CEEC is designed with efficiency in mind. However, no formal steps have been made towards the certification or documentation of applicable Leadership in Energy and Environmental Design (LEED) credits by the Green Building Council.

Goal and Objectives

This paper assesses and evaluates how problem-based-learning (PBL) and learning-through-service (LTS) can be used as robust learning pedagogies to enhance the required students' skill-set in order to make them better prepared to tackle and solve tomorrow's global and interdisciplinary evolving infrastructure challenges. This is achieved through showing the work of 22 junior undergraduate students towards developing a comprehensive Leadership in Energy and Environmental Design (LEED) analysis for the new Civil and Environmental Engineering Complex (CEEC) at Mississippi State University (MSU).

Background Information

Every year construction produces higher than average levels of carbon emissions, tons of waste equaling that of domestic curbside pickup levels, and the destruction of natural resources, whether renewable or not from normal practices [16]. However, some owners, designers, and builders are learning to lower these levels far below average using simple, yet innovative guidelines found in the practice of sustainable construction and design. Sustainable construction - often referred to as efficient construction or green construction - has become the new par for design projects across the globe, with a growing interest in civil and educational scopes of construction.

LEED is a sustainability certification system founded by the US Green Building Council (USGBC) to promote and uphold environmentally friendly design and building trades. The USGBC also accredits professionals who wish to design and construct LEED certified buildings. The building certification process is based on points gained from seven broad sustainable categories: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and

Resources, Indoor Environmental Quality, Innovation in Design, and Regional Priority [15]. With a total of 110 points total, the most points can be achieved through Sustainable Sites, Energy and Atmosphere, and Materials and Resources. These sections award points for site selection, storm water development, energy performance, material reuse, recycled content, regional materials, and rapidly renewable materials. Though the content of credits remains the same, there are three divisions of LEED that determine which credits apply to the project, dependent on its scope: Core and Shell, Schools, and New Construction [15]. LEED has been adopted by many American institutions and local governments as a required standard for their new construction and/or expansion [16].

Buildings which are designed to perform efficiently, and constructed responsibly, are often found applying for LEED certification through the Green Building Certification Institute, hosted by the US Green Building Council. This application process comprises both stringent and demanding evaluation of the structure from design to completion, with no steps left out. Being so, those buildings which reach certification are found to have longer life spans, lower energy costs, higher productivity rates, and produce an overall better way of life for their occupants. LEED Certification comes at no small charge, but owners have found its benefits far outweigh the costs, especially when compared to a structure not designed with sustainable green intentions.

Teaching Pedagogy Formulation

Both design and sustainability transcend traditional disciplinary boundaries. Typically, sustainability education has been promoted through green and environmental engineering. While Green engineering has focused on design that is in greater long-term harmony with the environment; environmental engineering has addressed the deleterious effects engineering has had on the environment. To this end, students often do not learn to perceive sustainability from a systems perspective; instead students associate the concepts uni-dimensionally with the environment rather than embracing a holistic and multidimensional interpretation [17]. Thus, in order for our future engineers to be able to work toward sustainability, they must be versed not only in sustainable engineering but also in engineering design [18]. To this end, the first author has developed an innovative undergraduate class titled: "*High Performance and Sustainable Construction*" that creates an integrated LEED-based educational approach to: (1) prepare students to deal with the complex problems of sustainability and provide them with a holistic education incorporating all contexts of sustainability, and (2) train future practitioners to think flexibly and to be adaptive to interdisciplinary working environments.

This course covers the following thirteen topics including: Sustainability and the Building Industry; Sustainable Design and Green Building; Cost Implications of Green Building; Site development Considerations; Site Water Runoff; Project's Water Use Efficiency; Energy Efficiency; Renewable Energy Resources; Onsite Power Generation Using Renewable Energy Resources; Building Material Use; Indoor Environment Quality; Industrial Environmental Performance; and Individual environmental performance. The following four projects were included in this offering:

- Each student was required to submit a ten page report illustrating the concepts of cradle-to-grave, cradle-to-cradle, and life-cycle assessment (LCA). The report should provide detailed analyzed example of how the two later concepts are implemented in construction-related activities both nationally and internationally;
- Each student was required to utilize a minimum of ten academic references (mainly peer-reviewed journal and conference papers) to develop a comprehensive technical report - including abstract, literature review, laboratory testing, and case studies - to show a certain construction material that is chosen by the student can be used to promote sustainable building developments;
- Each group of two students was required to develop a manual for "sustainable construction" using the LEED reference guide;
- All students were required to develop a detailed report including method statement and associated cost estimate to attain LEED certification for the New Civil and Environmental Engineering Complex (CEEC) at Mississippi State University. A complete set of drawings and specifications was distributed in class. To this end, students divided themselves into groups of two that specialize in one of the major LEED credits. Accordingly, each group developed a report pertaining to its assigned credit using the previously developed "sustainable construction" manual. Each group was asked to provide a comparative method and cost analysis between basic, Silver, Gold, and Platinum LEED certification. Last, all group members were tasked to work collectively towards compiling their individual reports into one complete and comprehensive assessment report.

During the process, the authors provide the students with the resources and support they need to take utmost advantage of the learning experience including their own mistakes. Also, through engaging students in discussions and guiding their reflections on scientific material, the authors were regarded as research collaborators with their students rather than a source of authority.

Student Output

The 22 junior undergraduate students enrolled under "the High Performance Sustainable Construction" class were tasked to show for the CEEC: (1) which credits are attainable in light of the current available design documents; (2) which credits are not incorporated in the current design documents but are achievable with some modifications and amendments; and (3) which credits are not obtainable regardless of any reasonable new design proposals

The methodology utilized by the students was based and adopted from the 2009 Reference Guide for Green Building Design and Construction as the basis of their analysis. The most important utilized concepts in this study include [15]:

- Low-Emitting Materials are specifically-listed set of material that is used to produce little or no volatile organic compounds;
- Indoor Air Quality Management Plan is used to outline the air quality before occupancy and during construction to identify how the HVAC system should be designed;
- Minimum Efficiency Reporting Value is a filter rating system established by ASHRAE 52.2-1999 as a method of testing general ventilation air cleaning devices for removal efficiency by particle sizes. The associated readings range from 1 (very low efficiency) to 16 (very high efficiency). LEED accreditation under Indoor and Environmental quality credit 5 requires installation of HVAC systems with filters generating a reading equal to 13 or higher;
- Outdoor Air Delivery Monitoring is based on the return air system and the outdoor air vents. There should be sensors to detect carbon dioxide as it enters the building and there should be an alarm to alert the system operator for a variance of 10% or more. There should also be sensors located between 3 and 6 feet above the floor in rooms with 25 occupants or more per 1000 sq. ft.;
- Predicted Mean Vote; is an empirical equation for predicating the mean vote on a rating scale of thermal comfort of a large population of people exposed to a certain environment. This is a comfort model that incorporates heat balance principles to relate the personal and environmental thermal comfort factors based on thermal sensation scale that shows 7 levels ranging from +3 (hot) to -3 (cold). This model is applicable to air speeds not greater than 40 feet/minute (FPM);
- Thermal Comfort is a state that exists when occupants express satisfaction with the thermal environment based on the performance and abilities of the environment in which the occupant finds themselves;
- Direct Line of Sight to Perimeter Vision Glazing; is used to calculate the regularly occupied areas with direct line of sight to perimeter vision glazing. The area determination includes full height partitions and other fixed construction prior to installation of furniture;
- Visible Light Transmittance is equal to the amount of visible spectrum light passing through a glazing surface divided by the amount of light striking the glazing surface. The higher the value, the more the incident light passes through the glazing;
- Whole Building Energy Simulation is very important tool to gain the most possible LEED points because it is worth up to 19 points under Energy and Atmosphere Credit 1: Optimize Energy Performance. LEED recognizes several building simulation computer software that must be utilized to gain the credit. The software that was used for modeling CEEC is called eQuest. This software asks the user hundreds of questions about the building to produce the most accurate possible computer simulation of the building. The user must answer questions about the materials used on the envelope of the building as well as interior materials, what the building will be used for, how many hours a day the building will be occupied, any and all equipment/appliances in the building, lighting, as well as many other very specific questions. Using the user input, eQuest will create a 2-D and 3-D model of the building representing its orientation and window configuration. In addition to the models, eQuest

will prepare a building project summary, describing different loads on the building, energy usage and costs, among many other summaries; and

- Commissioning the process of verifying and documenting that the facility and all of its systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the owner's operating requirements.

The LEED analysis of MSU's CEEC development was broken down by each available credit including Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, and Innovation in Design. Realizing though the page limitation for this paper; the authors could not present in detail the student work in relation to the previously mentioned credits and their associated sub-credits. However, this work is subject of a pending-review journal paper.

Based on the student work, and as shown below in Table 1, the CEEC new development can possibly earn 21 LEED points under Sustainable Sites, 8 LEED points under Water Efficiency, 21 LEED points under Energy and Atmosphere, 7 LEED points under Materials and Resources, 13 LEED points under Indoor Environmental Quality, 1 LEED point under Innovation in Design, and 0 LEED points under Regional Priority. This would mean earning a total of 71 LEED points out of 110 possible points. Thus, the new CEEC development on MSU's campus can earn a Gold LEED Certification.

Table 1: LEED Certification for CEEC

LEED 2009 for New Construction and Major Renovations
Project Checklist

Project Name
Date

Y	?	N		Credit	Points
21				**Sustainable Sites**	Possible Points: 26
Y			Prereq 1	Construction Activity Pollution Prevention	
1			Credit 1	Site Selection	1
5			Credit 2	Development Density and Community Connectivity	5
1			Credit 3	Brownfield Redevelopment	1
6			Credit 4.1	Alternative Transportation—Public Transportation Access	6
1			Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Rooms	1
			Credit 4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Vehicles	3
2			Credit 4.4	Alternative Transportation—Parking Capacity	2
1			Credit 5.1	Site Development—Protect or Restore Habitat	1
1			Credit 5.2	Site Development—Maximize Open Space	1
			Credit 6.1	Stormwater Design—Quantity Control	1
1			Credit 6.2	Stormwater Design—Quality Control	1
1			Credit 7.1	Heat Island Effect—Non-roof	1
1			Credit 7.2	Heat Island Effect—Roof	1
			Credit 8	Light Pollution Reduction	1
8				**Water Efficiency**	Possible Points: 10
Y			Prereq 1	Water Use Reduction—20% Reduction	
3			Credit 1	Water Efficient Landscaping	2 to 4
2			Credit 2	Innovative Wastewater Technologies	2
3			Credit 3	Water Use Reduction	2 to 4
21				**Energy and Atmosphere**	Possible Points: 35
Y			Prereq 1	Fundamental Commissioning of Building Energy Systems	
Y			Prereq 2	Minimum Energy Performance	
Y			Prereq 3	Fundamental Refrigerant Management	
10			Credit 1	Optimize Energy Performance	1 to 19
4			Credit 2	On-Site Renewable Energy	1 to 7
2			Credit 3	Enhanced Commissioning	2
2			Credit 4	Enhanced Refrigerant Management	2
3			Credit 5	Measurement and Verification	3
			Credit 6	Green Power	2
7				**Materials and Resources**	Possible Points: 14
Y			Prereq 1	Storage and Collection of Recyclables	
			Credit 1.1	Building Reuse—Maintain Existing Walls, Floors, and Roof	1 to 3
			Credit 1.2	Building Reuse—Maintain 50% of Interior Non-Structural Elements	1
2			Credit 2	Construction Waste Management	1 to 2
			Credit 3	Materials Reuse	1 to 2
				Materials and Resources, Continued	
2			Credit 4	Recycled Content	1 to 2
2			Credit 5	Regional Materials	1 to 2
			Credit 6	Rapidly Renewable Materials	1
1			Credit 7	Certified Wood	1
13				**Indoor Environmental Quality**	Possible Points: 15
Y			Prereq 1	Minimum Indoor Air Quality Performance	
Y			Prereq 2	Environmental Tobacco Smoke (ETS) Control	
1			Credit 1	Outdoor Air Delivery Monitoring	1
1			Credit 2	Increased Ventilation	1
1			Credit 3.1	Construction IAQ Management Plan—During Construction	1
1			Credit 3.2	Construction IAQ Management Plan—Before Occupancy	1
1			Credit 4.1	Low-Emitting Materials—Adhesives and Sealants	1
1			Credit 4.2	Low-Emitting Materials—Paints and Coatings	1
1			Credit 4.3	Low-Emitting Materials—Flooring Systems	1
1			Credit 4.4	Low-Emitting Materials—Composite Wood and Agrifiber Products	1
1			Credit 5	Indoor Chemical and Pollutant Source Control	1
1			Credit 6.1	Controllability of Systems—Lighting	1
1			Credit 6.2	Controllability of Systems—Thermal Comfort	1
1			Credit 7.1	Thermal Comfort—Design	1
1			Credit 7.2	Thermal Comfort—Verification	1
			Credit 8.1	Daylight and Views—Daylight	1
			Credit 8.2	Daylight and Views—Views	1
1				**Innovation and Design Process**	Possible Points: 6
			Credit 1.1	Innovation in Design: Specific Title	1
			Credit 1.2	Innovation in Design: Specific Title	1
			Credit 1.3	Innovation in Design: Specific Title	1
			Credit 1.4	Innovation in Design: Specific Title	1
			Credit 1.5	Innovation in Design: Specific Title	1
1			Credit 2	LEED Accredited Professional	1
				Regional Priority Credits	Possible Points: 4
			Credit 1.1	Regional Priority: Specific Credit	1
			Credit 1.2	Regional Priority: Specific Credit	1
			Credit 1.3	Regional Priority: Specific Credit	1
			Credit 1.4	Regional Priority: Specific Credit	1
71				**Total**	Possible Points: 110

Certified 40 to 49 points Silver 50 to 59 points Gold 60 to 79 points Platinum 80 to 110

Conclusion

The authors used the broad context of sustainability to assess how problem-based learning (PBL) and learning-through-service (LTS) can improve the traditional curriculum objectives and support required changes in the quality and skills of respective graduates. Classification of real-world research and industry problems will lead to a better understanding of complex problem solving techniques and processes [2, 19]. In fact, the learning outcomes of the students enrolled in this class has exceeded the same for previous groups who used traditional learning approaches where the average grade of the current students on a typical LEED exam was 87% compared to 72% for the Prior group.

Also, Based on the current available ABET assessment frameworks, the authors assert that the presented study promoted significant developments that are very much needed by today's graduates including:

- Develop students' exposure and mastery of wide knowledge domain, which allows them to appreciate and understand today's complex engineering and infrastructure systems;
- Promote students' desire and abilities to pursue a life of learning through acquiring set of real-world complex problem solving skills, which will make them equipped and driven to meet the future challenges of their profession;
- Build students' training and experience in the responsible and ethical conduct of professional practice and research;
- Strengthen the mission of science and engineering to truly reflect the usage of broad spectrum of technical and analytical skills to improve the natural and built environments in a sustainable manner; and
- Improve students' written and oral communication skills including professional report writing and technical presentations, which should eventually make engineers more prepared to secure leadership positions.

In fact, the MSU administrators as well as the CEEC project developers who the authors have shared the results of this LEED analysis with were amazed and thrilled that it is was carried out to this exactness by 22 junior undergraduate students.

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References

[1] Schmidt, H.G. (1993), "Foundation of Problem-Based Learning: Some explanatory notes", *Medical Education*, Vol. 27, No. 5, pp.422-432.

[2] Brody, Sam (2003), *CAREER: Modeling Watershed Flooding and Adaptive Flood Management: An Integrative Plan for Research, Teaching, and Learning,* College of Architecture, Texas A and M University, TX.

[3] Jonassen, D. H. (1997), "Instructional Design Model for Well-structured and Ill-structured Problem-solving Learning Outcomes," *Educational Technology Research and Development*, Vol. 45, No. 1, pp. 65-95.

[4] Jonassen D.H., J. Strobel, and C.B. Lee (2006), "Everyday Problem Solving in Engineering: Lessons for Engineering Educators," *Journal of Engineering Education*, April, pp. 139-151.

[5] Heywood, J. (2005), *Engineering Education: Research and Development in Curriculum and Instruction*, New Jersey: John Wiley and Sons, pp. 221-239.

[6] Carberry, Adam R. (2010), Characterizing Learning-Through-Service Students In Engineering By Gender And Academic Year, Ph.D. Dissertation, Tufts University,

[7] Boyer Commission on Education of Undergraduates in the Research University (1998), *Reinventing Undergraduate Education: A Blueprint for America's Research Universities*, New York.

[8] Boyer Commission on Educating Undergraduates in the Research University (2002), *Reinventing undergraduate education: Three years after the Boyer Report.* S.S. Kenny (chair). State University of New York-Stony Brook.

[9] National Science Foundation (1996), *New Expectation for Undergraduate Education in Science, Mathematics, Engineering, and Technology*, Washington, DC: NSF Directorate for Education and Human Resources.

[10] American Association for the Advancement of Science (2002), Project 2061 Update, Washington DC.

[11] National Research Council (2003), *Evaluating and Improving Undergraduate Teaching in Science, Technology, Engineering, and Mathematics*, Washington, DC: National Research Council.

[12] Perkins, D. and T. Blythe, (1994), “Putting Understanding Up-front”, *Educational Leadership,* Vol. 60, No. 2, pp. 4-7.

[13] Nicaise, M., T. Gibney, and M. Crane (2000), “Toward an Understanding of Authentic Learning: Student perceptions of an authentic classroom.” *Journal of Science Education and Technology,* Vol. 9, No.1, pp. 79-94.

[14] Pierrakos, O., R. Kander, E. Pappas, R. Prins, and R. Anderson (2009), *CCLI: Design and Implementation of an Innovative Problem-based Learning Model and Assessment Tools in Undergraduate Engineering Education,* School of Engineering, James Madison University, VA.

[15] U.S. Green Building Council "USGBC" (2009 Edition - updated June 2010)). *LEED Reference Guide for Green Building Design and Construction.* Washington, D.C.: USGBC

[16] Montoya, M. P. (2011). *Green Building Fundamentals: Second Edition.* Upper Saddle River, NJ: Prentice Hall.

[17] Prins, R., R. Kander, T. Moore, E. Pappas, and O. Pierrakos (2008), "Engineering for a Sustainable World: How Do We Incorporate Sustainability in Undergraduate Engineering Education?", *38th ASEE/IEEE Frontiers in Education Conference*, October 22 – 25, 2008, Saratoga Springs, NY.

[18] Pierrakos, O. (2009), *CAREER: Characterizing, Understanding, and Integrating Complex Problem Solving in Engineering Education*, School of Engineering, James Madison University, VA

[19] Nigel, R., O. Pierrakos, E. Pappas, and A. Ogundipe (2011), "The Integration of Sustainability, Systems, and Engineering Design in the Engineering Curriculum at James Madison University", *Proceedings of the ASME 2011 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference (IDETC/CIE 2011),* August 29-31, 2011, Washington, DC.