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Carol Considine
Old Dominion University, cconsidi@odu.edu

Vernon Lewis
Old Dominion University

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AC 2007-2133: INTRODUCING FRESHMEN TO CONSTRUCTION ESTIMATING AND SCHEDULING USING K'NEX BRIDGE KITS

Carol Considine, Old Dominion University

Carol L. Considine is an Assistant Professor of Civil Engineering Technology at Old Dominion University. She joined the faculty of Old Dominion University in fall 1999. She has fifteen years of industrial experience in construction estimating and project management. She received her B.S. in Civil Engineering from Virginia Tech and her M.S. in Civil Engineering from the University of California at Berkeley.

Vernon Lewis, Old Dominion University

Vernon W. Lewis, JR. P.E., Senior Lecturer, is Program Director of Civil Engineering Technology at Old Dominion University. He joined the faculty of Old Dominion University in January 1994. He has 30 years of professional experience in consulting, industry and forensic engineering and is registered in eight states. His areas of expertise include structural design, contract documents and materials testing.

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Abstract

The College of Engineering and Technology at Old Dominion University has developed project-based courses for freshmen engineering students in order to engage them in engineering early with the goal of increasing retention. The courses are divided into three five-week modules that are distributed among the various departments within the college. The Engineering Technology department is responsible for two of the five week modules. One module is comprised of all the engineering technology curriculums; civil, electrical and mechanical, and the other module is strictly a civil engineering technology project.

The civil engineering technology project is focused on the construction industry. Students are introduced to Civil Engineering as a discipline area, and then to the construction industry. Students are then taught how to estimate and schedule a simple bridge project using K'NEX Bridge Kits. Students build their bridges based on their estimates and can evaluate their quantity take offs for accuracy. This paper will describe the content of the module, describe how the bridge kits are used, and will detail the student enrollment changes that the civil engineering technology program has seen as a result of these projects based courses.

Introduction

Engineering 110 and 111 are two courses described in the catalog as a " **. . . .** series of projects to introduce a variety of engineering and technology disciplines; hands-on experiences with selected engineering problems and issues; team approach to managing engineering projects; discovering the unknown, formulating solutions, designing, manufacturing and testing; emphasis on learning modules, communication and presentation skills, creativity and innovation." These classes were introduced in the Batten College of Engineering and Technology at ODU in an effort to increase retention among engineering students. Beginning engineering students are often overcome or discouraged by the fundamental math and science courses that are required as prerequisites to the core engineering design courses. These freshmen engineering courses give the students exposure to engineering in a manner that keeps the students' interest alive without the rigors of mathematics for which the student is not prepared. The project-based classes introduce students to real life problems that are solved using engineering skills students will obtain through their degree programs.

Each course is organized into three five week-modules with approximately 35 students per section. This enables the freshmen students to be exposed to as many as six different engineering-discipline related projects during the course of their freshmen year. Engineering 110 is taught by the engineering departments within the college: civil and environmental, electrical and computer, and mechanical. Engineering 111 is taught by some of the same engineering departments but also includes two sessions taught by the Engineering Technology

department. All students take at least one five-week module from the Engineering Technology department and some students take both modules. This has greatly benefited the Engineering Technology department since it gives us an opportunity to explain the difference between engineering and engineering technology degrees.

Engineering Technology Modules

The Engineering Technology department originally developed one five-week module for the freshman engineering course. This module was developed in order to expose students to all of the disciplines represented in the Engineering Technology department - civil, electrical and mechanical. In this module, the class section is divided into three groups and each group spends three days exploring each of the three engineering technology disciplines. This multi-disciplinary section exposes students to surveying for civil engineering technology (CET); AC, DC and digital circuits for electrical engineering technology and gears and their applications for mechanical engineering technology.

The second engineering technology module that has been developed for the freshmen-engineering course is solely a CET module with an emphasis in construction. Students are introduced to civil engineering, and the seven major concentration areas within civil engineering: transportation, structural, environmental, water resources, geotechnical, construction and urban planning. The students are then introduced to the construction industry through discussions of the role of construction in the national economy, a comparison of the construction industry to the manufacturing industry, explanations of the different sectors of the construction industry and project delivery systems. After students have been introduced to the construction industry, the class topics focus on the role that an estimate plays in the construction industry and how estimates are performed. Students are taught how to perform a quantity survey, calculate direct material, labor and equipment costs, indirect field costs and apply office overhead and profit to their estimates. The K'NEX Bridge kits play a vital role in the estimating exercises for the course, which is discussed further below. In addition to estimating, students are taught basic gantt scheduling techniques and must use these techniques to determine their bridge schedule duration which is then used to calculate the indirect field costs. The five week module concludes with student submitting a competitive bid for a bridge project with a complete cost estimate and schedule.

K'NEX Building Bridges Set

The K'NEX Building Bridges set is comprised of 207 K'NEX building pieces, which can be used to construct 14 different bridge models. The kit includes color coded instructions to build beam, truss, cantilever, bascule, arch, suspension, and cable stayed bridges. The building instructions contain real life examples of the bridge type and key facts about bridges.[1] The instructor uses the color coded instructions as the plans for the bridges. The beam bridge model is used during the estimating and scheduling class instruction and the arch bridge model is used for the students in the competitive bid. Although the kits come with complete instructions for the building of the bridges, in order for students to estimate costs it was necessary to assign each K'NEX part a name, unit material cost and labor productivity rate**.** Figure 1 is the spreadsheet

that students were given to calculate direct material and labor costs for the beam bridge and Figure 2 shows the labels that were assigned to each K'NEX part.

Bridge Estimate Spreadsheet - Simple Beam Bridge

		Material Pricing		Labor Pricing	
Piece	**Quantity**	***Material Unit Price**	**Extended Material Cost**	**Productivity Rate (LH/Unit)**	**Extended Labor Hours**
90^ foundation		775		4	
180^ support		200		0.5	
135^ support		250		0.5	
180 joint		350		1	
360^ joint		450		1	
flat joint		150		0.5	
Deck		500		5	
16mm		250		0.4	
32mm		200		0.6	
52mm		250		1	
54mm		250		1	
85mm		350		1.6	
129mm		450		1.8	
187mm		600		4	
Subtotal material costs					
Taxes @ 5%					
Total material cost					
Total labor hours					
Total labor cost (hourly rate $25/hour)					
Equipment Cost (use 25% of labor hours @ hourly rate of $125.)					
Total Cost (Labor, Material, Equipment)					

*Price of materials at time of initial purchase.

Price of materials increases with by a factor of 2 with each trip to the material supplier.

Figure 1. Beam Bridge Estimate Spreadsheet

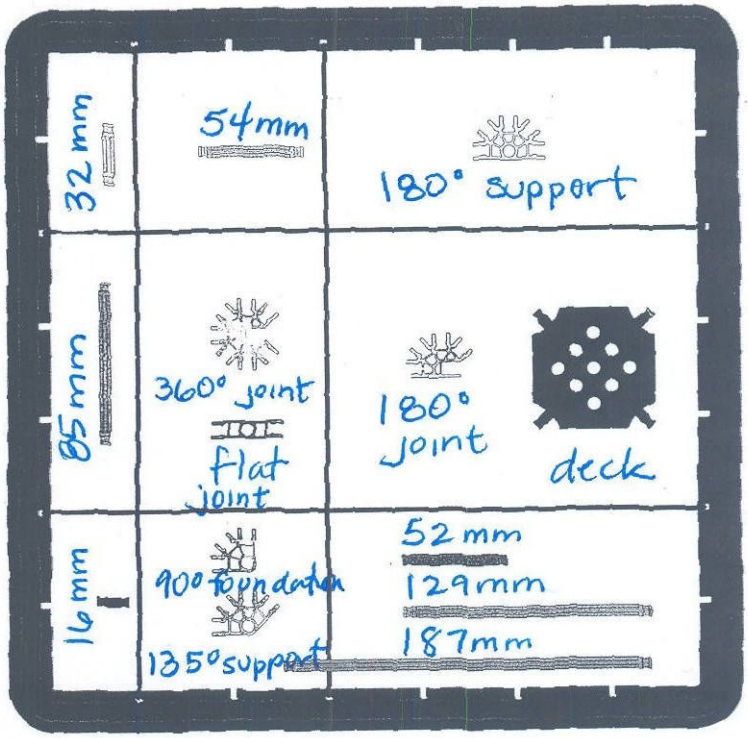

Figure 2[1]. K'NEX Part Labels

Students are taught estimating, using the beam bridge project is as an example. Students are divided into groups of four and must complete the estimate of the beam bridge as an in-class learning exercise. The group submits one final estimate of the direct field costs for construction. Then students are then required to build their bridges using only the parts included in their estimate. If they have an incorrect part count, or have used an incorrect part in their estimates this adds to the construction costs of their bridges. There are parts in the kit that are very similar in size and color. When they build the beam bridge, they have an opportunity to examine the bridge kits and distinguish similar parts by the total number in the kit, or size in relation to other parts. This is a crucial step to eliminating a similar mistake on their competitive bid and it is explained to the students as an opportunity for their companies to gain some experience with bridge construction materials. Once the students have completed the bridge construction, they are introduced to bridge terminology and gantt scheduling techniques. Students use these Gantt scheduling techniques for the beam bridge schedule as another in-class learning exercise. The students are then ready for their competitive bid. They must use the estimating and scheduling techniques they have learned for an arch bridge. The bridge is slightly more complex than the beam bridge used in the in-class exercises, and students must include indirect field costs, dependent on their schedule duration, office overhead and profit in their final bid price. They are required to fill out a bid form and submit their bids in sealed envelopes prior to bid time at the designated location. Bids are opened in the next class period and the student teams are then required to build their bridges using the materials that were included in their estimates.

Results

The Engineering Technology (ET) department has seen an increase in enrollment of sophomore students since the introduction of ENGN 111. Prior to the introduction of these classes, the majority of students in the ET department were junior and senior transfer students from community colleges. In addition to the increase in sophomore enrollment, enrollment trends in the CET program in general have increased significantly as shown below in Figure 3:

CET Program Headcount Trends					
Year	CET BSET	CET SDES BSET	CET SURV BSET	CET CONM	CET TOTALS
1999	86	3	16	N/A	105
2000	67	2	10	N/A	79
2001	74	2	10	N/A	86
2002	93	3	7	N/A	103
2003	98	5	10	N/A	113
2004	136	7	12	N/A	155
2005	110	13	23	1	147
2006	71	33	24	49	177

The CET program has three concentration areas for the Bachelor of Science in Engineering Technology (BSET): Structural Design (SDES), Surveying (SURV) and Construction Management (CONM). The construction management designation was not an added as a concentration area option until 2005. Students previously interested in construction would be included in the CET count.

It should be noted that ENGN 111 was first offered in the fall of 2000. The CET module at that time was focused on design and construction. Students designed the floor plan for a small commercial building, estimated construction costs, built a model and presented their project to the class. The bridge module was introduced in the spring semester of 2005 for the first time.

These headcount trends indicate a steady increase in enrollment since the introduction of ENGN 111. Headcount for the CET program have increased every year since 2000, with the exception of a slight decrease, 5%, for the 2004-2005 academic year. Headcount increased 9 percent for the 2000 - 2001 academic year, 20 percent for the 2001-2002 academic year, 10% for the 2002-2003 academic year, 37% for the 2003-3004 academic year and 20% for the 2005-2006 academic year[3].

The increase in enrollment noted above is due to several factors including, the fact that almost all CET classes are now offered in a video streaming format, the national increase in construction enrollments and the student exposure to CET through ENGN 111. Students in the CET program have been informally surveyed during advising, and a large percentage indicates that the knowledge gained about the CET program and the construction industry from the ENGN 111 course had an impact their major selection.

Conclusion

The CET program at Old Dominion University has seen an increase in enrollment associated with a freshmen engineering projects-based course using K'NEX Bridge Kits. These kits provide students with the opportunity to estimate materials required for a construction project and then build the project based on their estimate. Future plans for this course include the purchase of large scale K'NEX bridge kits that have 2,282 pieces and will build seven five foot long replicas of real world bridges including the Fourth of Fifth Cantilever Bridge in Scotland, the Golden Gate Suspension Bridge in San Francisco, and the Sydney Harbor Arch Bridge in Australia.[1] These kits have more complex bridges and will challenge student estimating and building skills. Students will be challenged to build their competitive bid bridges within a minimum time frame that will require planning and execution of the plan. Additional plans for this course include a formal survey of students regarding the impact on the course in the major selection.

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